The Economic Appraisal of Investment Projects at the EIB

2nd Edition, March 2023

European Investment Bank

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List of abbreviations and acronyms

3G:	Third generation (of mobile telecommunications technology)
AIC:	Average incremental cost
B/C:	Benefit–cost (ratio)
B&E	Biodiversity and ecosystem
BGC:	Behavioural generalised cost
CAPEX:	Capital expenditure
CAPM:	Capital asset pricing model
CBA:	Cost–benefit analysis
CEA:	Cost-effectiveness analysis
CO_2:	Carbon dioxide
CO_2e:	Carbon dioxide equivalent
DG REGIO:	Directorate-General for Regional and Urban Policy
DH:	District heating
DSL:	Digital subscriber line
EIB:	European Investment Bank, or "the Bank"
ENPV:	Economic net present value
EPO:	European Patent Office
ERDF:	European Regional Development Fund
ERIAM:	Economic Road Infrastructure Appraisal Model
ERP:	Enterprise resource planning
ERR:	Economic rate of return
ETS:	Emissions Trading System
EU:	European Union
FNPV:	Financial net present value
FRR:	Financial rate of return
FTTLA:	Fibre to the last amplifier
FTTH:	Fibre to the home
GC:	Generalised cost
GHG:	Greenhouse gas
GDP:	Gross domestic product
HV:	Heavy vehicle
IATA:	International Air Transport Association
ICT:	Information and communications technology
IER:	Institute of Energy Economics and Rational Energy Use
IM:	Infrastructure manager
IRR:	Internal rate of return
JASPERS:	Joint Assistance to Support Projects in European Regions
kV:	Kilovolt
kWh:	Kilowatt-hour
LC:	Levelised cost
l/c/d:	Littres/capita/day
LCU:	Local currency units
LCOE:	Levelised cost of energy
LCOH:	Levelised cost of hear
LRMC:	Long-run marginal cost

LV:	Light vehicle
MCA:	Multicriteria analysis
MW:	Megawatt
MWh:	Megawatt-hour
NOx:	Nitrogen oxide
NPC:	Net present cost
NPV:	Net present value
NTFP:	Non-timber forest product
OECD:	Organisation for Economic Co-operation and Development
O&M:	Operations and maintenance
OPEX:	Operating expenditure
PJ:	(EIB) Projects Department
PV:	Present value
R&D:	Research and development
RDI:	Research, development and innovation (including digitalisation)
RED II:	Renewable Energy Directive II
ROA:	Real options analysis
ROIC:	Return on invested capital
RP:	Revealed preference
RU:	Railway undertaking
SDR	Social discount rate
SOC:	Social opportunity cost
SO_2:	Sulphur dioxide
SP:	Stated preference
SRMC:	Short-run marginal cost
STP:	Social time preference
SWM:	Solid waste management
TEN-T:	Trans-European Network - Transport
TEU:	Twenty-foot equivalent (container) unit
VAT:	Value-added tax
VHC:	Very high capacity
VOC:	Vehicle operating cost
VOSL:	Value of a statistical life
VOT:	Value of time
WACC:	Weighted average cost of capital
WOP:	Without project
WP:	With project
WTP:	Willingness to pay

Contributors

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Foreword

The economic appraisal of an investment project goes beyond the financial appraisal by valuing all benefits and costs brought about by the investment to society as a whole. This way of appraising projects is central to the operations of the European Investment Bank (EIB). It allows the Bank to judge whether an investment will contribute to sustainable economic growth and cohesion in the European Union and to economic progress of its partner countries.

This guide illustrates how the EIB conducts economic appraisal across the various sectors of the economy where it operates. The Bank uses standard economic appraisal techniques, including cost–benefit analysis, cost-effectiveness analysis and multicriteria analysis, taking into account the evolving circumstances of each productive sector of the economy.

Economic appraisal is not a static discipline. With the development of new technologies and industries, advances in techniques and the publication of new academic findings, the methodologies and parameters used in project appraisal must evolve. Also, the policy context within which investments take place changes over time, with implications for appraisal techniques and parameters.

This second edition of the guide follows the EIB's adoption of the Climate Bank Roadmap in 2020, which incorporated into Bank operations the commitments established in the Paris Agreement. More precisely, through the roadmap the Bank committed to help transform and adapt the European economy and those of its partner countries to meet the 2050 target for an average global temperature no more than 1.5 °C above the pre-industrial level.

Crucially, this policy objective involves a revised approach to valuing greenhouse gas emissions in project appraisals. This second edition of the guide presents the implications for appraisals across economic sectors. Beyond global warming, the revised document also addresses developments in appraisal practice since the first edition was published in 2013. Importantly, the Bank is working to enhance the valuation of project benefits and costs for preserving biodiversity and supporting ecosystem services — a young, rapidly evolving frontier in applied economics. The guide summarises the Bank's progress in this field.

The overall aim is to keep the Bank at the forefront of viewing projects comprehensively; to identify the value of project outputs to citizens alongside any environmental costs and benefits; to allow for a fair, competitive return to private-sector investors while also valuing the implications of projects for public sector finances. The outcome should be to foster sustainable economic growth while ensuring that any public money invested is well spent, for the European Union and its partners.

Gunnar Muent
Director General, Projects Directorate

1. Introduction

J. Doramas Jorge-Calderón[1]

1.1 Objective of the guide

This document presents the economic appraisal methods that the European Investment Bank (EIB or "the Bank") uses in order to assess the viability of projects. An economically viable project is one that invests resources to generate a sufficiently high return to society. Given the societal focus, the terms economic and socioeconomic are used interchangeably in the document.

This guide gives the general reader an overview of methods, and the specialist insights into how the Bank applies analytical tools across sectors. It is not intended as a manual or set of instructions on how to conduct the economic appraisal of a project — there are already many widely available textbooks and guides.[2] Likewise, the aim is not to review the theory behind economic appraisal, as there are already many widely available references for that purpose.

This document has been written by over 30 EIB economists working on project appraisal, each reporting on their areas of specialisation. Economic appraisal is an ever-evolving field, and individual contributors have identified areas where work is ongoing to update parameters or revise methods. This guide thus gives a snapshot of economic appraisal practices at the time of writing and is intended to be updated over time.

Importantly, the guide covers economic appraisal only. Overall appraisal of a project by the EIB Projects Directorate also considers technical, environmental, social, financial and procurement aspects. More broadly, all Bank operations also involve credit, risk, compliance and legal assessments.

This introductory chapter presents the case for economic appraisal, which complements financial appraisal in measuring the returns of a project to society. It then describes how the conditions under which the Bank operates shape the type of appraisal performed. The chapter concludes by outlining the structure of this guide.

1.2 The need for economic appraisal

In competitive, undistorted markets with well-defined property rights, the revenues generated by an investment project measure the value of the output for users, while the costs (involving cash outflows) measure the value (or opportunity cost) of resources used in producing the output. In other words, prices for inputs and outputs are valid measures of societal value and scarcity. In addition, since projects tend to be marginal in relation to the size of the economy at large, they do not affect prices more than marginally, and hence there is no need to make additional considerations about consumer or producer surplus. Under such circumstances, the financial return on capital of the project would be a necessary and sufficient indicator to determine whether the project is worth undertaking or not from the social welfare point of view.

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[1] This introduction builds partly on the note to the Board of Directors of 2008 "The Economic Appraisal of Projects: An Overview of the Approach within the Bank" 08/580 prepared by J. Doramas Jorge-Calderón and Edward Calthrop with the cooperation of all PJ departments.

[2] The DG REGIO 2014 Guide to Cost-Benefit Analysis has such a pedagogic element, as it sets the principles that applicants for European Cohesion Fund financing should follow in their preparation of CBAs, adding an element of "how we want it done." See European Commission (2014) *Guide to Cost Benefit Analysis of Investment Projects*. European Commission Directorate General Regional Policy: Brussels. Available at: Guide to Cost-Benefit Analysis of Investment Projects for Cohesion Policy 2014-2020 - Regional Policy - European Commission (europa.eu) DG REGIO has recently published an Economic Appraisal Vademecum (EAV) developed with the support of JASPERS, which complements and updates the 2014 CBA Guide. The EAV provides a compilation of good practices in economic appraisal that can be used in the context of the preparation of projects for several EU funding sources in 2021-27. Available online at: https://ec.europa.eu/regional_policy/en/information/publications/guides/2021/economic-appraisal-vademecum-2021-2027-general-principles-and-sector-applications.

However, markets are not always sufficiently competitive, prices are often distorted, and property rights are sometimes not well defined, leaving externalities with no price assigned to them. For these reasons, a project's financial return may not be an adequate indicator of the desirability of the project for society at large. At times, such as with some public goods, a financial return may not exist at all. Provision of public goods may be offered free of charge to the user and generate no revenues to the investor, such as a dyke to preserve an eroding beach.

The standard economic appraisal technique for assessing a project's socioeconomic desirability is cost–benefit analysis (CBA). It is designed to produce a measure of project returns that corrects for the various market distortions and constraints mentioned above.

CBA has a long tradition in Europe. Originally conceived by French engineer Jules Dupuit (1848), it has been extensively developed by economists. CBA has become a standard part of public decision-making in many Member States, notably as a means to justify use of public funds. Besides the EIB, many other international financial institutions and international organisations also use CBA to appraise projects' economic desirability.

The outcome of a CBA is summarised in two complementary figures—the economic rate of return (ERR) and the economic net present value (ENPV). The ERR of a project is the average annual return to society on the capital invested over the entire project lifetime. It is, in other words, the interest rate at which the project's discounted benefits equal discounted costs, both valued from the point of view of society as a whole. A project is accepted if the ERR is equal to or exceeds a certain threshold (the social discount rate, or SDR). The ENPV of a project is the difference between benefits and costs, both discounted with the SDR. Projects are deemed to add value to society if the ENPV is positive.

Despite this seemingly schematic way of applying CBA, it is worth emphasising that economic appraisal by means of CBA is more than just a mechanical exercise. Good analysis can help clarify the aim of the project; estimate what will happen if the project is undertaken, and what will happen if it is not; evaluate whether the proposed project is the best option available; identify whether the components of the project are the most efficient; identify who wins and who loses from the project; quantify the overall impact on government's fiscal position; evaluate whether the project is financially sustainable; assess project risks; and, ultimately, give decision-makers an informed view on whether the project is worthwhile for society.

CBA measures the difference between the flow of costs and benefits with the project and those without — the "with-project" (WP) and "without-project" (WOP) scenarios, respectively. Policy choices are rarely between a project and no project — rather, there are usually several plausible policy alternatives. For instance, decision-makers might choose between constructing a new 100-kilometre greenfield motorway, constructing 50 kilometres of new greenfield motorway and upgrading the existing road for the other 50 kilometres, or upgrading the existing 100-kilometre road. Economic analysis will typically compare several policy scenarios against a common WOP baseline. Moreover, given the typically long lifespan of infrastructure and other capital assets, flows —whether benefits or costs— must be measured over many years for each scenario.

Depending on the nature of alternatives for assessment and on the type of data available, a comprehensive CBA may not be possible. In such cases, the economic appraisal may instead use cost-effectiveness analysis (CEA), which focuses on the cost of attaining a given target, or multicriteria analysis (MCA). These alternatives are not necessarily substitutes and may be seen as complementary to full CBA, particularly if economic viability is to be weighed against other policy considerations. However, the Bank makes a discrete choice among the methodologies, applying CBA where feasible, CEA where the appraisal focuses on choice of technology, and MCA where other methods are deemed impractical.

Much depends on the extent to which output variables, particularly benefits, can be measured and monetised. Where benefits are hard to quantify, traditional CBA becomes challenging and CEA is more practicable. On some occasions, the benefits of projects may be obvious, or policy may require that a project of one sort or another be carried out, without a need to prove societal value added at the project level. In such instances, the type of investment or programme is determined through a political process and CEA is used to determine the best project to achieve the desired results: this is generally the one that achieves the greatest output per unit of input.

MCA combines various evaluation techniques addressing different criteria, applying weightings to each to produce a single score that is used to compare alternative projects. Typical criteria include affordability, income distribution, compliance with strategic objectives, quality of the promoter's internal decision-making, aesthetic appeal of the project, etc. Both CEA and MCA are mere decision-making tools. Neither of the two measure the value added by the project to society.

The general suitability of the three techniques for different project circumstances is summarised as in Table 1-1. The two drivers are the extent to which output variables can be measured (and monetised) and the degree to which the project produces multiple outputs.

Table 1-1: Suitability of methodologies for project circumstances

		Number of output variables	
		High	Low
Degree to which output variables can be easily measured and monetised	High	CBA CEA	CBA CEA
	Low	MCA	CEA

The aim of all three techniques is to go beyond financial flows, and to allow for distortions that may be present in markets, to reflect wider benefits and costs to society, in order to assess the viability of the project to meet society's needs. However, only CBA comprehensively measures societal benefits and costs, making it the preferred method whenever practicable.

1.3 Economic appraisal at the EIB

The Bank finances projects in a very broad range of sectors, essentially covering all but a few industries (exceptions include tobacco and gambling). Targeted sectors include competitive industries, oligopolies and natural monopolies, as well as public goods. The outputs produced include manufactured goods and services. These services include, among others, basic services where consumer surplus may be impracticable to measure, as will be apparent in the sector presentations in Part 3 of the document.

Such variety requires the Bank to use an array of methodologies rather than a single, homogeneous one. About half of EIB project appraisals rely on ERR calculations, while the other half use alternative methods. This variety means that the results of appraisals across sectors are not always directly comparable. Nonetheless, it is necessary for appraisals to yield compatible results and guide decision making consistently, meaning that the application of alternative methodologies to projects (where feasible) would yield the same discreet decision on suitability for Bank financing.

1.3.1 Context of Bank appraisals

The previous section overviewed the role of economic appraisal in informing political choice on a project's socioeconomic value. This primarily benefits national authorities, not least in justifying to taxpayers the use of public funds. This type of appraisal is most useful when performed early in the project cycle, when very different courses of action could be taken (e.g. deploying alternative renewable energy technologies; high-speed rail versus upgrading a conventional rail system). In many Member States, economic appraisal is a sizeable industry in itself. A large project may require five to ten person-years of consultancy work on developing models, collecting data, and analysing different scenarios. In some sectors, such as road transport, economic appraisal is often undertaken by Bank services based on the project promoter's economic feasibility study. In other sectors, however, Bank services must normally construct the economic appraisal from scratch, based on business plans and financial projections.

If the promoter has produced an economic appraisal based on studies of consistently high quality, Bank services review and summarise the available material and their suitability for decision-making. In practice, however, several possible problems may be encountered when discussing a project's economic justification with the promoter.

1.3.2 Possible problems with studies presented to the Bank

"No appraisal". In some countries, there is only a weak tradition of justifying the selection of a particular project via an explicit analysis of costs and benefits. Whilst regular attempts are made to improve this situation, often initiated by the Bank itself,[3] the fact remains that, for the time being, many projects come accompanied with little more than a financial model. In addition, if the domestic political decision to fund has already been made, there may be inadequate incentives for the promoter to go back and quantify the impact of discarded options or a "without project" scenario. In this case, the Bank's services perform their own economic appraisal.

"Deficient appraisal": While views may differ on specific points (e.g. the assumptions of a particular model), a feasibility study prepared by a consultant may not meet the minimum standards for transparency, rigour and internal consistency, such as under guidance from the Directorate-General for Regional and Urban Policy (DG REGIO). In such cases, the Bank extracts the key assumptions from the existing work, discusses them with the promoter, and reworks the analysis within a consistent appraisal framework. In this respect deficiencies may concern the use of impacts on the regional economy or on jobs created as part of the project benefits, which constitutes mostly double counting and confuses benefit and impact analysis.[4]

"Over-optimistic appraisal": In some cases, promoters are over-optimistic on future demand patterns for their project – indeed, this may even be a strategic response to the need to outbid other competing claims for national and European funds. As a result, Bank services revisit the promoter's basic model but with different key assumptions – lower demand growth, perhaps, or including a more realistic project implementation schedule, as well as extending the sensitivity analysis. In this exercise, the Bank draws on extensive experience in appraising similar projects. If the Bank lacks access to the promoter's model, it is necessary to "translate" that model into a simplified format, and then explore how robust findings are to different assumptions on key inputs.

1.3.3 Need for consistent tools within the Bank

Even within Europe, promoters' studies vary in quality as regards plausibility, rigour and transparency. Accordingly, the Bank's services need to have a common approach when presenting projects to the Bank's decision makers, including the Management Committee and the Board of Directors. That is to say, even where promoters provide studies that are plausible, rigorous and transparent, there is a need to develop internal tools to provide a consistent view on projects across different countries.

For those sectors where financial appraisal is a poor proxy for economic appraisal, Bank services to develop simple, practical appraisal tools that can be rapidly applied to a wide variety of projects. The Bank has been using such models for many years, developing the nature and type of models over time as new methods become available.

[3] Reference is made to RAILPAG, JASPERS and technical assistance provided by the Bank.
[4] See chapter 8 on Wider Economic Impacts.

1.3.4 Use of methodologies across sectors

In appraising the economic viability of projects, the EIB uses CBA, CEA and MCA as substitutes rather than complements, and employs CBA whenever possible. In some sectors it may not be practical to estimate the benefits yielded by a project, such as where the policy context demands that the output be offered: examples include provision of clean water or a minimum level of healthcare. There are also some projects that normally involve simultaneous interventions in various economic sectors, such as in regional or urban development. The economic appraisal then focuses on whether the project constitutes the most efficient way to supply the good or service. CEA is only practicable when the output or service is homogeneous and easily measurable, such as the provision of electricity. In sectors where outputs can have many dimensions and may not be easily measurable, such as education, health and projects addressing the urban environment, MCA constitutes a better substitute to CBA than CEA.

Table 1-2 summarises the Bank's use of methodologies across sectors. The table is indicative, as the choice of appraisal technique is ultimately determined by the circumstances of each project.

Table 1-2: Methodology use by the EIB across sectors

CBA	CEA	MCA
Agro-industry Energy Health Manufacturing Telecommunications Transport Water and wastewater	Energy Solid waste management Water and wastewater	Education Health Research infrastructures Urban and regional development

1.4 Structure of the guide

The document is structured in three parts. The first two parts address methodological topics, whether relevant across many sectors (Part 1) or sector-specific (Part 2). These two parts do not seek to present an exhaustive guide to carrying out an economic appraisal; instead, they describe how the EIB addresses key methodological issues. This 2023 edition of the guide expands on the treatment of environmental externalities in the preceding 2013 edition. Whereas this topic was previously addressed in only one chapter, it is considered in three chapters herein: the first explores the treatment of carbon emissions following the adoption of the Climate Bank Roadmap (CBR) in 2020; the second discusses ongoing work on valuing biodiversity and ecosystem services externalities; and the third addresses other externalities such as air pollution and noise. Future versions of the guide may address additional issues in response to new policies or methodological developments deemed noteworthy.

Part 3 describes the application of appraisal methods to specific sectors. Each chapter identifies the key variables and circumstances affecting economic appraisal in individual sectors, and overviews the important parameters and assumptions used. One or more short case studies are also presented for each sector.

Part 1:

Methodology topics: Cross-sector

2. Financial and economic appraisal

Harald Gruber and Pierre-Etienne Bouchaud

2.1 Financial appraisal

The essence of financial appraisal is identifying all spending and revenues over the project lifetime, with a view to assessing the project's ability to achieve financial sustainability and a satisfactory rate of return. The appraisal is usually performed at constant market prices and in a cash flow statement format, listing all revenues and spending at the time they are incurred.

2.1.1 Revenues

The cash flow statement sets out the revenues to be derived from a project. These revenues can take several forms depending on the source. The easiest to identify are the products and services sold through normal commercial channels, as well as any commercially exploitable by-products and residues. Revenue is then forecast by simply estimating the sales values of these products and services. For certain types of projects (e.g. some infrastructure projects), revenues can be derived indirectly by monetising usage or availability. Whereas for projects run by private-sector promoters, or public-sector promotors acting as such, the revenues can be easily identified in the accounts, public-sector projects generally do not generate revenues. The financial appraisal of such public-sector projects is thus limited to determining whether public transfers will cover the operating and capital costs throughout the project lifetime.

2.1.2 Expenditures

The cash flow statement lists both capital and operational expenditures. Capital expenditure (CAPEX) is spending on those items needed to set up or establish the project. It usually covers items related to constructing facilities, including site preparation and other construction costs; plant and equipment, comprising not only acquisition cost but also the costs of transport, installation and testing; vehicles; and working capital. For projects involving innovation components, certain cost items such as research and development (R&D) and other current expenses related to innovation can also be capitalised, and hence treated as CAPEX.

Operating expenditure (OPEX) is spending incurred in operating and maintaining the project. It typically comprises raw materials, labour and other input services, repairs and maintenance. Pre-operating expenses, sunk costs, preparatory studies and working capital may be included under certain conditions, particularly when they have longer-term effects on the project. In a financial appraisal used as the basis for economic appraisal, other costs such as depreciation, interest and loan repayments are not included. Depreciation is excluded because it would double-count the capital cost, while interest and loan repayments are excluded because a major purpose of deriving cash flow is to determine what interest rate the project can bear.

Some projects do not lead to any direct increase in revenues but achieve their objective by reducing OPEX. When these flows can be quantified, they are included in the cash flow as negative OPEX. This can be quite straightforward for greenfield projects. However, where the project adds to an existing activity, a difference between WP and WOP scenarios is established and the project's output should be denoted by increased revenues or decreased OPEX, not the outcome of the activity as a whole. This ensures that only the project's impact is calculated. Care must be exercised in constructing a counterfactual, as some increases in spending or revenues after the project's establishment would have occurred even without it. "Before and after" is not the same as "with and without," and in project analysis the "with and without" comparison matters. In such cases it has proven effective to prepare two separate cash flow projections, one with the new project and one without it, and then treat the differences as the project's impact.

2.1.3 Subsidies and other public finance items

Project revenues, as is generally the case with all commercial activities, are subject to taxes and may also attract operating subsidies. Likewise, capital spending can be supported by subsidies. Reporting these items separately in the profitability calculation also helps to identify potential levers for increasing or decreasing the project's financial profitability.

2.1.4 Financial profitability

The financial profitability calculation evaluates the rates of return to the project's financiers, including suppliers of both equity and debt. This step provides indications about the incentives for improving the project's operational and financial structure. The cash flow statement illustrates the project's ability to raise its own financing and whether it is financially sustainable. Sustainability is summarised, for instance, by the financial rate of return (FRR), denoting the discount rate that yields a zero NPV of cash flow over the project lifetime. The FRR is then compared with the overall cost of funding rate, which represents the private incentive to undertake the project. If the FRR falls below the cost of financing,[5] the project is financially not worth undertaking, and thus requires a redesign and/or additional funding sources such as grants and subsidies.[6] These considerations are important for policymakers to determine the appropriate level of subsidies for a project that — owing to market failure — the private sector will not implement independently. In such cases, the level of subsidies should be designed for the promoter to reach the level of cost of funding in a competitive market setting. At the same time, financial profitability also allows competition authorities to determine whether subsides are justified or excessive.

These considerations are illustrated by a schematic example in Table 2-1. With subsidies the project would lead to an FRR of 6%. If the current cost of financing for private-sector companies in the same sector, such as the weighted average cost of capital (WACC), exceeded 6%, the promoter would not undertake the project. Subsidies (or net tax reductions) would need to be higher to make the project financially viable for the promoter. Clearly, if additional subsidies would cause the FRR to rise too much, competition authorities (particularly the European Commission) would step in and object to over-subsidisation under state aid regulations. One often-observed feature of EIB funding is allowing the promoter to significantly reduce the financing cost and, therefore, also ensure the financial viability of projects that previously would not have been undertaken.

Table 2-1: Example financial rate of return (FRR) calculation

Year		1	2	3	4	5
Revenues from project		10	30	80	100	100
− Operating costs		20	40	50	50	50
− Net taxes		0	0	0	0	0
Operating margin		−10	−10	30	50	50
− CAPEX		100	0	0	0	0
CAPEX subsidy		10	0	0	0	0
= Total profit		−100	−10	30	50	50
FRR	6%					

For public sector projects, particularly those not raising revenues but requiring transfers from the public treasury, the FRR is not applicable. Financial analysis is thus limited to assessing whether the public sector is willing or able to provide the funding required for costs over the project lifetime.

Finally, the FRR calculation is normally complemented with a sensitivity analysis. This tests the robustness of the FRR base-case estimate against deviations in typical parameters driving profitability, such as price, unit cost and capital cost. This analysis is important for assessing the likelihood of a private-sector project having sustainability issues due to adverse economic effects, and for finding ways to mitigate the possible impact of these effects.

[5] This is normally indicated by the cost to a promoter of raising funding, such as the weighted average cost of capital (WACC).

[6] A frequently used alternative indicator is the Net Present Value (NPV) of the project, which is calculated by using the cost of funding rate as discount rate. The project is financially viable if the NPV is positive. The FRR and NPV capture different aspects of the project return, but in any case lead to the same conclusions with respect to financial viability.

2.2 Economic appraisal

2.2.1 Elements of economic appraisal

Indications of financial profitability do not necessarily provide reliable estimates of a project's value from a social welfare or European view, focusing instead on private investors' perspective. Interests do somewhat coincide, making financial appraisal a valid starting point to assess a project's economic viability: financial profitability can even be valid guidance on economic profitability. In most cases, however, such guidance does not apply, for instance when there are important spillovers or externalities. Projects can lead to both positive and negative externalities for society and the net effect could be in either direction. These costs or benefits would arise as a direct consequence of a project but accrue to economic agents other than the project sponsors or outside the primary market. Such indirect effects can be very important, especially when environmental or information resources such as innovation are involved, and they should clearly be considered when deciding whether or not to accept a project proposal. Accordingly, the analysis must be broadened to include these external benefits of a project. For example, in the transport sector such economic benefits of improved roads typically include (i) the value of time (VOT) saved by users, (ii) the diminution of vehicle operating costs (VOCs), (iii) the reduction in accidents, and (iv) environmental benefits linked with a reduction in CO_2 emissions. These may be accompanied by economic costs, such as increased maintenance costs, or negative externalities, such as higher CO_2 emissions resulting from induced traffic or higher travel speeds.

Differences between financial and economic profitability can also be due to price distortions resulting from taxes or subsidies. In this case, the prices used in economic analysis should differ from those used in financial analysis, which are typically market prices (on shadow prices, see section 2.2.3). The prices may differ significantly where a project's inputs or outputs display distorted prices, particularly when they do not include all environment costs, such as CO_2 emissions or environmental degradation. This could lead to private investors either investing more than is optimal for society or undertaking projects not in society's interest. A project may be profitable only for its sponsors because it benefits from subsidies or regulated prices. This is a common situation where the project's products or inputs compete with others at market prices. The consequence is either the government losing revenue or consumers paying higher prices than they would otherwise pay, with the risk that the country becomes a high-cost producer unable to compete internationally.

Economic analysis also captures positive externalities of projects involving research, development and innovation (RDI). It is well known from the economic literature that innovative activities generate positive knowledge spillovers in the economy, and that product innovation leads to considerable consumer surplus. Such effects are not considered in financial analysis as the private promoter is generally unable to appropriate them. However, economic analysis includes these effects.

The economic analysis should also net out public transfers and subsidies paid to the project, which are neither a benefit nor an economic cost.[7] From the promoter's perspective, taxes and subsidies affect project revenues and spending, but from society's point of view, a tax levied on the promoter produces income for the government whereas a subsidy is a public expense. Thus, the flows net out. Transfer payments affect the distribution of project cash flows, so it is important to assess who gains and who loses from the project. Usually, the government collects taxes and pays subsidies. In these cases, the difference between the financial and economic analyses accounts for a major portion of the project's fiscal impact.

Some care must be exercised in identifying taxes. Not all charges levied by governments are transfer payments: some are user charges levied in exchange for goods sold or services rendered. For example, water charges paid by farmers to the irrigation authority (a government agency) are in exchange for use of water. Whether a government levy is payment for goods and services or a tax depends on whether it is directly associated with a purchase and accurately reflects the real resource flows associated using a product or service. For example, irrigation charges rarely cover the true cost of supplying the service; thus, while they indicate a real resource flow rather than a pure transfer payment, the real economic cost would be better measured by estimating the long-run marginal cost (LRMC) of supplying the water and treating the difference between this cost and the charge as a subsidy to water users.

[7] This of course ignores the fact that raising taxes may itself causes distortions that lead to significant economic costs and inefficiency.

Subsidies are taxes in reverse and should thus be removed from a project's receipts when carrying out economic analysis. From society's perspective, subsidies are transfers that shift control over resources from giver to recipient but do not represent a use of resources. The resources needed to produce an input (or import it from abroad) represent the input's true cost to society. For this reason, economic analysis uses the full cost of goods, not the subsidised price.

In some cases, a project may not only increase an output but also reduce its price for consumers. Output price changes typically (but not only) occur in power, water, sanitation and telecommunications projects. When a project lowers the price of its output, more consumers can access the same product and existing consumers pay a lower price than before. Valuing benefits using the new quantity and the new, lower price would thus understate the project's contribution to societal welfare by ignoring the consumer surplus: the difference between what consumers are prepared to pay for a product and what they actually pay. In principle, the benefits of a project include the increase in consumer surplus of existing users (thanks to lower prices flowing from lower costs) and the willingness of new customers to pay, net of incremental cost.

2.2.2 Economic profitability

After taking into account all costs and benefits for society, the economic analysis determines whether the project is worth undertaking. The economic analysis is a crucial decision tool for a public sector, policy-driven bank such as the EIB, which is bound by its statutes to support the European public interest. The Bank uses the ERR as a benchmark, i.e. the discount rate that yields a zero NPV of economic net benefits over the project lifetime. The ERR is then compared to the SDR (see chapter 10). If the ERR falls below the SDR, the project as defined is economically unjustified and so should not be undertaken, as it would constitute a misallocation of economic resources. An ERR at or above the SDR is a prerequisite for the Bank to finance the project.[8] A commonly used alternative indicator is the NPV, calculated using the discount rate: a project is economically viable if its NPV is positive. The ERR and NPV capture different aspects of the project return but lead to the same conclusions on viability (except in cases of multiple ERRs, which makes the ERR irrelevant for the decision-making process).

The ERR calculation is illustrated by a schematic example in Table 2-2. The project's net economic benefits over its lifetime lead to an ERR of 11%. If the SDR of the economy is below 11%, then financing of this project is justified. The nature of the benefits may differ considerably depending on the sector and, in particular, the type of promoter. Projects promoted by the public sector typically have low (if any) revenue streams. Hence, the benefit calculation must include non-monetary benefits accruing from the project and its economic externalities. Projects with an ERR below the SDR are an inefficient allocation of resources and, ultimately, an economic burden to society throughout the project lifetime.

Table 2-2: Example ERR calculation

Year		**1**	**2**	**3**	**4**	**5**
Direct benefits from project		10	30	80	100	100
Net externalities to society		1	3	8	10	10
− Operating costs		20	40	50	50	50
− CAPEX		100	0	0	0	0
= Net economic benefit		−109	−7	38	60	60
ERR	11%					

The ERR therefore captures the net value added by the project to society, while the FRR captures the value added to the investors. The Bank takes the spread between the two (ERR-FRR) as an indicator of the "broader social benefit" added by the project to society (see chapter 10)—broader in in the sense of being over and above the value captured by investors.

[8] If the decisions concern more than one project, the ERR should be used for ranking the contributions of projects for welfare purposes.

2.2.3 Shadow prices

In the financial analysis, costs and benefits are valued at prices the promoter is expected to pay and receive. These prices are usually set by the market but may, in some cases, be controlled by the government. However, these prices do not necessarily reflect economic costs to society. The economic values of inputs and outputs may differ from their financial values because of market distortions created by the government, the macroeconomic context or the private sector. Such distortions or market biases can reflect GHG emissions, over- or undervaluation of the domestic currency and imperfect market conditions, including low labour mobility and large underemployment. To compensate for such distortions, shadow prices can be calculated that more closely reflect the project's opportunity costs and benefits. Compared to possibly distorted market prices amid market imperfections, shadow prices better reflect the values of willingness to pay (WTP) and willingness to accept compensation. Shadow pricing may, for instance, apply to:

- **Cost of carbon**. The shadow cost of carbon is an important parameter in the economic assessment of investments. As part of the wider framework of alignment with the Paris Agreement, it is important to set the shadow cost of carbon in line with the best available evidence and EU ambition. Accordingly, the shadow cost of carbon is taken as the cost required to drive the world economy to net zero GHG by 2050. Estimating this value requires complex economic-climate models. As discussed in chapter 4, authoritative studies suggest that the full shadow cost will rise to around €250 per tonne by 2030 and €800 by 2050. If a project reduces carbon, the economic case is strengthened by adopting a higher cost of carbon, for instance in climate-action projects (e.g. energy efficiency, most public transport, renewable energy).

- **Situations where the project country's official exchange rate does not properly reflect the scarcity value of foreign exchange.** This occurs where the costs of imports are held artificially low (in case of overvaluation) or high (in case of undervaluation), meaning that demand for them is arbitrarily altered. To estimate shadow exchange rates reflecting the scarcity value of foreign exchange, conversion factors can be used that establish the correct relationship between the prices of internationally traded goods and services and the prices of goods and services not so traded. Distortions arise from many sources, such as import or export taxes/subsidies and quantitative restrictions on trade. Such distortions vary in their effects on different goods, but it is not practical to use a different conversion factor for each commodity involved in a project. Accordingly, a single conversion factor corresponding to the economy-wide shadow exchange rate, and termed the "standard conversion factor," is calculated. This is a summary indicator of trade distortions expected to prevail in the future. Notably, globalisation may have reduced the necessity of such shadow pricing.

- **Cost of labour**. In countries where the labour market functions smoothly, the wages actually paid are adequate for financial and economic analyses. However, government interventions in some labour markets introduce distortions[9] that could justify using shadow wage rates to reflect the opportunity cost of using labour in a project. In such cases, the monetary cost of labour does not necessarily equal the marginal output of labour and so needs correction. Most commonly, in an environment where unemployment or underemployment prevails, the economic cost of unskilled labour is less than the monetary cost of labour paid by the project. Reducing labour costs through shadow pricing increases the project's NPV (social net benefits) in comparison with its financial value.

[9] Depending in the theoretical approach, the distortions may be caused by minimum wage legislation, legal impediments to labour mobility or especially high taxes on labour.

3. Defining the counterfactual scenario

J. Doramas Jorge-Calderón

3.1 Introduction

The economic and financial profitability of a project are estimated by considering the project's incremental benefits and costs, namely the benefits and costs over and above those that would have occurred without the project.

The analyst makes assumptions on what would happen without the project by building a counterfactual or WOP scenario. Two broad situations arise, involving the degree of competition in the market concerned. In highly competitive markets, where entry and exit is free and the goods or services produced by the project face close substitutes, neither project nor promoter has any power to dictate the price, quantity and quality of the output. If the proposed project did not proceed, other competitors would take the promoter's place by producing and selling on the same terms as the promoter would have done. In such cases, the project merely adds incremental output on terms determined by the market.[10]

The WOP scenario would thus exclude the capacity supplied by the project, resulting in a marginal price difference and a small loss of consumer surplus relative to the WP scenario. Since competitive markets tend to be highly atomised, the price difference and consumer surplus loss are small. In practical terms they are both ignored, which means that in the absence of other distortions, the financial appraisal closely approximates the economic appraisal. This, in turn, implies that there is no need to construct an ad hoc counterfactual; the WOP scenario thus comprises the opportunity cost of resources devoted to the project, including the cost of capital.

In uncompetitive markets, by contrast, entry is restricted and substitutes are inferior, giving the promoter at least some power to determine market terms on price, quantity and quality. Not carrying out the project at all could even lead to superior profitability for the promoter. With insufficient competition, the project appraisal must include an ad hoc scenario describing what could be expected to happen without the project. Since the promoter has the power to dictate supply terms, various WOP or counterfactual scenarios may be possible.

This section summarises the criteria to be used to define counterfactual scenarios across the various methodologies used by the Bank — CBA, CEA, and MCA — in situations where markets lack sufficiently close competing substitutes.

[10] In the case of a project consisting only of introducing efficiency gains in a highly competitive market, for the project not to have any output effect demand would need to be completely inelastic. The without project scenario would then consist of portion of the market being supplied at a higher cost.

3.2 Types of counterfactual

3.2.1 The three basic types

Projects financed by the Bank involve capital formation concerning a facility to produce an output, whether tangible (say, an infrastructure) or not (say, research), and so always entail capacity investment, whether new, upgraded or rehabilitated. In this sense, the project (or WP scenario) is always a "do-something" scenario. There are three basic types of counterfactual (or WOP) scenarios against which to compare the project:

1. "Do nothing": This scenario assumes that without the project there will be no investment at all. Capacity will gradually deteriorate, reducing the future ability of the facility to meet demand. This type of WOP scenario is suitable for capacity-rehabilitation projects.

2. "Do minimum": This scenario assumes there will be sufficient investment to keep existing capacity operational in the future. It is a suitable counterfactual for capacity-expansion or -upgrade projects. The investment analysis compares the project with the counterfactual scenario of making necessary investments to keep installed capacity operational for the full project lifetime.

3. "Do something else": In contrast to the "do-something" scenario embodied in the project, a "do-something else" scenario is an alternative approach to meeting the same objectives. This may involve an alternative technology, a different project scale or an alternative project location. It is an appropriate counterfactual for analysing project benefits and costs after recognition that something must be done (e.g. fulfilling a legally mandated level of service).

As mentioned in chapter 1, appraisal methods must fit the Bank's remit, which nomally excludes acting as a planning agency and deciding on the best project option. Only when providing technical assistance for project conception may the Bank explore alternative project options. Otherwise, in standard lending operations, the EIB considers projects for financing only once the preferred option has been chosen and preparatory work or construction has begun. Likewise, the Bank does not engage in a budgeting exercise whereby only the projects with the highest returns are financed. Bank operations are embedded in the commercial lending market, and the EIB has limited foresight on the future project pipeline, such that possibilities for budgeting are, at best, limited. Therefore, the Bank focuses on ensuring that supported projects are viable and generate sufficient economic value.

For these reasons, Bank appraisals do not normally evaluate alternative project options. Therefore, the counterfactuals used in project appraisals normally adopt the "do-minimum" criterion for capacity-expansion or -upgrade projects and the "do-nothing" criterion for capacity-rehabilitation projects. With both types of counterfactuals, the appraisal considers the case for a project to take place. The "do something (else)" counterfactual may be used when there is no reason to question the case for a project; the appraisal focuses instead on the relative value of one technology over another.

3.2.2 Cost–benefit analysis

For CBAs, the Bank normally uses the "do-minimum" scenario by default, except for capacity-rehabilitation projects. For capacity-expansion or -upgrade projects, the analysis asks, "Do we expand capacity or keep capacity at current levels?" The analysis then compares the "do something" with a "do minimum."

If the analyst instead compared the "do something" with a "do nothing," the capacity-upgrade project would be evaluated not against no capacity upgrade but rather against letting capacity deteriorate until potentially inoperable. Using a "do-nothing" instead of a "do-minimum" counterfactual would normally overestimate the returns of a capacity-expansion/upgrade project, as "do-minimum" scenarios include fewer benefits or higher costs to society. This is illustrated in the example in section 3.3 below.

By nature, rehabilitation projects call for comparing the "do something" with a "do nothing." A pure rehabilitation project generally involves keeping existing capacity constant, rather than expanding it — the WP scenario involves no growth in capacity. In that sense, a rehabilitation project could be viewed semantically as comparing a "do minimum" with a "do nothing."

Whenever the case to carry out a project is unquestionable or there is a legal obligation to meet demand, the CBA may also use a "do-something (else)" counterfactual. The CBA then measures the relative value of one technology over another, somewhat resembling CEA.

3.2.3 Cost-effectiveness analysis

CEA starts from the premise that the good or service concerned must be supplied, meaning the counterfactual must be at least a "do-minimum" scenario. The appraisal then focuses on whether the project constitutes the most effective technology to deliver the desired output per cost unit. Where there is room for selection among alternatives, the analysis may evaluate the "do-something" against several "do-something else" options to help identify the most efficient option.

3.2.4 Multicriteria analysis

An MCA-based appraisal can be constructed with the same array of scenarios as a CBA, and the Bank uses the same criteria to define counterfactuals in both types of analysis: for a capacity-expansion/upgrade project, the comparison is between the "do something" and a "do minimum"; for a rehabilitation project, it is between the "do something" and a "do nothing."

MCA, like CBA, lends itself to considering alternative project options — to comparing "do something" with "do something else." This type of analysis can be performed when there is no reason to question the case for a project, and the appraisal evaluates whether one project option (such as technology) is more effective than another.

3.3 Illustrating the impact of an inadequate counterfactual

A common source of error while building scenarios for capacity-enhancement projects is mixing up a "do-nothing" with a "do-minimum" counterfactual. When the appraisal asks whether capacity should be expanded or kept constant, the WP scenario should be compared with a "do-minimum" scenario. If the appraisal instead asks whether capacity should be expanded or left to degrade, the proposed project should be compared against a "do-nothing" scenario. The economic returns of the capacity expansion would be overestimated if management seeks to answer the first question but the project analyst focuses on answering the second. This may lead management to make a wrong decision, probably by overinvesting.

Table 3-1 illustrates the issue with a hypothetical project, presenting net operating benefits and investment costs for three possible scenarios: "do something," "do minimum" and "do nothing." The scenarios are mutually exclusive, but their technologies could be considered cumulative. The "do-something" scenario involves investing €450 million, and will result in benefits growing by 5% per year. It combines rehabilitating existing capacity with expanding capacity. The "do-minimum" scenario involves investing €30 million in rehabilitating existing capacity, leading to constant benefits. The "do-nothing" scenario involves no investment at all and will let existing capacity deteriorate over time, affecting the amount of output the facility can produce. Consequently, net benefits will fall by 5% per year. The table's first numerical column includes the present value (PV) of the flows along each row, discounted at 3.5%.

Table 3-1: Project return under alternative counterfactuals

	Scenarios				PV	1	2	10	21
(1)	Do something		Net benefit	(EURm)	1058	45	47	70	119
(2)			Investment	(EURm)	435	450			
(3)	Do minimum		Net benefit	(EURm)	661	45	45	45	45
(4)			Investment	(EURm)	29	30			
(5)	Do nothing		Net benefit	(EURm)	442	45	43	28	16
(6)			Investment	(EURm)	0	0			
	Project returns								
	"With project"	"Without project"							
(7)=(1)-(2)-(3)+(4)	Do something	Do minimum	Net flows	(EURm)	**-9**	-420	2	25	74
			IRR		**3%**				
(8)=(1)-(2)-(5)+(6)	Do something	Do nothing	Net flows	(EURm)	**182**	-450	5	41	103
			IRR		**6%**				
(9)=(3)-(4)-(5)+(6)	Do minimum	Do nothing	Net flows	(EURm)	**191**	-30	2	17	29
			IRR		**28%**				

The last three rows of Table 3-1 present the calculation of (incremental) project returns for the three possible scenario combinations. Row (7) presents the capacity-expansion scenario, comparing a project that expands capacity with leaving capacity constant. The calculation compares the “do-something” with the “do-minimum” scenario, in which the necessary investments will be made to keep current capacity constant for the entire life of the comparative project (“do-something”). The project presents an IRR of 3%.

In row (8), the capacity-expansion project is instead compared against the “do-nothing” scenario, leading to the IRR increasing to 6%. However, this analysis estimates the returns from not only increasing capacity but also rehabilitating existing capacity. Such an analysis would be correct if the operator could either rehabilitate and expand capacity or let capacity degrade, but not if the choice were between expanding capacity and keeping it constant. Essentially, the IRR value of 6% combines low returns on capacity expansion (3%) with high returns on rehabilitating existing capacity (28%). If the threshold for accepting projects was 5%, for example, then the capacity-expansion investment would clearly not be viable, but it would appear so by using the “do-nothing” instead of the “do-minimum” counterfactual.

4. Cost of carbon

Edward Calthrop[11]

4.1 Introduction

The EIB's approach to estimating the value of GHG emissions is set out in Annex 5 of the CBR (EIB, 2020). The roadmap sets out the conceptual basis for the shadow cost — i.e. the least cost to society of meeting the 1.5 °C temperature goal. It also explains the empirical evidence, reviewing the estimates produced the relevant scenarios from large-scale climate-economy models. Table 4-1 reproduces **the EIB shadow cost of carbon** (measured in 2016 euros).

Table 4-1: EIB Shadow cost of carbon

		2020	2025	2030	2035	2040	2045	2050
Value (€_2016/tCO2e)		80	165	250	390	525	660	800

Source: Table A6, EIB (2020).

This chapter focuses on the economic and financial assessment of projects associated with GHG emissions. First, it considers the valuation of emissions from projects operating under different regulatory frameworks — notably with a carbon tax or an emissions trading scheme. This is relevant as the EIB supports projects throughout the world, and thus deals with very diverse regulatory environments. The chapter concludes that, under some assumptions, it is reasonable to apply the shadow cost of carbon presented in Table 4-1 to value GHG emitted or saved by the project, irrespective of the regulatory environment.

Second, the chapter considers how to treat any divergence between the shadow cost of carbon and the financial price for carbon faced by a project in practice. It advocates developing a reference scenario consistent with long-term emission-reduction targets, even if the equilibrium values of key variables (e.g. demand, cost curves) reflect carbon prices differing from the shadow cost.

This chapter focuses solely on the economics of projects that will change GHG emissions. In this sense, it is relevant to climate mitigation. The chapter does not consider the economics of projects, or project components, designed to adapt to current and future climate change (though chapter 12 deals with decision making under uncertainty). The EIB will develop separate guidance on the economics of adaptation in due course.

[11] This chapter draws heavily on Rosendahl and Wangsness (2020a,b). I would also like to thank in particular Doramas Jorge Calderon for discussions over many years on this issue, as well as Per-Olov Johansson and Bengt Kriström for detailed comments. Errors and omissions remain my own.

4.2 Valuing emissions in practice: Basic intuition

This section provides insight on valuing GHG emissions[12] from projects operating under different regulatory environments. Based on Rosendahl and Wangsness (2020b), and as elaborated in Annex 1, this section distinguishes three regulatory settings:[13] (i) a carbon tax; (ii) an emissions trading scheme with a fixed emissions cap; and (iii) an emissions trading scheme with an endogenous cap. Consider the impact of a project emitting a tonne of CO_2 in each setting:

- Case A — carbon tax: Given an economy-wide emissions target, if the project emits an extra tonne, society incurs the additional cost of having to abate an extra tonne elsewhere in the economy. This is precisely the shadow cost of the economy-wide emissions constraint, meaning the shadow cost of carbon. Note that this result holds regardless of the level of carbon tax applied in practice, which is relevant solely to assessing the project's FRR.
- Case B — fixed-cap emissions trading scheme: By emitting one tonne of CO_2 within the scheme, the net effect of the project is to require an additional unit of abatement from other economic activities operating within the scheme. As long as the emissions cap is considered fixed, the opportunity cost of one emission unit inside the scheme is measured by the permit price.[14] Note that this holds regardless of the shadow cost of carbon, which may be higher or lower than the permit price. In this case, financial and economic analyses of the project refer to the permit price.
- Case C — endogenous-cap emissions trading scheme: Assuming that the cap is adjusted positively to demand for emission allowances, Case C[15] can be characterised as a weighted average of Cases A and B. In an extreme case where the cap responds one-to-one with the increase in demand, Case C corresponds to Case A (carbon tax) and emissions are valued at the shadow cost of carbon. Under the other extreme case in which there is no adjustment to the cap, Case C corresponds to Case B (fixed cap scheme) and emissions are valued at the permit price. In general, the value of an emissions increase is the weighted average of Cases A (the shadow cost of carbon) and B (the permit price), with weights determined by the cap's degree of responsiveness. The economic and financial returns will diverge by a fraction — depending on relative weights — of the wedge between the shadow cost of carbon and the carbon tax.

Consider applying this insight in the context of project assessment. For a project operating outside the EU ETS but subject to a carbon tax, it is relatively intuitive[16] that emissions are valued at the shadow cost of carbon (Case A). For projects operating within the EU ETS, the specificities of the Market Stability Reserve make it arguable that the emissions cap is partially endogenous (Case C) — see Perino (2018). The key empirical question becomes the extent to which the change in emissions demand resulting from the project translates into a change in the overall emissions cap via the Market Stability Reserve.

[12] For ease, this chapter refers to a project emitting a tonne of greenhouse gas though the same result holds symmetrically for a project saving a tonne.

[13] In commenting on this issue, Professor P.O. Johansson examines CBA under a combination of instruments. He distinguishes a *second best case* – in which the coverage of the permit scheme is optimised alongside carbon taxes to meet the economy wide emissions target at least cost - from a *third best case* in which the coverage of the permit scheme is fixed. He shows that under the third best case, it is correct to value the change in emissions at the permit price. In the second best case, with optimised coverage, the tax and permit price are equalized. He also discusses a *fourth-best case* in which different countries agree to contribute to the target but then select their own policy instruments.

[14] See Jorge-Calderón and Johansson (2017) for a formal presentation of the case with a fixed emission cap, and an application in the context of the airport investment.

[15] See Johansson (2020) for a formal analysis of the case of a reduction in emissions within the ETS leading to a future reduction in permits. This net reduction in emissions is shown to be valued by households' willingness to pay for emissions reduction and the effect on profits minus the permit price. This generalises the approach in this chapter in which the goal of reaching 1.5 degrees is taken as given (and hence measured through the shadow cost of carbon).

[16] This may be challenged if a particular country has a non-ETS targets in the short run which imply higher carbon taxes (and marginal abatement costs) than the overall economy wide shadow cost - see Carlén and Kriström (2019) for a discussion of the difference in abatements costs in Nordic countries versus other parts of the EU. In general, however, this is unlikely to be the case.

As explored by Gerlagh et al. (2021), in the short run a high share of project emissions will likely translate into reductions in the cap via the Market Stability Reserve – not one to one, but possibly close to that ratio. In the medium to long run, however, the impact on the overall cap is smaller though may still be sizeable, depending on the extent to which the market anticipates these changes in future emissions and therefore adjusts its net emissions banking. This suggests that short-term emissions (with a relatively large impact on the emissions cap) should be valued at the shadow cost of carbon, while longer-term emissions (with less impact on the emissions cap) should be valued closer to the forecast permit price.

The previous paragraph develops a line of reasoning based on the current ETS legislation. It is important to recognise, however, that the EU ETS operates within a broader EU policy commitment to climate neutrality. The European Climate Law provides a robust framework with clear GHG targets for 2030 and 2050. As an EU institution, and in line with its own Climate Strategy, the EIB treats the 1.5 °C target for 2050 as an exogenous policy commitment. In this wider sense, it can be assumed for CBA purposes that the EU ETS cap (and other climate policy instruments) will be adjusted over time to ensure the policy commitment is met. In other words, **policy is assumed to be endogenous** over the long term, regardless of the current mechanics of the Market Stability Reserve. If so, it follows – as per Case A above, that emissions should be valued at the shadow cost of carbon irrespective of actual carbon taxes or permit prices.

Given the widespread adoption of the Paris Agreement, as well as the global nature of models used to estimate the shadow cost of carbon, this line of reasoning holds for projects globally – at least from an efficiency point of view. When working in some of the poorest and most vulnerable countries, the Bank may conduct sensitivity analysis around the shadow cost to help inform better internal decision-making.[17]

In summary, this section sets out the rationale to apply the EIB shadow cost of carbon to value the change in emissions resulting from a project, irrespective of the regulatory environment. It also highlighted the assumptions underpinning this approach, which in addition has the operational advantage of being particularly simple to apply in practice.

4.3 Forecasting key variables for economic and financial analyses

The previous section highlights the potential wedge between the shadow cost of carbon and the carbon tax or permit price applicable to the project in practice. We refer to these actual charges as the "financial price of carbon." This section considers the divergence between the shadow cost and financial price in estimating the equilibrium values of key variables in a project assessment.

In the short term, current climate policies — including taxes, permit prices, standards and regulations — are the most relevant factors in estimating key variables such as relative prices, cost curves and demand projections. For emissions in the longer term, however, it is necessary to draw on applied modelling exercises. A natural reference point for the EIB within the European Union is the large-scale modelling[18] performed for the European Commission in designing EU climate policies. This may be complemented by more detailed sectoral or national studies.

Such sources are useful to construct a long-term reference scenario of the project's key exogenous parameters: economic, technological and social trends. This reference scenario should reflect relevant emission-reduction targets, noting that a large portion of the global economy is committed in some way to net zero. Depending on the local context, there may be uncertainty over the timing of regulatory and market developments: for instance, the implementation of climate policies may be slower than anticipated. Ideally this should be reflected in the scenario assessment — in analysing the project's net benefits under different assumptions about the (exogenous) reference scenario.

[17] In practice, the eligibility for Bank finance for projects associated with significant carbon emissions is often defined primarily through technical criteria e.g. power generation below 250 g/CO2e per kWh, no airport expansion etc. This is set out in EIB (2020). Nevertheless, in working in particularly poor countries, and where relevant to the financing decision, the economic analysis of projects may employ sensitivity analysis around carbon pricing, using local conditions and carbon switching values to help inform EIB decision makers. In particular, this can be used to address particular concerns around imperfect instruments to redistribute globally highlighted by Professor Stiglitz and co-authors in the High level Commission on carbon pricing (2017).

[18] See for example Modelling tools for EU analysis (europa.eu). A recent application can be seen in European Commission (2018).

Chapter 32 illustrates the development of a consistent reference scenario in assessing capacity increases for a road network. Forecasts on electrification of the vehicle fleet are combined with demand growth projections from long-term modelling exercises consistent with climate-neutral goals. Similarly, chapter 20 on power generation shows the use of the shadow price of carbon in the LRMC of different technologies, with wider price and demand forecasts helping to inform the operation of a particular plant in practice.

France Stratégie (2019) provides a number of recommendations regarding the CBA of climate-action projects. These recommendations include valuing flexibility in projects with long lifespans (to avoid locking in existing technologies) and taking account of the entire project lifespan, from construction to dismantling. The EIB will seek to monitor best practice and will apply it, as and where material, to help inform better decision-making.

This section emphasises the distinction between the shadow cost of carbon, capturing the full value to society of a change in emissions resulting from the project, and the financial price of carbon, which combines with other climate policies to drive the equilibrium values of key variables underpinning the project assessment. It is natural to consider any difference between the shadow cost and financial price as a distortive wedge. However, where a wide range of climate policies is applied in the reference scenario, such a wedge may not reflect a distortion.[19] For instance, if a regulation requires that all new passenger vehicles are electric by 2035, it may be consistent to assume strong growth in the share of electric vehicles in an economic model with an excise duty on petrol and diesel sales (i.e. the financial price) significantly below the shadow cost of carbon.

That said, the equilibrium price path for goods and services assumed in the economic analysis — in practice often drawing on studies by consultants on the project promoter's behalf — should be broadly consistent with the emissions trajectory implied in the EIB shadow cost of carbon. If not, the Bank risks supporting projects which are unprofitable — in economic or financial terms — at the new price vector.

4.4 Conclusions

The CBR presents the values adopted by the EIB for the shadow cost of carbon, as shown in Table 4-1. This chapter focused on the application of these values within CBA. It explains the basic rationale behind using the shadow cost of carbon to value a change in emissions resulting from a project, irrespective of the prevailing regulatory framework.

This chapter also distinguishes the shadow cost of carbon, as a parameter to capture the full value of emissions, from the financial price of carbon, as reflected in the reference scenario for key variables (e.g. cost curves, demand). While there may be divergence between the financial price and shadow cost used in analyses, broad consistency should be ensured in the equilibrium quantities over time and the emissions reduction target of the relevant country or region.

As reflected in this chapter's list of references, the topic of valuing GHG emissions in different regulatory settings continues to receive considerable interest in the applied economics literature. The EIB will, therefore, continue to monitor developments in this field and adjust, as necessary, the approach set out here.

[19] As well established in the literature, under standard assumptions and with one externality, a carbon tax decentralises the first best solution. Multiple instruments are likely to be less efficient – or at least cannot be more efficient. Note however that this result changes with multiple externalities (e.g. research and innovation; learning by doing etc).

4.5 Annex 1: Valuing a change in GHG emissions from a project subject to a carbon tax or an emissions trading scheme

This annex uses a simple example to illustrate how to value the change in emissions resulting from a project subject to a carbon tax or operating within a cap and trade scheme such as the EU Emissions Trading Scheme (ETS). It highlights the conditions under which the shadow cost of carbon is relevant, drawing heavily on the example[20] provided by Rosendahl and Wangsness (2020b).

1. A carbon tax set lower than the shadow cost of carbon

Consider the following simplified project parameters:[21]

- The project requires public CAPEX of €400 million.
- It is a polluting project that leads to an increase in emissions of 5 million tCO_2 over the project lifetime. Note that the results hold symmetrically for a project reducing carbon emissions, which is more typical of EIB operations.
- Excluding climate considerations, the project provides users with a net benefit of €1 billion (gross benefit of €2 billion minus user costs of €1 billion). This means that the project leads to a welfare increase of €600 million (net user benefits of €1 billion minus €400 million CAPEX).
- The shadow cost of carbon is assumed to be €100 per tonne. In other words, given that this project increases emissions, the marginal cost to society is €100 per tonne to compensate for the project with additional abatement measures.
- Project emissions are assumed to be taxed at €50 per tonne — below the shadow cost of carbon. (This will be varied under different scenarios below.)

Table 4-2 summarises the flows of costs and benefits to different parts of society from the project. Shaded rows are not used at this stage. The total carbon tax revenue collected — €50 per tonne * 5 million tonnes = €250 million — is a transfer to government. The cost of emissions from the project is valued at the shadow cost — the cost of measures that will need to be employed elsewhere in the economy to reach the emissions target.

The project results in an overall surplus to society of €100 million. The gains to project users (+€750 million) outweigh the combination of the net cost to government to construct the project (−€150 million) and the costs to society of other abatement measures required to deliver the emissions target (−€500 million).

Notably, in a more realistic context with a stream of costs and benefits over time, the ERR of this polluting project (with NPV of €100 million) would fall below the FRR (with project users gaining €350 million, as the CAPEX of €400 million is deducted from €750 million). In the opposite case of a project saving carbon (and thus avoiding paying the carbon tax), the ERR would exceed the FRR.

[20] Rosendahl and Wangsness also include the cost of public funds. This is removed from this annex to provide further simplicity. In addition, some parameter values are trivially adjusted simply to give greater relevance to EIB values (e.g. shadow cost of carbon).

[21] To keep the presentation as simple as possible, we abstract from time (or implicitly consider all values in net present terms).

Table 4-2: Costs and benefits of a project under a carbon tax

	Project users	Government	Other agents in society	Total
CAPEX		−400		−400
Gross user benefits	+2 000			+2 000
User cost excluding carbon charges	−1 000			−1 000
Cost of CO_2 permits				
Cost of abatement for other ETS firms				
Cost of carbon tax paid by users	−250	+250		0
Cost of project CO_2 emissions			−500	−500
Total	+750	−150	−500	+100

2. A carbon tax set equal to the shadow cost of carbon

Let us consider a different case where the carbon tax equals the shadow cost of carbon (a Pigouvian tax). In general, this change in an exogenous parameter impacts the equilibrium values of key variables under the WP and WOP scenarios. Hence, all assumptions about the project are maintained except:

- The carbon tax is assumed to be €100 per tonne — equal to the shadow cost of carbon;
- Reflecting the higher carbon tax, the project leads to an increase in emissions of 4.5 million tCO2 over its lifetime — a reduction from the 5 million tonnes emitted with the lower carbon tax rate assumed in the preceding example;
- User cost is assumed to increase to €1.02 billion, reflecting the change in equilibrium. Hence, absent environmental costs, the project leads to a welfare increase of €580 million (€980 million net user benefits minus €400 million CAPEX).

Table 4-3: shows the relevant flows under this scenario.

Table 4-3: Project costs and benefits where the carbon tax equals the shadow cost of carbon

	Project users	Government	Other agents in society	Total
CAPEX		−400		−400
Gross user benefits	+2 000			+2 000
User cost excluding carbon charges	−1 020			−1 020
Cost of CO_2 permits				
Cost of abatement for other ETS firms				
Cost of carbon tax paid by users	−450	+450		0
Cost of project CO_2 emissions			−450	−450
Total	+530	+50	−450	+130

In this scenario — with more efficient pricing — the overall net benefit of the project improves to €130 million. However, comparing the results for different stakeholders between Table 4-2 and Table 4-3, project users lose out as carbon taxes and user charges are higher (€530m − €750m = −€220m), government gains more tax revenue (€50m – (-€150m) = €200m) and society has less cost from abating pollution (-€450m – (-€500m)= €50m). Efficient pricing improves the net economic benefit from the investment by €30 million. With the carbon tax matching the shadow cost, private incentives are thus aligned with the social optimum. In other words, the ERR equals the FRR.

3. An emissions trading scheme with an exogenous cap

We now consider a project operating within a fixed, binding emissions trading scheme. The coverage of the scheme and the clearing price of a permit are assumed to be exogenous to the project.

A standard result from environmental economics is that, under some conditions, an emissions trading scheme can replicate a carbon tax: the emissions quota is set equal to that arising from a particular level of carbon tax.[22] However, symmetry between the two instruments breaks down if demand for emissions changes because of a new project. Under the emission trading scheme, the total emissions remain unchanged (and the price will adjust), whereas under a carbon tax the total emissions will adjust (and the tax rate remains unchanged).

Table 4-4: shows the CBA results for a project operating within the ETS. Given the fixed quota of emissions, project emissions will be netted out within the ETS cap. This is often termed the “waterbed effect” (Perino, 2018). As shown in the row for “Cost of project CO_2 emissions,” net carbon emissions are zero, so net carbon costs are too. There is no need to compensate for project emissions outside the ETS. Hence the shadow cost of carbon is irrelevant. The permit price (clearing price within the ETS) is assumed to be €50 per tonne, thus resulting in a total transfer to permit owners of €50 * 5 million tonnes = €250 million, which they are required to abate.

Table 4-4: Project costs and benefits under a fixed-cap emissions trading scheme

	Project users	Government	Other agents in society	Total
CAPEX		−400		−400
Gross user benefits	+2 000			+2 000
User cost excluding carbon charges	−1 000			−1 000
Cost of CO_2 permits	−250		+250	
Cost of abatement for other ETS firms			−250	−250
Cost of carbon tax paid by users				
Cost of project CO_2 emissions			0	0
Total	+750	−400	0	+350

The overall net value of the project is estimated at €350 million – higher than the €100 million in Table 4-2. Comparing the two tables, there is clearly no difference in net benefits for project users between the two settings: the level of the carbon tax is identical to the permit price. The government misses out on €250 million of tax revenue through the ETS scheme, which instead passes to permit owners. However, it is assumed that additional emissions from the project can be abated at the relatively low marginal cost of €50 per tonne under the ETS: this is less than the marginal cost measured by the shadow cost of carbon at €100 per tonne. Aggregating, this means an abatement cost of €250 million within the ETS (Table 4-4) instead of €500 million throughout the entire economy (Table 4-2).

The key point here is that the coverage of the ETS scheme is taken as fixed. Although large differentials between the permit price and the shadow cost of carbon may suggest that the coverage of the ETS is suboptimal,[23] this is not relevant to the project under appraisal. It follows that the project generates a higher net social value under the ETS scheme than if subject to a carbon tax. Moreover, under these same assumptions, the project’s ERR in the ETS setting is the same as its FRR.

[22] And vice versa: a tax can replicate the emissions trading scheme if the tax level replicates the price emerging from a particular level of emissions quota.
[23] In general, the clearing price for a scheme covering only a few sectors of the economy may be higher or lower than the carbon tax for the non-ETS sectors required to reach an economy-wide (ETS and non-ETS) emissions target.

4. An emissions trading scheme with an endogenous cap

Turning next to consider a scheme with an endogenous cap, it is assumed that:

- The emissions cap increases at x% of the project emissions, i.e. 5x million tonnes of emissions where $0 \leq x \leq 1$. If x = 0, this corresponds to the fixed cap case in Table 4-4; if x > 0, the project results in new emissions that, as under a carbon tax, are valued at the shadow cost of carbon;
- 5x extra ETS permits are auctioned by the government to other firms in the ETS system;
- The permit price remains at €50 per tonne (i.e. the project is “small”).

Table 4-5 shows the results on the economic case for the investment.

Table 4-5: Project costs and benefits under an endogenous-cap emissions trading scheme

	Project users	Government	Other agents in society	Total
CAPEX		−400		−400
Gross user benefits	+2 000			+2 000
User cost excluding carbon charges	−1 000			−1 000
Cost of CO_2 permits	−250	+250*x*	+250(1−*x*)	0
Cost of abatement for other ETS firms			−250(1−*x*)	−250(1−*x*)
Cost of carbon tax paid by users				
Cost of project CO_2 emissions			5*x**(−100) = −500*x*	−500*x*
Total	+750	250*x*−400	−500*x*	350−250*x*

Note: *x* corresponds to the share of project emissions that add to the cap.

As stressed by Rosendahl and Wangsness (2020b), the case of the endogenous cap can be considered as a weighted average of the carbon tax and an emissions scheme with a fixed cap. fixed ETS cases. In the extreme case where the emissions cap adjusts 100% to project emissions (*x* = 1), the values for the tax case in Table 4-2 apply; by contrast, if the cap does not adjust (*x* = 0), the values for the fixed ETS case in Table 4-4 apply. If we assume an equal weighting (*x* = 0.5), the value of the project is €225 million, calculated as the mean of the fixed ETS case (€350 million, Table 4-4) and the tax case (€100 million, Table 4-2).

Johansson (2021) provides a formal analysis of the case where a reduction in emissions under an ETS leads to a future reduction in permits.

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5. Biodiversity and ecosystem services

J. Doramas Jorge-Calderón

5.1 Introduction

Valuation of biodiversity and ecosystem services (B&E) is underpinned by intrinsic and utilitarian values, making it a contentious subject. The Bank acknowledges in its Environmental and Social Standards the intrinsic value of biodiversity and the potential impact of EIB operations on B&E. These standards and the *EIB statement on environmental and social principles and standards* (2009) provide the necessary safeguards for preserving and enhancing B&E, as justified by their intrinsic value. Yet the utilitarian value of B&E provides another rationale for channelling investments towards environmentally sustainable projects and for giving mainstream focus to B&E investments as a whole.

With increasing anthropogenic pressures on B&E, the marginal value of B&E and its relevance to economic appraisal both rise. Current economic valuations of B&E are incomplete because of limited understanding and lack of relevant data; they thus fail to encompass B&E's intrinsic value.

Numerous initiatives worldwide are attempting to integrate the value of B&E into decision-making processes, particularly through national accounts. For example, the UN System of Environmental-Economic Accounting and the UK Office of National Statistics are building natural capital accounts based on land-use categories. Similar approaches are also being used in the World Bank's WAVES projects (Wealth Accounting and the Valuation of Ecosystem Services) and in the European Union's Knowledge Innovation Project on Accounting for Natural Capital and Ecosystem Services.

The field is in the early stages of developing empirical economic evidence, and it encompasses significantly more diverse factors than carbon emissions. Therefore, the incorporation of B&E variables in economic appraisals is bound to proceed progressively, including a period for testing and calibrating appraisal models. The next two sections describe, respectively, the scoping study carried out by the EIB towards incorporating B&E into economic appraisals and the Bank's upcoming valuation study.

5.2 EIB scoping study

In 2018 the EIB commissioned a study to scope the feasibility of integrating B&E externalities into its economic appraisal of investment projects. The scoping study was carried out by the consultants eftec and Biotope, who produced a consultation report, a literature and evidence review and a recommendations report, all delivered to the EIB in December 2018.

The consultation report overviews a series of interviews with financial institutions and wider stakeholders, including government agencies, EU institutions, UN agencies, NGOs and industry/sector representatives. The literature and evidence review outlines the conceptual principles for assessing B&E externalities and reviews current economic appraisal guidance and associated tools and databases. The recommendations report presents a set of high-level suggestions for integrating B&E externalities into the Bank's economic appraisal of investment projects. Two key issues requiring focus are (i) what ecosystem services should be valued and what variables should be used to value them and (ii) how the values for those variables should be determined for application in economic appraisals.

Regarding the first issue, Table 5-1 lists the services to be valued. They are grouped into four categories: provisioning, regulating, habitat, and cultural services. Each ecosystem service can be valued though different variables, and any service may be valued through more than one variable simultaneously. In the follow-up valuation study that the Bank is on course to carry out, the Bank is seeking to determine what variables to use for each ecosystem service. To ensure consistency and comparability across sectors where the EIB intervenes, it is crucial that every variable is applicable across different sectors. Table 5-2 presents the likely relative importance of each ecosystem service in each EIB activity sector.

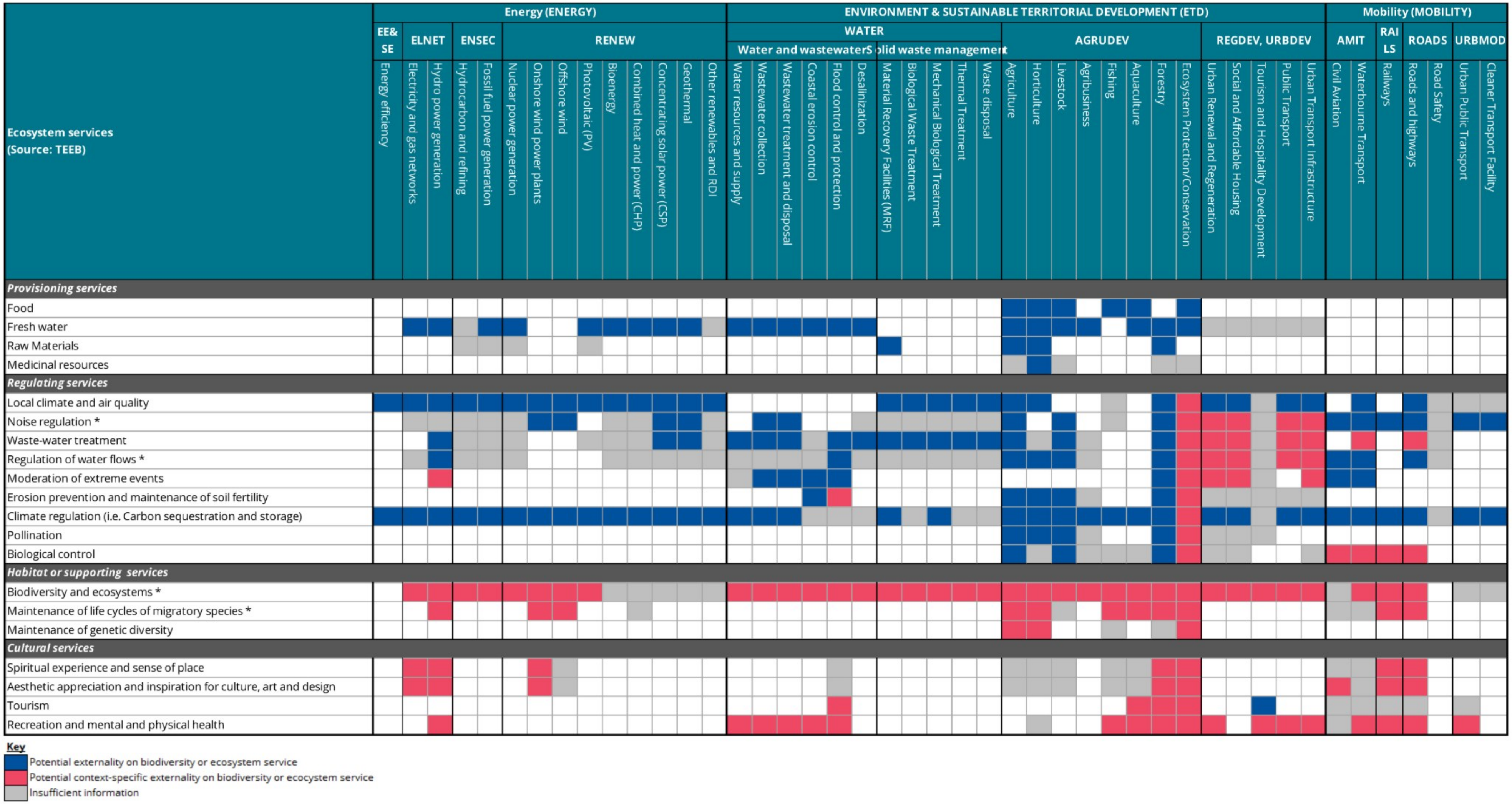
Table 5-1: List of ecosystem services (including biodiversity)

Service	Definition
Provisioning services	
Food	Ecosystems provide the conditions for growing food. Food comes principally from managed agro-ecosystems but marine and freshwater systems or forests also provide food for human consumption. Wild foods from forests are often underestimated.
Fresh water	Ecosystems play a vital role in the global hydrological cycle, as they regulate the flow and purification of water. Vegetation and forests influence the quantity of water available locally.
Raw Materials	Ecosystems provide a great diversity of materials for construction and fuel including wood, biofuels and plant oils that are directly derived from wild and cultivated plant species.
Medicinal resources	Ecosystems and biodiversity provide many plants used as traditional medicines as well as providing the raw materials for the pharmaceutical industry. All ecosystems are a potential source of medicinal resources.
Regulating services	
Local climate and air quality	Trees provide shade whilst forests influence rainfall and water availability both locally and regionally. Trees or other plants also play an important role in regulating air quality by removing pollutants from the atmosphere.
Noise regulation *	Unwanted natural and human-derived sounds, often associated with traffic and urbanisation, are commonly termed as 'noise'. Such noise can be regulated by ecosystems by altering the sound itself or by adsorbing or reflecting the sound before it reaches the hearer.
Waste-water treatment	Ecosystems such as wetlands filter both human and animal waste and act as a natural buffer to the surrounding environment. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced.
Regulation of water flows	Regulating surface water run off, aquifer recharge etc. (e.g. natural drainage, irrigation and drought prevention)
Moderation of extreme events	Extreme weather events or natural hazards include floods, storms, tsunamis, avalanches and landslides. Ecosystems and living organisms create buffers against natural disasters, thereby preventing possible damage. For example, wetlands can soak up flood water whilst trees can stabilize slopes. Coral reefs and mangroves help protect coastlines from storm damage.
Erosion prevention and maintenance of soil fertility	Soil erosion is a key factor in the process of land degradation and desertification. Vegetation cover provides a vital regulating service by preventing soil erosion. Soil fertility is essential for plant growth and agriculture and well functioning ecosystems supply the soil with nutrients required to support plant growth.
Climate regulation (i.e. Carbon sequestration and storage)	Ecosystems regulate the global climate by storing and sequestering greenhouse gases. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues. In this way forest ecosystems are carbon stores. Biodiversity also plays an important role by improving the capacity of ecosystems to adapt to the effects of climate change.

List of ecosystem services (including biodiversity) (continued)

Pollination	Insects and wind pollinate plants and trees which is essential for the development of fruits, vegetables and seeds. Animal pollination is an ecosystem service mainly provided by insects but also by some birds and bats. Some 87 out of the 115 leading global food crops depend upon animal pollination including important cash crops such as cocoa and coffee (Klein et al. 2007).
Biological control	Ecosystems are important for regulating pests and vector borne diseases that attack plants, animals and people. Ecosystems regulate pests and diseases through the activities of predators and parasites. Birds, bats, flies, wasps, frogs and fungi all act as natural controls.
Habitat or supporting services	
Biodiversity and ecosystems *	Ecosystems: "A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". Biodiversity: "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems". See: http://uknea.unep-wcmc.org/EcosystemAssessmentConcepts/EcosystemsandBiodiversity/tabid/102/Default.aspx
Maintenance of life cycles of migratory species (incl. nursery service)	Habitats provide everything that an individual plant or animal needs to survive: food; water; and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle. Migratory species including birds, fish, mammals and insects all depend upon different ecosystems during their movements.
Maintenance of genetic diversity	Genetic diversity is the variety of genes between and within species populations. Genetic diversity distinguishes different breeds or races from each other thus providing the basis for locally well-adapted cultivars and a gene pool for further developing commercial crops and livestock. Some habitats have an exceptionally high number of species which makes them more genetically diverse than others and are known as 'biodiversity hotspots'.
Cultural services	
Spiritual experience and sense of place	In many parts of the world natural features such as specific forests, caves or mountains are considered sacred or have a religious meaning. Nature is a common element of all major religions and traditional knowledge, and associated customs are important for creating a sense of belonging.
Aesthetic appreciation and inspiration for culture, art and design	Language, knowledge and the natural environment have been intimately related throughout human history. Biodiversity, ecosystems and natural landscapes have been the source of inspiration for much of our art, culture and increasingly for science.
Tourism	Ecosystems and biodiversity play an important role for many kinds of tourism which in turn provides considerable economic benefits and is a vital source of income for many countries. In 2008 global earnings from tourism summed up to US$ 944 billion. Cultural and eco-tourism can also educate people about the importance of biological diversity.
Recreation and mental and physical health	Walking and playing sports in green space is not only a good form of physical exercise but also lets people relax. The role that green space plays in maintaining mental and physical health is increasingly being recognized, despite difficulties of measurement.

Table 5-2: Expected affectation of ecosystem services across sectors of EIB activity



The second issue is which method to use to provide values for each variable. The recommended method is the value-transfer approach, where values from existing studies are taken and, if necessary, adjusted to project characteristics. Therefore, two questions must be addressed. First, what values may be "readily available" for transfer from one project to another? This would most likely involve B&E externalities that are relatively well researched and universal in nature. Second, what criteria should be used to adjust "readily available" values to project-specific circumstances? These "adjusted" values are expected to be particularly relevant where the externality is context-specific.

The scoping study also recommends initially narrowing values to selected B&E externalities and focusing on sectors where their impact on project value is expected to be greatest. While the merits of this recommendation are appreciated, intensifying time pressures since the scoping study was completed make it preferable to produce a comprehensive set of transfer values for application across all sectors financed by the EIB, while phasing the roll-out to allow for extensive testing.

5.3 EIB valuation study

The EIB has commissioned consultants to report on what B&E values should be used in project appraisal. The Bank expects to start testing B&E values in actual appraisals by late 2022; by mid-2023, the CBA should incorporate a comprehensive set of B&E values. By nature, the scope of this task differs greatly from that of deriving values for carbon emissions. Carbon consists of a single variable (GHG emissions, albeit from different sources), with a single unit (tonnes of CO_2) and a single price (the social, or shadow, cost of carbon), or two when dealing with offset mechanisms. For B&E, by contrast, all of these dimensions change. There are many variables to measure — at least one for every service listed in Table 5-1 — and each one may be dependent on context. In addition, each sector will affect a different combination of variables. Consequently, the introduction of B&E values is bound to be staged, as testing is inevitably more complex than for carbon.

The valuation study is expected to generate a selection of variables that can be used to value each ecosystem service listed in Table 5-1, as well as advice on how to adjust them for different contexts. Table 5-3 displays the combination of circumstances we expect to encounter, along three dimensions: whether or not the externality is frequently present; whether it is universal or context-specific, and the potential size of its impact on project ERR.

Table 5-3: Incorporating B&E externalities according to their incidence

Frequency of occurrence of externality	**Scope of externality**	**Impact of externality on ERR**	
		Large	**Small**
Frequent	Universal	"Readily applicable" value transfer	Value transfer
	Context-specific	"Adjusted" value transfer	"Adjusted" value transfer applied selectively
Infrequent	Universal	"Readily applicable" value transfer	Value transfer
	Context-specific	"Adjusted" value transfer or commissioning of ad hoc valuation study	Included selectively

The externalities to be immediately incorporated are those occurring frequently, universal in nature, and expected to significantly affect ERR in numerous sectors. Where an externality is context-specific, the analyst will rely on guidance for adjusting values. If this externality is also met infrequently, the economic appraisal may involve commissioning an ad hoc valuation study.

Where an externality is expected to only marginally affect the ERR, its inclusion will rely on readily available values and adjustment criteria. It is important to highlight that these considerations affect only the incorporation of externalities: projects will still need to comply with all mitigating measures prescribed by environmental regulation, and the costs of doing so internalise the external cost. These costs are automatically included in the economic appraisal as project capital investment or operating costs.

6. Other environmental externalities

Susana Lagarto and Diego Ferrer

6.1 Local and regional air pollution

This chapter describes the method used to estimate monetised health risks caused by one emission unit of a range of air pollutants, and details how these unit figures are used in the economic appraisal of projects. The monetised damage estimates are for harm caused by emissions of pollutants, including small particulate matter[24] (PM_{10} and $PM_{2.5}$), sulphur dioxide (SO_2), nitrogen oxide (NOx), ammonia and ground-level ozone. These risks are relevant to electricity generation projects, transport projects and many industrial processes. Values are also available for non-methane volatile organic compounds and certain heavy metals.

The damage estimates are based on a study commissioned by the Bank and conducted by the Institute of Energy Economics and Rational Energy Use (IER), University of Stuttgart, Germany, in 2014. IER has been a core partner in EU-funded research on external cost valuation and application, notably through the External Cost of Energy project (ExternE) and the development of an integrated environmental impact assessment tool (EcoSenseWeb).

The study aimed to estimate in monetary terms the damage per emission unit, or per output unit (e.g. MWh). This was done through the Impact Pathway Approach, whereby changes in emissions of pollutants from economic activities are mapped onto changes in ambient concentrations of pollutants, which are, in turn, mapped onto changes in physical damage to human health, ecosystem functioning, crop yields and buildings. In the final step, the changes in physical damage are estimated in monetary terms.

The Impact Pathway modelling comprises the following steps:

1. **Baseline emissions:** Full estimation of the background emissions, with a data set covering all emission sources in the relevant region, to take into account the concentration of substances that react with any pollutant emitted by the project;
2. **Concentration modelling:** Calculation of the concentrations of pollutants linked to the two emission scenarios ("with" and "without project"), modelled using the emission sources information obtained in step 1. Concentrations are calculated using atmospheric transport and transformation models on different scales;
3. **Atmospheric dispersion:** Modelling of the changes in concentration due to the emission of different air pollutants;
4. **Concentration-response functions:** These functions are used to estimate the health effects caused by the population's exposure to pollutants;
5. **Impact on health:** Calculation of monetary values attributed to certain health effects, including market and non-market costs. Values express the WTP to avoid these effects and — for morbidity only — the cost of illness (e.g. for hospital treatment and medicine);
6. **Impact on crops:** Quantification of changes in crop yield, focused on the impact of acidification and eutrophication;
7. **Impact on biodiversity:** Quantification of biodiversity losses, estimated by the potentially disappeared fraction of species per square-metre and year compared with the number of species that would be present without the human intervention. The monetary valuation is based on restoration costs. However, as described in chapter 5, the EIB is currently seeking to enhance the valuation of B&E externalities.

In calculating the values of impact on health, crops and biodiversity, parameter corrections and specific models are used to take into account the characteristics of regions beyond Europe and the urban increment (i.e. the difference between rural and urban background pollutant concentrations), as appropriate and required.

[24] Small measured as having a diameter less than 10 or 2.5 micrometres.

The monetised impact categories made available to the Bank thus include damage to human health, materials, crops and biodiversity losses. As damage depends on the release site, damage costs per tonne vary between country. Furthermore, damage costs need to be disaggregated by release height.

Empirical evidence suggests that WTP to avoid environmental damage is an increasing function of income per capita, and therefore grows in real terms over time as gross domestic product (GDP) per capita rises. In the NEEDS[25] project, evidence was found that the monetary value of health risks for future years increases with GDP per capita growth with an inter-temporal elasticity of 0.7–1.0, according to the following formula:

$$WTP \text{ for year } 2021 + n = WTP \text{ for year } 2021 * (1+g)^{0.85 * n}$$

where

WTP = willingness to pay

g = average growth rate of GDP per capita income.

On this basis, the base monetary values provided by the 2014 IER report are updated annually using the resulting uplift factors. On top of this damage impact correction, inflation must be considered to correctly reflect the future impact values of a project over its lifetime.

The Bank periodically reviews the impact values, as considered appropriate, and seeks to apply them consistently across the several sectors and projects.

The IER report presents results mainly for EU countries, though impact valuation is available for several other countries (over 40 in total). Within the European Union, results are broken down at subregional level (e.g. five subregions in France, four in Germany), by stack height (high and low stacks) and between urban and rural sites.

Figure 6-1 illustrates estimates of health damage per tonne of small particulate matter ($PM_{2.5}$), NO_x and NH_3 across different countries. A key point is that damage varies significantly depending on where emissions take place.

6.1.1 Application in appraising power generation projects

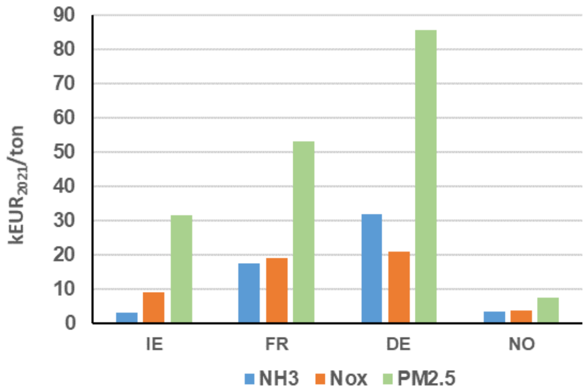
Before the 2014 IER review, the Bank’s appraisal of energy generation projects assumed a cost from local and regional air pollution of €2 per MWh for combined-cycle gas turbines (CCGT) and €5 per MWh for coal plants. Taking the EU average in euros per tonne for each pollutant and the emissions factors relevant for natural gas and coal generation, the report’s findings suggest that the previously assumed cost for CCGTs appeared broadly appropriate and it continues to be used (with the appropriate annual uplifts); however, the assumed cost for coal plants was a significant underestimate, and €16 per MWh is now used. For biomass-based power plants, the impact of particulates is also considered in the cost function of the levelised cost of energy (LCOE), averaging approximately €4 per MWh at present in the European Union (for < 50 MW wood chip boilers). These costs are reflected in the total unit cost of power generation, whether new[26] or displaced by a project subject to Bank appraisal.

Albeit merely estimates, these values are comprehensively applied in the economic profitability analysis of power generation projects. Moreover, given the regional basis of atmospheric dispersion modelling, these estimates in principle include damage incurred by relevant populations, regardless of geographical borders.

[25] NEEDS (New Energy Externalities Developments for Sustainability) s an integrated project that worked on the external costs of energy use, built as a series of research streams undertaken by a consortium of partners (universities, research institutions, industry, etc.).

[26] For the avoidance of doubt, the Bank does not support power generation technologies that exceed the EIB emissions threshold: currently 250 g CO_2/kWh_e. However, it is still important to consider conventional power generation technologies in the baseline (or counterfactual to the project).

Figure 6-1: Average damage costs per tonne of NH3, NOx and $PM_{2.5}$ emitted in Ireland, France, Germany and Norway (low urban release height, 2021 prices)



6.1.2 Application in appraising transport projects

Micro-particulate emissions are known to have the most significant health impact. Vehicle $PM_{2.5}$ emissions are divided into exhaust and non-exhaust emissions. Exhaust emissions are reduced as fuel technology develops, and vary with vehicle speed. The costs are higher in urban areas, where residents are exposed to greater concentrations of emissions, whereas concentrations are more dispersed in less densely populated areas. Non-exhaust emissions are produced predominantly by tyre and brake wear. While $PM_{2.5}$ emissions have little impact on a project's economic value, their health impact can be significant.

The default $PM_{2.5}$ emissions (in grams per vehicle-kilometre) for urban, suburban, interurban roads and motorways are the average values for the project country, weighted according to vehicle type, fuel type and fuel technology distribution. These values come from either the Ricardo-AEA Handbook (default values) or the EIB Energy Department (CORINAIR/Copert model).

Two alternative calculations of $PM_{2.5}$ emissions and costs are made. The first (main) calculation determines the combined exhaust and non-exhaust $PM_{2.5}$ emissions. The emission rates remain constant irrespective of speed. In the second calculation, currently performed only in road appraisals, functions are introduced to vary exhaust emission rates according to speed for different vehicle categories. This second calculation is particularly relevant when assessing the impact of congestion.

6.2 Noise

The impact of changes in the noise level is included in the appraisal of projects based on values in the 2019 update to the European Commission's *Handbook on external costs of transport.*[27] These values are typically defined as costs per kilometre for different vehicle types and countries.

[27] See: Handbook on the external costs of transport—Publications Office of the EU (europa.eu)

7. Land acquisition and resettlement

Edward Calthrop

7.1 Introduction

Many infrastructure projects financed by the EIB involve land acquisition.[28] This change in land-use may lead to some degree of physical or economic displacement of people living on or using the land. This chapter focuses on valuing land acquisition in economic analysis where the land is acquired under a free-market transaction where affected individuals or communities have the right to refuse i.e. it is voluntary[29]. In principle, the full opportunity cost of this land and associated services need to be considered in the economic appraisal of the project. Estimating this cost is not always straightforward. Where land markets operate, one proxy might be the market price of land, but when is this a reasonable approximation? When should the analyst be concerned, and what can be done to improve the estimate? This chapter reviews the basic economic intuition associated with valuing voluntary land acquisition.

7.2 The opportunity cost of land — going beyond the market price

In the context of a well-developed and liquid land market, the market price may generally be a good indicator of the opportunity cost of land.[30] Several countries even tie compensation under compulsory purchase orders to market valuation.[31] In cases of resettlement, this estimate of the opportunity cost needs to be augmented by the resource cost of organising and administering any resettlement programme.

However, in developing countries, notably in rural areas, there may be no market at all. Property rights, including access and use, may be unclear: the affected persons may not own the land they use but instead hold customary tenure or even be squatters. In such cases, the opportunity cost of rural land may be calculated as the agricultural and/or animal husbandry output foregone, measured at economic prices — i.e. the value of the income to be earned from that land for the foreseeable future. This narrow measure may need to be expanded to include non-market, subsistence-related income from land (charcoal, medicinal plants, bushmeat, etc.). However, to the local community, the land's real value may be as a cultural asset vested with spiritual significance, including shrines, places of prayer, burial grounds and access to social services. As discussed in chapter 6 on environmental externalities, the value of the land may also include ecosystem services, such as biodiversity provision and carbon sequestration. If so, the appraisal framework needs to account for these benefits foregone by the project.

The same principle of measuring the opportunity cost of land applies in an urban context. Given existing spatial patterns, urban derelict space may have little or no formal market value. Nevertheless, the opportunity cost of the land should reflect the value provided to current users.[32] In short, the market price of land, even where available, may provide only a lower bound to the opportunity cost.

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[28] The Bank is mandated to finance asset creation. As a result, it typically excludes land purchase from its estimation of the eligible project cost. However, the Bank does include the opportunity cost of land within the economic analysis of a project.

[29] Resettlement is considered involuntary when affected individuals or communities do not have the right to refuse land acquisition resulting in displacement. This occurs via (a) land acquisition, (b) expropriation or restrictions on land use based on eminent domain, (c) forfeiting of a livelihood/subsistence strategy dependant on the use of natural resources, and (d) negotiated settlements in which the buyer can resort to expropriation or impose legal restrictions on land use if negotiations with the seller fail.

[30] The price is likely to be a good approximation for surplus when land acquisition is marginal and demand is relatively elastic.

[31] This would be complemented by additional compensatory elements assuring the attainment of the full replacement cost principle. Such principle, in turn, guarantees that all costs arising out of the resettlement have been effectively addressed by the global compensation offered to each affected party.

[32] For a recent article arguing that a better use of land use can be achieved by considering preferences, see Li, C., Managi, S. Land cover matters to human well-being. *Scientific Reports* 11**,** 15957 (2021). https://doi.org/10.1038/s41598-021-95351-6.

7.3 Valuation techniques

In principle and where appropriate, economic valuation techniques can be used to estimate displaced peoples' willingness to accept compensation for resettlement, thereby capturing valuations of cultural assets and non-market benefits. However, valuation techniques based on surveys — known as contingent valuation — must pay careful attention to problems of free riding, moral hazard, framing and starting-point bias.[33] Studies of willingness to accept are also relevant to market assets because of the likely presence of consumer surplus, reflected by valuations of assets over and above their market price. There is a large literature reviewing such valuation techniques in the field of environmental economics;[34] however, there appear to be few practical applications in the context of involuntary resettlement programmes.[35]

7.4 Measuring economic cost in practice

Where no valuation studies are available, a replacement cost approach may be used to estimate the opportunity cost of land, albeit recognising that this will likely represent a lower bound to the true opportunity cost. The replacement cost is:

- For agricultural land, the pre-project or pre-displacement — whichever is higher — market value of land of equal productive potential or use located close to the affected land, plus the cost of preparing that land to levels similar to those of the affected land;
- For land in urban areas, the pre-displacement market value of land of equal size and use located close to the affected land, with similar or improved public infrastructure facilities and services;
- For houses and other structures, the market cost of the materials to build a replacement structure with similar or superior area and quality to the affected structure, or to repair a partially affected structure, plus the cost of transporting building materials to the construction site, plus the cost of any labour and contractors' fees.

In determining the replacement cost, asset depreciation and the value of salvage materials are not taken into account. Moreover, the value of benefits to be derived from the project is not deducted when valuing an affected asset.

Where these replacement cost rules are used to determine actual compensation, the financial cost of resettlement thus becomes a lower bound for the opportunity cost in the economic appraisal.

7.5 Equity and the Bank's social standard

In practice, economic appraisal tends to focus on economic efficiency, implicitly valuing a euro of additional income equally across different income and social classes. Explicit welfare weights can be introduced in theory but have proven difficult to apply in practice, raising the problem of how to establish appropriate welfare weights.[36] This shortcoming can be exposed in projects displacing some of the poorest and most vulnerable in society. This partly explains why the Bank requires that — outside any cost–benefit calculation — meeting its social guidelines is a precondition for project financing.[37]

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[33] Given the difficulties of measuring compensation in practice, in the case of the Exxon Valdez disaster, the valuation question did not concern compensation for the actual spill but rather the willingness to pay to prevent future spills. In principle, compensation required may be infinite, i.e. there is no compensation that the individual is willing to accept.
[34] See for example Richard Carson, 2012, Contingent Valuation: A practical alternative when prices aren't available, *Journal of Economic Perspectives*, 26(4), pg27-42.
[35] An example is Tofail, M. and Kaida, N., 2015, Evaluating Potential Benefits of Welfare Packages for Development-Induced Involuntary Resettlement in Bangladesh, *Journal of Sustainable Development* (8) https://doi.org/10.5539/jsd.v8n1p203
[36] As one reviewer commented: ''The land issue is a good illustration of where the separation of efficiency and equity does not hold e.g. when no feasible compensation exists. The winners cannot compensate the losers in such a case''.
[37] The EIB Group Environmental and Social Sustainability Framework (ESSF) – including Standard 6 on involuntary resettlement - is available online: European Investment Bank Environmental and Social Standards (eib.org)

8. Wider economic impact

Edward Calthrop

8.1 Introduction

Suppose that a project is judged economically weak. More precisely, suppose the ERR of a proposed investment, measured using the standard appraisal techniques described elsewhere in this guide (including externalities), is below the SDR. Is this a sufficient condition for the Bank to reject the project? Or could it be that the standard techniques somehow fail to capture all relevant benefits?

This chapter briefly reviews the evidence for including in economic appraisal wider economic impacts, meaning the tangible benefits or costs to the economy that stem from an investment but are not included in standard economic appraisal techniques.[38] It tries to identify conditions under which it may be valid to include wider impacts although they may be difficult to measure. This is necessary: with many projects competing for scarce public funds, there may be a temptation for project promoters to exaggerate the benefits and minimise the costs (Flyvbjerg et al., 2003).

Discussion of wider economic benefits is often beset by confusing terminology and concepts, including external benefits, economic multipliers, job creation, impact on public finances, and regional or urban development. This chapter is therefore structured as follows. First, building on a simple distinction between primary and secondary markets, it sets out the conditions under which impact on secondary markets is a valid consideration and when this would constitute double-counting. Second, it explores other notions of wider economic impact, notably on growth and public finances. Third, it examines some developments in evaluating wider benefits in the context of transport projects.

8.2 Impacts on secondary markets

8.2.1 The basic framework

In this section, wider economic impact is taken to mean the impact of investment in a primary market on secondary markets. For instance, suppose a new road increases urban labour supply by reducing commuting times. Should the impact on the (secondary) labour market be included in the appraisal? Or do the direct time savings in the (primary) transport market already capture this benefit? Equivalently, when appraising a new steel factory in the (primary) regional steel market, should the boost in productivity in the (secondary) automobile manufacturing industry be considered?

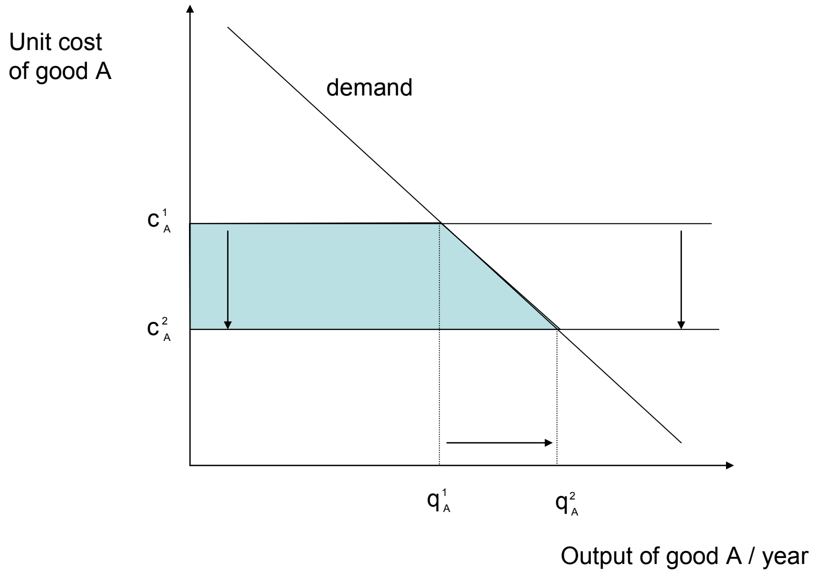
Imagine an investment in a primary market (e.g. good A). As shown in Figure 8-1, the marginal cost of producing one unit of A before the investment equals c_A^1. After the investment,[39] it falls to c_A^2. In a competitive market, consumer prices equal unit costs, so prices also fall from c_A^1 to c_A^2. As shown by the shaded area, consumer surplus increases by the reduction in cost (Δc_A) to existing customers (q_A^1) and by the triangular benefit to new customers. Using conventional appraisal techniques, the project would pass a cost–benefit test when:

$$\Delta c_A \left(q_A^1 + \frac{\Delta q_A}{2} \right) > INV \qquad (1)$$

where *INV* denotes the annuitised investment cost of the project.

[38] The definition of wider economic impacts will be made more precise below. Clearly, there can also be simple errors in applying standard appraisal techniques, including data input errors or poor forecasting techniques. As this is more an issue of quality assurance, it is not considered further.
[39] This is a very general (and simple) example. It could apply to reduced travel time from new transport infrastructure, which lowers the generalised cost of travel, lower electricity prices from new power generation, or lower product prices from an industrial facility.

Figure 8-1: Impact of investment on primary market A



Investment reduces the unit cost of good A from c^1 to c^2. In a competitive market, where consumer price equals unit cost, demand increases from q^1 to q^2. The welfare benefit (in the primary market) is denoted by the shaded area.

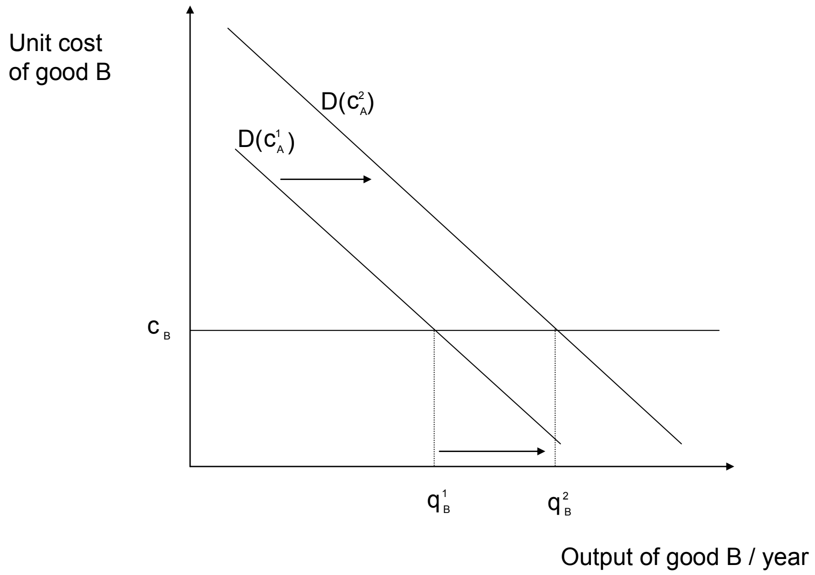
Thus far, attention has been exclusively on the primary market A. Let us now assume that the cost reduction for good A impacts on the secondary market of good B. Does this need to be included in the appraisal formula of equation (1)?

The answer is intuitive. When the secondary market is perfectly competitive — i.e. price equals marginal cost of production — no adjustment is required to the formula because the measured direct benefits in the primary market capture all relevant benefits. Equation 1 suffices. This is shown in Figure 8-2. Any attempt to add the impact on secondary markets would amount to double-counting.

However, if a distortive wedge exists between price and marginal cost in market B, equation (1) needs to be expanded. A distortive wedge may exist for numerous reasons: the presence of taxes or subsidies, imperfect competition, returns to scale, externalities or asymmetric information. If the consumer price (i.e. marginal benefit) is higher than the marginal cost for the last unit, welfare increases if the proposed investment boosts demand in market B. Conversely, if the investment were to further reduce demand for good B, the subsequent reduction in welfare should be included in equation (1). The first case is shown in Figure 8-3, which denotes the welfare gain in the secondary market with the shaded rectangle. Equation (1) becomes:

$$\Delta c_A\left(q^1_A + \frac{\Delta q_A}{2}\right) + (p_B - c_B)\Delta q_B > INV \quad (2)$$

Figure 8-2: Impact of investment on secondary market B in absence of market distortions



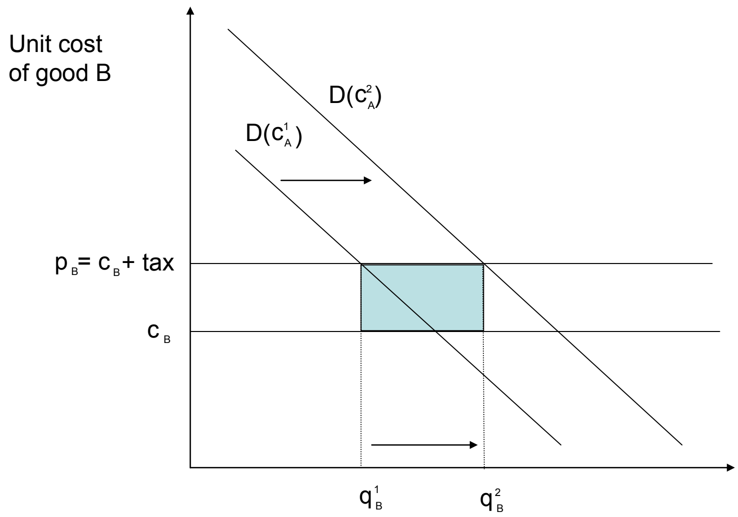
The investment in the primary market causes demand for good B to increase, i.e. A and B are complements. Demand for good B therefore shifts from $D(C^1)$ to $D(C^2)$ and the equilibrium output of good B rises from q^1 to q^2. However, if market B is perfectly competitive, there is no welfare impact. Rather, the shift in demand for good B is just the equilibrium response to the investment (and welfare benefit) in the primary market.

When might this adjustment matter in practice? The second term in equation (2) will likely be relatively large in absolute terms when (i) there is a relatively large pre-existing distortive wedge between price and cost in the secondary market and/or (ii) there is relatively large cross-price elasticity between the primary and secondary markets. Note that the sign of this second term can be positive or negative: the secondary market can complement or substitute for the primary market, and may be subject to taxes or subsidies. In general, an investment can therefore generate wider economic benefits or costs.

This result on wider benefits and costs was established in Harberger's (1974) work on monopoly pricing. It has been subsequently generalised in the academic literature, most notably by Drèze and Stern (1987, 1990), and is reflected in several practical appraisal guides (e.g. European Commission, 2014; World Bank, 1996; ITF, 2011). Johansson (2021) derives results in the case of open and closed economies. See the appendix below for a more formal derivation of equation (2).

In reality, of course, market distortions are pervasive. Hence, even when measured accurately, equation (1) only approximates the total benefit. This might suggest that appraisal should consider numerous secondary markets, including labour markets — thus focusing on general rather than partial equilibrium. However, general equilibrium models are rarely used to appraise individual projects: in many cases, the added complication and expense of including many secondary markets would not be justified by the (relatively small) refinement to net benefits estimated by a partial equilibrium approach (for a review, see ITF, 2011; Johansson and Kriström, 2016).

Figure 8-3: Impact of investment on secondary market B in the presence of pre-existing distortions



In contrast to Figure 8-2, this figure depicts a secondary market characterised by a pre-existing distortive wedge between consumer price (*p*) and unit cost (*c*), perhaps due to a tax. Before the investment, marginal benefit $D(p_B, c_A^1)$ is higher than marginal cost c_B. Investing in the primary market shifts the demand curve for good B, thus increasing output for a good that is undersupplied. This increases welfare by the shaded amount.

An alternative approach is to approximate wider distortions by converting market prices (in the primary market) into shadow prices (reflecting distortions in secondary markets). This approach was set out in the mid-1970s by Little and Mirrlees (1974), who most famously advocated using border prices to value tradable goods and LRMC for non-traded goods. A rather abstract approach to using shadow prices to perform CBA in distorted economies is set out in Drèze and Stern (1990). Shadow pricing is further discussed in chapter 2.

8.2.2 Implications for analysing labour market impact

Let us apply this framework to consider the impact on local labour markets of an investment project (e.g. new road construction). In particular, we might distinguish three potentially relevant effects:

- A short-term increase in demand for labour during construction;
- A long-term increase in demand for labour during operation;
- For transport projects, an increase in labour market supply resulting from improved accessibility.

Recall that it is theoretically valid to include wider impacts if secondary markets are distorted. This is generally the case for labour markets, not least given the presence of taxes. However, because it is difficult to construct a labour market model, standard practice is to substitute shadow wages for market wages (see chapter 2; European Commission, 2014). The size of the adjustment (per hour of labour) to market wages in order to convert into shadow wages clearly depends on the size of the market imperfection ($p_B - c_B$ in equation (2)) and the project's impact on local labour supply (skilled, unskilled, etc.) — see Johansson and Kriström (2020) for a fuller treatment. Such an adjustment requires detailed information on the local labour market, as well as estimates for job creation by the project. In short, equation (2) helps develop the intuition needed to capture secondary labour market benefits.

8.3 Wider impact on public finances and GDP

The previous section focused on the impact of investments on secondary markets. However, there are other interpretations of wider economic impact, two of which are reviewed in this section.

8.3.1 Impact on public finances

As is well known, the cost of a project is measured by the opportunity cost of resources. As taxes and subsidies do not constitute resource flows, they are usually considered as pure transfers and thus stripped out.[40]

This approach is correct if governments have access to non-distortive instruments to raise public revenues (so-called lump-sum transfers). In reality, however, governments impose an array of distortive taxes on income and consumption. Consequently, each euro of government tax revenue has an opportunity cost — the welfare cost of the distortion in consumer and producer behaviour induced by the tax (for a review, see Riess, 2008). In the literature, this welfare cost per unit of tax revenue raised is usually termed the marginal cost of public funds. Where the marginal cost of public funds exceeds one, the welfare cost of raising €1 is greater than the tax received.

Extensive empirical literature has attempted to estimate the marginal cost of public funds from different tax instruments (e.g. Myles, 1995; Riess, 2008). In general, it is estimated to be larger than one, although, in the case of reform of the tax structure, the marginal cost of funds depends on the instruments used to raise revenue and recycle it (see Goulder et al., 1997).

Large investment projects — even when wholly financed by the private sector — can significantly impact on regional and even national net tax receipts. For example, the indirect effects on public finances of a new urban rail line in London (presented in Table 8.1 below) are estimated to equal approximately one-quarter of total user benefits. If the marginal cost of public funds is one, no value is placed on this resource transfer. If above one, however, an additional cost is placed on the government having to address the loss in tax revenue that requires raising distortive taxes elsewhere in the economy.

In line with a number of practical guidelines, including European Commission (2014), the Bank's practice is to abstract from these wider impact on public finance by assuming the marginal cost of public funds equals one. This is questionable, at least in principle, particularly amid periods of acute strain on public finances. However, as the primary purpose of the Bank's analysis is to screen out relatively poor projects in a single sector, the degree of inaccuracy introduced may be rather small.

8.3.2 Impact on GDP

CBA estimates the impact of an investment on social welfare. When done well, it should quantify the impact on all relevant people and firms affected by the project. In this sense, CBA is a wider concept than aggregate income, captured by GDP.[41] Nevertheless, many policymakers remain sceptical about the merits of CBA, preferring to know what a project contributes to economic growth (Worsley, 2011). This is a legitimate enquiry, and as witnessed in Europe in response to the 2008 financial crisis, it can become especially relevant during times of economic crisis when investment in "shovel-ready" projects becomes a means to boost aggregate demand.

The impact of projects on GDP growth can, in principle, be measured. However, this is generally a separate metric from welfare. As discussed by the UK Department for Transport (2005), care is required to avoid combining welfare measures with GDP measures, as this normally entails double-counting of a project's impact.

[40] There are exceptions to this rule. In the case of a distorted market, the tax revenue from increased demand resulting from the investment can be used as a measure of social surplus.
[41] As commented by reviewers, change in GDP (or rather NNP) is a linear welfare index in the simplest form. Moreover, the standard Ramsey model can be used to derive an expression in terms of GDP growth. Adding GDP in addition to the cost benefit analysis is therefore not recommended.

The impact of public investment on productivity (and GDP) has been a lively research area over the last 20 years. Early research by Aschauer (1989) found that public infrastructure has a large positive impact on productivity, but other studies quickly found contrasting results. For surveys of this literature, including the inherent methodological difficulties, see Warner (2014) and Melo et al. (2013).

In conclusion, although measures can be developed to capture the impact of projects on GDP, these are largely separate from welfare measures and should not generally be added. In some cases lacking measures of welfare, measuring GDP can approximate project benefits.

8.3.3 Focus on transport infrastructure

The wider benefits of transport projects are often espoused by promoters, perhaps more than in any other sector financed by the Bank. This may reflect a legitimate need to capture the full range of benefits from transport infrastructure within a wider regional network. However, it may also reflect that many transport infrastructure projects are, at least partly, publicly funded and so compete for scarce public funds. The higher the stated benefits, the higher the chance of public funding.

A lively academic debate continues over wider economic impacts in the field of transport (ITF, 2007, 2011). This section identifies two transport-specific issues: agglomeration benefits and property price increases. Other more general issues, such as impact on government finances or the labour market, have been discussed above.

8.3.3.1 Economies of agglomeration

A controversial development in transport appraisal concerns the benefit of improving access to dense urban agglomerations (for reviews, see UK Department for Transport, 2005; ITF, 2011; Laird and Venables, 2017). Economic theory supports recognising an additional agglomeration benefit where a project effectively brings firms closer to one another, hence boosting productivity.[42] Standard appraisal techniques capture part of the benefit, via the reduction in generalised cost (GC) valued at the gross wage rate. However, given the returns to scale[43] (or externality) in firms' production function, it can be shown that the social returns from investment exceed private returns.

In a 2005 discussion paper, the UK Department for Transport proposed a methodology to measure agglomeration benefits in practice. The results for a large urban rail project in London (Crossrail) and for a new intercity high-speed rail line (HS2) are respectively shown in Tables 8-1 and Table 8-2. These results suggest that the magnitude of agglomeration impact depends strongly on the context of the individual project: for Crossrail, the agglomeration impact is valued at approximately 25% of conventional time savings benefits, but for HS2 the estimated agglomeration impact equals less than 10% of total user benefits.

However, some studies have challenged the techniques used to estimate agglomeration economies, concluding that estimates may not be precise and solid enough for inclusion in routine appraisal of transport projects (Graham and Van Dender, 2009; de Rus, 2021). While the conceptual case remains, it is difficult to develop estimates in the context of a typical project. At a 2007 workshop run by the Organisation for Economic Co-operation and Development (OECD), it was concluded that using a rule of thumb to account for agglomeration benefits should not be considered best practice.

[42] In fact, two different effects need to be distinguished. For a given pattern of location, the investment reduces generalised travel cost. However, the investment may alter location decisions, as firms or people move in response to the investment. In particular, some firms may respond to the improved access to relocate from core to periphery. The net impact on agglomeration levels in the core is ambiguous and needs to be determined empirically on a case-by-case basis.

[43] This is consistent with the model presented in section 2. One of the conditions required to ignore impacts on secondary markets was precisely (locally) constant returns to scale.

Table 8-1: Wider benefits of Crossrail project

	Welfare (£ million)
Business time savings	4 487
Commuting time savings	4 152
Leisure time savings	3 833
Total transport user benefits	12 832
Agglomeration benefits	3 094
Increased competition	0
Imperfect competition	485
Exchequer consequences	3 580
Addition to conventional appraisal (percentage of conventional benefits)	7 159 (55%)
Total (excluding externalities)	19 991

Source: UK Department for Transport (2005). For an update, see Worsley (2011).

Table 8-2: Wider benefits of High Speed 2 (HS2)

	Welfare (£ million)
Business time savings	17 600
Commuting and leisure savings	11 100
Other benefits: accidents, air quality, noise	< 100
Total transport user benefits	28 700
Agglomeration benefits	2 000
Increased competition	0
Imperfect competition	1 600
Exchequer consequences	0
Addition to conventional appraisal (percentage of conventional benefits)	3 600 (13%)
Total	32 300

Source: UK Department for Transport (2010). The project involves constructing a new high-speed rail line between London and Birmingham (with possible extensions northwards).

8.3.3.2 Local property prices

In urban infrastructure projects, such as upgrading a metro line, promoters sometimes add as a benefit the positive impact on local property prices. This generally constitutes double-counting,[44] since the benefit is already captured in measuring the impact on the primary transport market, primarily in time savings and improved reliability. Although there may be effects on local public finances through property taxation, this is only a resource cost if the marginal cost of funds is assumed to exceed one.

8.4 Conclusions

When the NPV of a project's benefits, measured using standard appraisal techniques, fails to outweigh the costs, it may be tempting for promoters to point to wider economic impact. This chapter briefly reviewed several candidates for inclusion as wider benefits, including the reduction of pre-existing distortions in secondary markets and the impact on public finances and GDP. Particular attention has been given to transport projects, given the widespread application of full cost–benefit techniques and the common need to justify use of public funds.

Based on this review, it seems appropriate to draw the following conclusions for appraisal work:

- In line with standard practice in CBA, the central focus of economic appraisal is to capture accurately the flows in relevant primary markets (e.g. transport networks, energy markets, industrial sector). In this sense, there is a presumption against including wider impact on secondary markets, GDP or public finances, so as to avoid double-counting project benefits and thus biasing the funding decision.

[44] See Johansson (2021) for conditions under which this may break down.

- Under some strict conditions, however, economic theory supports including specific wider benefits. From the Bank's perspective, if the ERR estimated using standard techniques exceeds the SDR, the funding decision can already be made[45] and any additional benefits are of academic interest only.
- Where appropriate, one practical way to deal with the impact on secondary markets is converting market prices into shadow prices (e.g. to capture structural rigidities in the local labour market). Even with this approach, the overall impact on the estimated ERR is likely within the range of sensitivity testing.
- Exceptionally, secondary markets may be considered more explicitly by the promoter, for instance by forecasting the impact of an urban rail scheme on business productivity. Such cases are considered by the Bank on an individual basis, with a view to ensuring consistency of approach to evaluations of similar projects across different countries. In these cases, good practice requires the project analyst to provide clear justification for wider benefits, based on quantifiable evidence of the impact on pre-existing market distortions.
- Despite relatively strong developments on the theoretical basis for wider economic impact in recent years, there remains little established practice on how to translate these ideas into robust techniques for individual projects. This situation justifies a cautious approach by the Bank, although it underlines the importance of monitoring closely any developments in this field.

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[45] Strictly speaking, this need not be true. In theory, wider economic impacts could work in either direction. Thus it is possible that the true ERR is below the estimated ERR based on standard techniques, but there is little evidence for this in practice.

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8.5 Appendix: Formal presentation of equation (2)

This section provides a more formal treatment of the discussion in section 8.2. A very simple setting[46] is assumed to illustrate the main result. Let us assume an economy with three goods: x_1, x_2 and x_3. Quantities are defined in units such that the producer price (without investment) equals 1. Let x_1 be the untaxed numeraire, such that $p_1 = 1$. We assume the government can invest amount *k* in a second market to reduce the price, such that $p_2 = 1 - k$. The third market is subject to a distortive wedge between consumer and producer prices, such that $p_3 = 1 + \tau$. This setup equates to the example given graphically in section 8.2, with x_2 equivalent to market A and x_3 to market B.

Consumer problem
A representative consumer is assumed to maximise a utility function with standard properties defined over the three goods, $U(x_1, x_2, x_3)$, subject to a budget constraint in which $x_1 + (1-k)x_2 + (1+\tau)x_3 \leq G$. Solving this problem leads to demand functions $x_j(k, \tau, G)$. Substituting these back into the utility function gives an indirect utility function $V(k, \tau, G)$. Using Roy's identity, this implies $\frac{\partial V}{\partial k} = \lambda x_2$ where $\frac{\partial V}{\partial G} = \lambda$.

Government budget constraint
The government collects taxes from good 3, pays for investment *c*(*k*) and returns any balance to the consumer. Hence, the budget constraint is given by $\tau x_3 - c(k) = G$.

Welfare impact of marginal investment
The welfare impact of marginal investment is given by:

$$\frac{1}{\lambda}\frac{\partial W}{\partial k} = \frac{1}{\lambda}\left(\frac{\partial V}{\partial k} + \frac{\partial V}{\partial G}\frac{dG}{dk}\right)$$

Substituting the various terms and rearranging gives the result:

$$\frac{1}{\lambda}\frac{\partial W}{\partial k} = x_2 - c'(k) + \tau\frac{dx_3}{dk}$$

This result is the formal equivalent of Figure 8-1 and Figure 8-3. At the margin, the benefit of the investment in the primary market is given by x_2 (equal to the shaded area in Figure 8-1 as the dQ is very small) minus the cost of the investment. The welfare impact on the secondary market is measured by the distortive wedge (τ) multiplied by the change in demand. In the special case that no distortion exists (τ = 0), analysis of the primary market suffices.

[46] See Calthrop *et al.* (2010) for a more general model, including labour market distortions and a full set of feedbacks. Note that – as pointed out by Professor Johansson – care is required when generalising the simple result presented here. For instance, once lump sum taxes are not available, it is in general not correct to adjust costs on the primary market by a marginal cost of funds parameter and, in addition, retain the tax wedge on the secondary market.

9. Economic life and residual value

Diego Ferrer

9.1 Introduction

There are two reasons for estimating a project's economic life: first, it is a basic parameter in the evaluation of economic profitability; and second, it is relevant to determining the tenor of the loan financing the project.

In line with sound banking practice, the Bank ensures that the tenor of its loans is shorter than the underlying project life. When lending to guaranteed public sector projects, the Bank caps the loan tenor primarily to ensure that beneficiaries pay for the project, thus avoiding potentially adverse intergenerational transfers. When the Bank lends to the private sector, and particularly in project finance (whereby the promoter is normally a special purpose vehicle), the "user pays" principle tends to inherently apply to the project, and the link between loan tenor and project life is mostly based on credit risk considerations.

In general, assessment of a project's economic life is largely at the discretion of the appraisal team in the EIB's Projects Department (PJ), and depends on the sector and project specificities. In the early 2000s, amid growing investment in high-speed railway lines, the Bank decided to adopt a specific methodology (as detailed in section 9.3).

9.2 Definitions of project life

The literature features various notions of life in the sense of an asset's utilisation time, causing potential confusion. Terms such as average life, useful life, economic useful life, technical life, effective life and mean life are used in different contexts, sometimes incorrectly. The EIB applies three main life definitions: economic, physical and financial. The notion of design life is closely related to physical life.

The following generally accepted definitions provide a useful introduction to the PJ's methodology.

9.2.1 Economic life

Economic life is the period over which an asset is expected to be usable, with normal repairs and maintenance, for the purpose for which it was acquired, rented or leased. Usually expressed in number of years, process cycles or units produced, it is typically shorter than the asset's physical life.

At any given time, a project may be considered economically alive if it has a positive NPV, meaning that discounted future revenues exceed future discounted costs. On the cost side, economic life depends on the same factors determining physical life (see section 9.2.2). On the benefit side, economic life depends primarily on the level of demand and on the willingness to pay for the project's output, in turn depending on exogenous variables such as market risk (competition, possible change of use, etc.) and risk of obsolescence (technological, regulatory, etc.). Externalities may also affect the benefit stream and, thus, the project's economic life.

9.2.2 Physical life

Physical life is the length of time over which the facility is designed to operate under given conditions. It ends when the asset becomes unable to produce a good or service. The notion of a project's physical life concerns the physical deterioration of its components over time. It depends on the intrinsic quality of those components (initial capital investment), the type of maintenance applied (operation and maintenance regime), usage rates (demand) and environmental conditions (e.g. storms, salinity or humidity levels). While the first and second variables are mainly endogenous (i.e. controllable by the promoter and/or operator), the third and fourth are primarily exogenous (i.e. uncontrollable) and thus need to be estimated, largely based on empirical evidence.

Predicting physical life is a difficult exercise. Efforts concentrate on empirical evidence and statistical approaches, aiming to estimate the minimum physical life.

For an infrastructure project, the minimum physical life is termed the design life, as defined in the project's technical specifications. The notion of design life is highly adaptable, for instance for industrial products such as rolling stock. Load, fatigue and corrosion tests can be run to predict the nominal design lives of individual components. Despite uncertainty over various factors, engineers can normally determine an asset's design life fairly accurately. In general, achieving a physical life in excess of the design life depends on the quality of empirical evidence available at the design stage and on the safety factors employed.

9.2.3 Financial life

Financial life is defined as the period over which a project generates a financial cash flow. Analogous to the methodology for determining economic life, a project is considered financially alive as long as the NPV of future net financial cash flow exceeds the financial residual value of the project's components. Financial life can be affected by fiscal and/or accounting considerations, and also by the promoter's opportunity cost of capital.

9.3 EIB methodology to assess economic life

The Bank's approach to estimating the economic life of an infrastructure project begins by calculating the average physical life — the cost-weighted average of the physical life of project components under normal operations and maintenance (O&M) conditions.

The calculation is normally done by the Bank engineer appraising the project, based on cost information from the promoter and a set of tabulated physical life values for project components. Reference values are available for the main components of transport projects but also water and building operations.

The EIB documents the average physical life and analyses the factors affecting a project's economic life. The latter is normally determined by CBA modelling and sensitivities. If applicable, a risk matrix is developed to assess risks associated with the asset's intrinsic quality and use, the O&M policies and environmental conditions. The project appraisal team also assesses the probability that the economic life is ultimately shorter, or in some cases longer, than the average physical life.

Qualitative or statistical considerations should indicate the expected economic life relative to the calculated average physical life. As an example, calculations for a tramway project are presented in Table 9-1.

The project's average physical life is calculated to be 36 years, with the shortest life corresponding to both equipment and urban works, both with a 20 years life. To assess the economic life, additional factors are considered. From a functional perspective, the project is pioneering an innovative type of rolling stock running on tyres, meaning it can operate as a tramway and a trolleybus. This type of technology has no precedent and, despite thorough testing, could suffer from market risk. In particular, if users do not accept it over alternative technological options, it could quickly become obsolete. Because of these risks, the project team deemed it prudent to limit the economic life to 25 years.

Table 9-1: Example calculation of a project's average physical life

COST	M EUR	%	Physical life	Average project physical life
Infrastructure	59	34%	60	20.5
Energy & signalling	36	21%	25	5.2
Equipment	9	5%	20	1.1
Workshop	1	1%	25	0.2
Urban works	28	16%	20	3.2
Rolling stock	40	23%	25	5.8
TOTAL	175	100%		**35.9**

For projects involving heavy physical infrastructure, such as transport projects with significant earthworks and tunnels, the expected physical life is typically very long. Two interrelated issues arise. First, the weighted average physical life of the entire project may not accurately approximate its economic life. Second, the strength of maintenance efforts to manage the risk of asset depreciation is an important determinant of the project's economic life. There is, therefore, a need to exercise judgment over the extent to which average physical life is representative of economic life, and it is essential to assess the solidity of long-term maintenance and major replacement provisions. Comparative analysis of similar existing assets with proven long operational lives can also provide supporting empirical evidence.

9.4 Residual value

In general, the PJ appraisal team determines a project's residual value based on the nature of the technology concerned and the surrounding market risks. For example, in the case of rail projects, where rolling stock is normally replaced after 20–25 years of operation, the in-house CBA models assume by default that the residual value at the end of the project's physical life is zero. The default assumption can be modified for a specific project when justified.

10. Social discount rate

J. Doramas Jorge-Calderón

10.1 Introduction

Financial appraisals in business plans normally discount cash flows at the promoter's weighted average cost of capital (WACC). This measures the opportunity cost of capital to the promoter, which — because of distortions — does not necessarily represent the opportunity cost of capital when looking at the investment from society's point of view. While the WACC can be computed before and after (corporate profit) tax, there are other distortions for which the WACC does not account, such as the income tax paid by savers on funds they supply to the capital market. Also, the risk considerations included in the WACC are not directly translatable from private to government financing, where society at large bears the risk on a project, which is normally tiny compared to the size of the economy.[47] For private promoters and their investors, projects normally represent a substantial part of their capital, reflected as a risk premium in the WACC.

Given all these considerations, the social discount rate (SDR) normally differs from the discount rate used by the private sector. The following section briefly describes the two main approaches used to estimate the SDR, while section 10.3 discusses the EIB's rationale for choosing between the two, and in section 10.4 how the Bank applies the chosen approach.

10.2 Approaches to estimating the social discount rate

The two main models for applying a social discount rate are the social opportunity cost (SOC) and the social time preference (STP); both are introduced briefly below.

The SOC approach assumes that funds to finance the project are sourced from the capital markets, and more precisely from the domestic debt market (Sandmo and Drèze, 1971; Burgess and Zerbe, 2011; Moore et al., 2013). The debt raised to finance the project pushes up domestic interest rates, thereby crowding out alternative investment, encouraging savings in lieu of consumption and triggering a higher inflow of foreign capital. The SOC approach estimates the SDR as the weighted average of three possible fund sources:

$$SDR^{SOC} = \alpha ROI + \beta CRI + \gamma FB \quad (1)$$

where α is the proportion of funds displaced from private-sector investment, priced at the private-sector rate of return on investment (*ROI*); β is the proportion of funds made available through foregoing consumption (increasing savings), priced either at the consumer rate of interest (*CRI*) — the (if applicable, after-tax) interest rate on consumer loans — or at the after-tax return on savings; and γ is the proportion of funds attracted through increased foreign borrowing (*FB*), priced at the interest rate on foreign debt.

In the SOC approach, the same SDR applies to all projects in an economy, instead of applying weights to reflect how a project is financed. This rests on the assumption that all projects have a single source of financing, namely government domestic borrowing.

[47] This is based on the argument by Arrow and Lind (1970) that, for projects that are not large relative to the size of the economy and that are independent from other projects, should the government pass on the cost of any losses from such a project to taxpayers, the cost to each individual taxpayer would be negligible. This argument has become generally accepted in economic appraisal literature and practice.

By contrast, the STP approach focuses on maximising the PV of utility from the stream of present and future consumption per capita. An investment project comes at the initial expense of consumption but should allow higher future consumption. The appraisal de facto converts all flows into consumption equivalents and then discounts these at the SDR, as set out in the following Ramsey equation:[48]

$$SDR^{STP} = \rho + g\varepsilon = SRTP \qquad (2)$$

where ρ is a measure of pure impatience — the preference to consume today rather than in the future, irrespective of other considerations; g is the expected rate of growth in per capita consumption, often proxied by the expected growth in per capita GDP; and ε is the absolute value of the elasticity of the marginal utility of consumption with respect to consumption — measuring how that marginal utility declines as consumption grows. This approach also labels the SDR as the social rate of time preference (*SRTP*). The *SRTP* is then the SDR resulting from applying the STP approach ($SRTP = SDR^{STP}$).

Note the difference in the nature of the SDR approaches. In the SOC approach, the SDR incorporates the opportunity cost of funds (including any foreign loan). In the STP approach, by contrast, the SDR only measures the social cost of postponing consumption. Since SDR^{STP} measures the opportunity cost of foregoing consumption, for practical purposes it is often considered the same as the consumer rate of interest element in SDR^{SOC} (Campos et al., 2015).

In the STP approach, the marginal source of finance is assumed to be government taxation. Taxation comes primarily at the expense of consumption (Moore et al., 2013), so the opportunity cost of funds consists primarily of postponed consumption. If part of the funds used to finance the project are instead at the expense of alternative investment, the STP approach charges such part of the funds a shadow price of investment (Dasgupta et al., 1972), subsequently referred to in the literature as the shadow price of capital (SPC). The SPC is determined as follows:

$$SPC = \frac{(1 - fr)ROI}{SDR - frROI} \qquad (3)$$

where *fr* is the fraction of returns on investment that is immediately reinvested rather than consumed, and (1−*fr*) is the share of investment proceeds that is immediately consumed. The other components of the formula have already been introduced. By including the *SDR* in the denominator, the foregone proceeds from alternative investment (and reinvestment) are converted into consumption equivalents, and thus directly comparable to all other flows in the appraisal.[49]

However, the SPC is rarely used in practice for two reasons. First, all government spending is ultimately funded by taxes; since taxes are mainly at the expense of consumption rather than investment, the opportunity cost of postponing consumption is a close enough approximation of the opportunity cost of funds (Moore et al., 2013). Second, where access to competitive international capital markets is relatively frictionless, $SPC \approx 1$ (Johansson and Kriström, 2015).

Disregarding the SPC also gives more operational flexibility. Any discount rate can be used to compute the net present value (NPV) or the internal rate of return (IRR). However, when using the STP method, the SPC formula also includes the discount rate, making it challenging to apply the IRR. Accordingly, by not considering the SPC, computing the IRR is equally easy with the STP and SOC approaches. We address next the choice between NPV and IRR, before discussing the SDR method chosen by the EIB.

10.3 Net present value or economic rate of return?

Irrespective of which SDR method is followed, the question arises of using the SDR to estimate the project's NPV or, alternatively, the ERR. The NPV is better suited to maximise the value of a portfolio of projects. The investor's task is to select projects whose combined value maximises the project portfolio's NPV. Alternatively, the SDR can be used as a reference threshold against which to assess the project ERR. This

[48] For a summary, see Boardman et al. (2018) and Johansson and Kriström (2015). For background on how the formulation developed in the literature, see Moore et al. (2013).
[49] For alternative ways to formulate the SPC see, for example, Johansson and Kriström, 2015 and Boardman et al. 2018. Spackman, 2008 addresses projects procured through public private partnerships.

is an inferior budgeting tool since the ERR measure does not reflect the size of the project and, hence, how much capital in the investor's budget is used by each project. However, to perform an NPV budgeting exercise, the investor must decide at the same time on all projects it will finance. This is impractical for the EIB as project financing proposals are submitted at different times through the calendar year. Moreover, the degree of readiness of each project varies, and so does the time taken to understand the social returns of each operation. Selecting simultaneously all projects to be financed in a year is not workable.

For non-budgeting purposes, NPV is a poor guide on whether to accept projects because project size affects project value, meaning that NPV can only validly compare projects of the same size. Although combining NPV with the benefit–cost (B/C) ratio could overcome this limitation, that complicates the analysis by relying on two indicators. Instead, ERR allows easier comparison of the economic efficiency of differently sized projects, which is why the EIB uses it.[50] Therefore, the EIB employs the SDR as a reference threshold to rate projects and decide on their acceptability.

10.4 Use of social time preference by the EIB

Besides any debate as to the relative merits of the SOC and the STP approaches, consistency in decision making and comparability across projects calls for any investor to stick to a single approach. In principle, the SOC method would seem most appropriate for EIB appraisals, since it assumes the capital market to be the main source of funds. Conversely, the SDR method would seem most appropriate for the European Commission, as the source of funds is taxpayers. In reality, though, the picture is somewhat blurred. Debt and taxes are used interchangeably in public finance and, ultimately, public debt is guaranteed by the government's ability to raise taxes.

The EIB and the European Commission interact in many ways. Perhaps most importantly within the project finance context, the EIB supports DG REGIO policy in its development mandates. DG REGIO employs CBA to decide on project viability for Cohesion Fund grants. In principle, the SDR should not lead to differences between Commission and EIB decisions on project viability. Since the Commission uses the STP approach, adopting the same would help the Bank make decisions more consistent with those of the Commission.

Conversely, the EIB also finances projects in competitive markets where operations do not require subsidies and would not, therefore, receive Cohesion Fund support. EIB intervention in competitive sectors is justified by the presence of externalities or by prices not reflecting social opportunity costs. These projects operate in sectors where the rates of return are normally much higher than the SDR. In these circumstances, the Bank applies a higher rate of return threshold for projects in sectors that normally command much higher rates of return than the SDR, thereby ensuring that financing is not given to sub-par projects in those sectors.

Over the last two programming periods, the European Commission has recommended an SDR ranging from 3% to 5.5%, with some small variation between the periods and with differentiation between regions — cohesion regions at the upper end of the range and non-cohesion regions at the lower end.[51] The EIB adopts 3.5% as the default threshold for all operations but a higher rate of 5% for private-sector projects in competitive markets. For projects beyond Europe, where higher rates of economic growth could be expected, associated with higher rates of time preference, the default ERR is 5%. Exceptionally, for projects with very long-term climate benefits, the Bank accepts projects with an ERR of 3.5%.

Reaching the minimum ERR threshold is a necessary condition for project acceptance. Provided a project meets that criterion, its ERR is one of the various criteria used to rate overall performance in meeting EIB policy objectives, as set out in the Additionality and Impact Measurement framework (AIM).[52] The top three rows of relate project rate of return to project rating, including not acceptable, fair, good, very good and excellent.

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[50] The IRR measure has well-known computational problems under certain circumstances. For example, when net project flows change sign (from positive to negative) more than once, the IRR becomes unreliable. However, such circumstances are rare in the context of investment appraisals, at least within the realm of EIB operations. Flows tend to be negative only during construction and then turn positive during operation, implying a single switch in sign.
[51] For the last CBA guide published by DG Regio, see European Commission (2014). The 2008 guide is also available online (Guide to cost-benefit analysis of investment projects - Regional Policy - European Commission (europa.eu)).
[52] Additionality and Impact Measurement (eib.org)

Table 10-1: Implications of project ERR for rating within the AIM framework

		Not acceptable	Fair	Good	Very good	Excellent
ERR ratings (level of ERR, in percentages):						
EU	Default	< 3.5%	3.5–5%	5–7%	7–10%	> 10%
	Private sector in competitive markets	< 5%	5–7%	7–10%	10–15%	> 15%
Non-EU	All operations	< 5%	5–7%	7–10%	10–15%	> 15%
Ratings of ERR–FRR spread (in percentage points):						
Broader social benefit	All operations	< 0 pp	0–1 pp	1–3 pp	3–5 pp	> 5 pp

As an additional policy tool, for projects in sectors financed by the Bank but contentious on climate grounds (e.g. road and air transport), the ERR threshold is set at 7%. This means that such projects are only accepted if rated at least "very good," rather than 7% being the threshold between a "fair" vs. "not acceptable" rating.

As discussed in chapter 2, the spread between the ERR and FRR of a project is used to measure the extent to which financial flows accruing to private investors exclude societal value. Other things being equal, the greater the spread, the stronger the societal case for public support for the project and the greater the risk of undersupply in the absence of support.

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11. Multicriteria analysis

Christine Blades

11.1 Introduction

Multi-criteria analysis (MCA) is an appraisal technique used to establish preferences amongst different options for delivering a given set of objectives. It does this with reference to an explicit set of criteria, which helps appraisers to assess the extent to which the investment objectives are met by the different solutions available to them. The problems addressed by MCA consist of a finite number of alternatives that are known explicitly at the beginning of the process. The purpose may be to identify the best alternative, rank options in preference order, or shortlist a number of options for more detailed appraisal. A standard tool of MCA is the "performance matrix", which compares the performance of each option against multiple appraisal criteria.

MCA can take different forms. These vary according to the nature of the decision and the time, resources and data available to appraise the alternatives, as well as by the skills of the analyst and the requirements of the organisation or culture in which the appraisal takes place. Whether simple or more sophisticated, explicit or implied, all MCA requires judgements to be made by the evaluator. The analytically more sophisticated form of MCA described in this chapter translates the "performance matrix" into a numerical value that provides an overall assessment of the relative contribution of options to delivering the objectives of the project. The assignment of these values is based on the informed judgement of the appraiser.

The advantages of MCA over judgement unsupported by analysis are that:

- The technique is transparent, open and explicit;
- It elucidates the problem or question being addressed and sets out the pros and cons of different solutions;
- The choice of objectives and appraisal criteria are open to analysis, as well as to challenge and change if they are judged to be inappropriate;
- Criteria "weights" and option "scores" are explicit, developed according to established techniques, can be cross-referenced to other sources of information and amended if necessary, provide a clear audit trail;
- It can provide an important means of communication, both within the decision-making body and between that body and external interested parties;
- Simple sensitivity testing can be used to assess the robustness (and/or decision turning-points) of appraisal conclusions.

Where full Cost-Benefit Analysis (CBA), Cost-Effectiveness Analysis (CEA) or other more standard quantitative appraisal techniques are not possible, MCA brings structure, transparency and consistency to the Bank's appraisal of investment projects. The method is also useful to inform and supplement CBA and other studies when it is not possible to express all costs and benefits in monetary terms. It can, therefore, contribute to Bank appraisals that generate ERRs or other economic indices but leave some relevant factors outside the calculations.

This chapter outlines the application of MCA principles to the appraisal of investment proposals prepared by promoters seeking to secure EIB funding for their projects in a way that is both transparent and contestable. In doing so, it focuses on the fuller form of MCA, in which the relative performance of options is expressed numerically (using "weights and scores") – and, as such, represents an "indicator" of project effectiveness in delivering investment objectives. The quantitative outcome of MCA is then compared with total project costs, represented by the outcome of a standard discounted cost analysis.

11.2 Stages of multicriteria analysis

In summary, the steps of the MCA approach described in this chapter are six-fold:

1. Establish the decision context and the aims of the MCA.
2. Identify the options to be considered and compared, the project and relevant counterfactual(s).
3. Identify the investment objectives and constraints.
4. Identify the benefit criteria that reflect the value associated with the outcome of each option.
5. Assess the benefits:
   a) "weight" the benefit criteria for relative importance;
   b) describe the expected performance of each option against the criteria and "score" the ability of each to deliver the benefits; and
   c) combine the weights and scores to derive an overall value for each option (total weighted scores) and rank them accordingly.
6. Conduct sensitivity analysis to assess the robustness of MCA results to changes in weights and scores.

The stages of the analysis are outlined below, with supporting material provided in appendices.

11.2.1 Step 1 — Decision context

The purpose of the EIB's appraisal of projects is to inform the Bank's funding decisions based on proposals prepared by Member State and other project promoters. In doing so, it focuses on the evaluation of the appropriateness and robustness of investment projects within the strategic context in which they have been developed – it does not make the investment decision (the promoter does), nor does it prioritise projects across different countries or sectors. In this context, MCA is a suitable appraisal alternative when other techniques cannot be used for reasons of insufficient or inadequate data and limited time and resources available to appraise projects. It enables a comparison of the project with other options, where appropriate, and facilitates the ranking of multiple options from best to worst, as a result of assessing the relative benefits of the project and other options for meeting the investment objectives.

EIB experience shows that its assessment of investment proposals for projects in certain sectors and/or countries are more suited to appraisal using MCA than other methods. In particular, sectors for which project benefits are difficult to measure and value pose a challenge for the EIB to appraise systematically using CBA/CEA techniques (and hence the calculation of project ERRs and ENPVs). This includes, for example, investments in education, health and urban development. Whilst the capital investment and operating costs of these projects are more straightforward for the Bank to appraise, the benefits are rarely expressed in monetary terms. For this reason, the MCA approach described below focuses on the assessment of a project's benefits, which are combined with project costs to facilitate an assessment of the overall economic robustness of the project. When combined with the total discounted costs of options, it enables an assessment of the comparative economic value of the project, where the economic decision-criterion is represented by a comparison of (incremental) costs and benefits, where the latter is expressed in total "weighted benefit scores".

Weighting of criteria and scoring of options are not exact sciences and represent, respectively, opinions about the relative importance of different criteria and the practical benefits that will be received from the implementation of each option. Although the method is itself transparent and systematic, it is important that the Bank's MCA based appraisals are undertaken by a small appraisal team (not an individual analyst in isolation) and that the results of the appraisal are queried and tested for robustness through sensitivity analysis.

11.2.2 Step 2 — Option identification

MCA is an incremental approach to comparing alternatives. Differences in the costs and benefits of the situation *with* the project (i.e. do something specific) and one or more counterfactual scenarios *without* the project are compared in the option analysis. The “without” scenario could be represented by one or more of the following:

- “Do nothing” – a baseline option that should be realistically considered, which may or may not be acceptable or possible or could be catastrophic for the service/business in question.
- “Do minimum” – the minimum investment required if the project is not implemented, incorporating the costs of maintaining the current service/operation over the lifetime of the proposed project.
- “Do something else” – other projects that could be implemented to meet the objectives of the investment (typically, to differing degrees).

Project promoters variably consider and evaluate alternatives to the investment project that are submitted to the EIB for funding. At a minimum, however, the Bank’s appraisal of its promoters’ projects should always involve a comparison of the project with a “do nothing” or preferably, a realistic “do minimum” option (and not simply the static situation before and after the project is implemented) – see chapter 3 of this guide.

The alternatives should be described, and wherever possible key descriptors should be quantified; where this is not possible, they should be described qualitatively. Examples include:

- Intended outcomes;
- Expected workloads and performance targets, planned capacity;
- Accessibility;
- Physical characteristics and infrastructure implications;
- Phasing and timing of implementation;
- Flexibility to accommodate future change;
- Staffing consequences;
- Impact on financial parameters;
- Effects on others (other aspects of the business, other parties).

11.2.3 Step 3 — Identify objectives and constraints

As a guiding principle, investment objectives and the benefits that flow from their achievement will be determined by the needs of the end users/intended beneficiaries. They focus on the required outputs/outcomes (i.e. “what” needs to be achieved) rather than the means of achieving them (i.e. “how” they will be delivered). Investment objectives may be expressed in terms of criteria, such as relevance, appropriateness, effectiveness, equity, efficiency, acceptability, etc.

The objectives must be consistent with the policies and strategies of the sector and the context in which the project has been designed and will function. They will reflect the business aims of the promoter, as established in existing business plans, and reflect how the investment will contribute to these. As far as possible, objectives should be SMART: specific, measurable, achievable, relevant and with a time dimension. Objectives that are important but difficult to express in SMART terms should be incorporated into appraisals with as much objectivity as possible. However, statements like “upgrade the quality of accommodation” or “improve the quality of information” are typically not useful objectives, as they:

- refer to a means rather than the desired ends (there may be multiple ways of delivering the outcome sought); and
- are not SMART – have no timescale and no standard for measuring improvement.

Constraints are factors that impact on strategic, business and investment objectives and, as such, set the boundaries for the investment. They may relate to policy commitments, the physical environment, availability of appropriate staff, appropriate timescales, minimum standards, and so on. Investment constraints may also be related to financial issues, such as, maximum capital value or a limit on the operating cost implications of an investment.

11.2.4 Step 4 — Identify benefit criteria

Benefit criteria are used to identify and evaluate the investment options that are compared during a project's appraisal (the project and at least one alternative, such as "do minimum"). Derived from the strategic and business objectives and constraints, they fall into the following categories:

- Benefits that can be quantified financially – these should be included in the cost analysis;
- Benefits that can be quantified, but not financially;
- Benefits that cannot be quantified.

There is no "right" answer to the appropriate number of benefit criteria, as this very much depends on the nature of the decision to be made and the availability of supporting information, time and resources. A large number of criteria means additional analytical work. At the same time, there is a danger that important attributes may be ignored if there is a very small number of criteria. It is good practice to check that duplicate, potentially redundant criteria or those that do not help to differentiate the options are removed and the key investment objectives (ends not means) are adequately reflected in the benefits appraisal. The aim is to produce a manageable number of relevant criteria (possibly between 5 and 10) consistent with a well-founded conclusion that effectively compares the project with other options.

Each criterion is described by a list of potential benefits and, where relevant, disbenefits. These are drawn from the hierarchy of objectives, starting from policy aims, the promoter's strategic and business objectives, through to those directly related to how the project will contribute to these objectives. Where benefits can be expressed in monetary terms (e.g. cost savings) they are included in the cost analysis and **not** treated as a benefit criterion – to do otherwise would lead to double-counting. Benefit criteria might, for example, reflect the following kinds of factors:

- Strategic fit and coherence;
- Meeting needs/demands;
- Quality of services/products delivered;
- Effectiveness/efficiency of service/product delivery;
- Accessibility of the project's services/products;
- Staffing factors (e.g. recruitment and availability of staff);
- Flexibility to respond to changing demands and technological developments;
- Environmental quality;
- Ease and timing of implementation.

11.2.5 Step 5 — Assess benefits

The evaluation of project benefits focuses on the non-monetary implications of investment options. The benefits delivered by the project are assessed comparatively using the benefit criteria identified at Step 4. Where possible all benefits should be quantified. The construction of weighted benefit scores is preferable to, and more robust than, the simple ranking of alternatives, with no clear measure of the degree to which one option is better (or worse) than another.

Weight benefit criteria (Step 5a): the purpose of weighting is to establish the relative importance of each criterion *vis-à-vis* the others. There are different ways of identifying criteria weights, though the following approach is recommended for its simplicity and transparency:

- Rank the criteria in order of importance;
- Attribute the most important criteria a weight of (say) 100;
- Examine each of the remaining criteria relative to the highest ranking attribute using pair-wise comparison (e.g. if the most important is 100, what is the relative value of the second (say, 70), the third (say, 50) and so on);
- Repeat the process for each successive pair of benefit criteria until each has been weighted;
- Scale the outcome to 100 (%), thereby attributing each criterion a % that reflects its importance compared with the other criteria;
- Record the weights and the rationale behind them.

Score options (Step 5b): the following practical approach is recommended for scoring options for their relative performance against each of the benefit criteria:

- Examine each option against each criterion, using the option descriptions to help make comparative assessments;
- Score each between 0 and 10 on each criterion (again using the descriptions to help make assessments), the better the performs the higher the score;
- Record the scores and the rationale behind them.

Preference ranking of options (Step 5c): to rank options and identify the preferred solution in terms of the **non-monetary benefits** of the project:

- Calculate total weighted scores;
- Rank options from highest to lowest weighted scores, thereby identifying the best way for achieving the investment objectives from the options selected for appraisal.

See Appendix 2 to this chapter for an illustrative assessment of the benefits of three investment options.

11.2.6 Step 6 — Undertake sensitivity analysis

Given the subjective (if systematic and transparent) nature of judgements made about benefit criteria weights and option scores, sensitivity testing is particularly important for assessing the robustness of the appraisal's conclusions. In the sensitivity analysis, facilitated by simple spreadsheet calculations, the weights and scores can be varied to understand how the preference ranking is affected by these factors.

The following steps are undertaken to assess the sensitivity of the appraisal conclusions (i.e. total weighted scores) to the scores assigned to options. For each option:

- Determine the agreed range of scores for each criterion;
- Alter the score of the first criterion within its agreed range;
- Repeat the analysis for scores of each of the other criteria;
- Note the implications for the total weighted benefit score when all scores for the option are at a maximum and when they are at a minimum.

Undertaking sensitivity analysis on criteria weights is complicated by the fact that altering the weight (%) of one criterion affects the weights of other criteria. In this case the process is as follows:

- Determine the agreed range weights for each criterion;
- For the first criterion to be examined, allocate the change in weight across the other weights (proportionately with the originally assigned weights of these);
- Adjust the weights arising from the change in weight of the first criterion and note the implications for the total weighted scores of options;
- Repeat the analysis for the weights of each of the other criteria.

See Appendix 2 to this chapter for some simple example sensitivity tests on option scores and criteria weights.

11.3 Incremental costs and benefits

As in other forms of economic appraisal, the analyst's conclusion on the value of the project submitted by a promoter for EIB funding is based on the balance of project costs and benefits relative to the alternatives, i.e. the incremental cost-benefits of the options examined in the appraisal. Costs are expressed as the total discounted costs of the investments under appraisal and benefits by the outcome of the MCA. By expressing project benefits in a single indicator (total weighted scores), the outcome of MCA approximates the "effectiveness" indicator used in CEA and the principles of CEA can be applied. In particular, the "cost-effectiveness plane" illustrated below is a useful way of comparing the project with other investment options, including when only one alternative (typically do nothing/minimum) is evaluated in the Bank's appraisal.

When this approach is applied to a comparison of an investment with the next best alternative (e.g. do minimum) the four-quadrant depiction, shown in Table 11-1, illustrates that:

- The project is better (more "cost-effective") if it offers higher benefits at lower costs than the alternative (south-east quadrant of the plane);
- The project is worse (less "cost-effective") if it delivers fewer benefits at higher costs that the alternative (north-west quadrant of the plane);
- Where the project is more costly but offers greater benefits (north-east quadrant) or is less costly but offers fewer benefits (south-west quadrant), incremental cost-effectiveness is unclear and the appraisal conclusion depends on the magnitude of the incremental cost-benefits.

Figure 11-1: Cost-effectiveness plane (four-quadrant depiction)

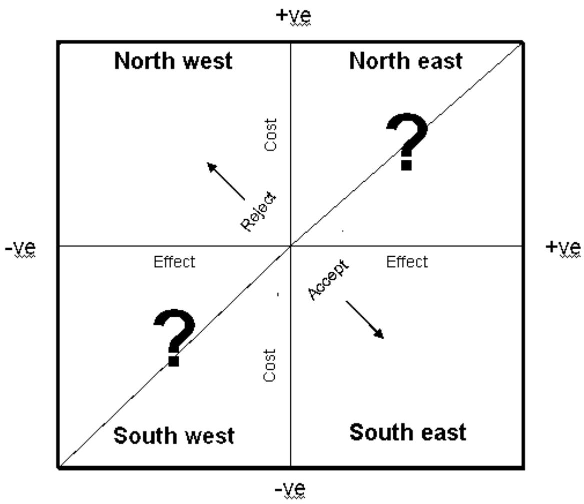

Table 11-1 below summarises the outcome of an illustrative investment appraisal involving three options, a minimum option and two major investment options. The more beneficial options are also the more costly, with Option 1 generating the lowest benefits (total weighed scores) for the lowest costs (NPC) and Option 3 the greatest benefits for the highest costs – such that Option 2 is in the north-east quadrant of the cost-effectiveness plane when compared to Option 1, and Option 3 is also in the north-east quadrant when compared to Option 2.

Table 11-1: Illustrative incremental cost-benefit comparison of options

	Option 1	Option 2	Option 3
Costs (EUR m) & benefits:			
Initial investment costs	47.6	206.8	210.7
Life-cycle investment costs*	13.2	34.1	38.4
Annual operational cost	43.9	44.3	44.2
Net Present Cost (3.5% discount rate** , 30 years)	**752**	**1 050**	**1 069**
Cost preference rank	1	2	3
Total Weighted Score	**380**	**710**	**800**
Benefits preference rank	3	2	1
NPC/benefit point (EUR m)	1.98	1.47	1.34
Rank	3	2	1
Incremental CB comparison:			
Cost differences:			
NPC option 1	+752		
NPC option 1 vs. 2, EUR m		+298	
NPC option 2 vs. 3, EUR m			+19
Benefits differences:			
TWS option 1	+380		
TWS option 1 vs. 2		+330	
TWS option 2 vs. 3			+90
NPC/TWS differences:			
Option 1	1.98		
Option 1 vs. 2		0.90	
Option 2 vs. 3			0.21
Rank	3	2	1

* The investment costs incurred throughout the life of the Project (excludes annual maintenance)
** Non-convergence region

When compared to the minimum option (the "best" cost scenario), the NPC of Option 2 is EUR298 million higher and generates 330 more benefit points than Option 1. This balance represents an incremental "cost-benefit" ratio of 0.90, with each additional EUR1 million NPC spent generating 1.1 times as many additional benefits compared to Option 1. Likewise, when Options 2 and 3 are compared, the additional NPC is EUR19 million for 90 additional benefit points, representing a "cost-benefit" ratio of 0.21, with each additional EUR1 million NPC generating 4.7 times as many additional benefits. Overall therefore, and assuming Option 1 is a real option and options are mutually exclusive, Option 2 is more "cost-beneficial" than Option 1 and Option 3 more "cost-beneficial" than Option 2.

11.4 Other MCA considerations

11.4.1 Mutual independence and double-counting

An underlying principle of MCA is that preferences associated with the options are independent from one criterion to another, such that a score can be assigned to one criterion without knowing how the option scores on other criteria. If this proves not to be the case, there are a few ways this can be addressed, such as:

- By combining into one criterion the two non-mutually independent criteria;
- Establishing a minimum requirement for each non-independent criterion and rejecting options that do not satisfy it because their poor performance on one criterion cannot be compensated for by better performance on another;53
- More advanced models might be needed if simpler approaches fail to ensure that the independence of criteria scores is ensured.

As in CBA and other appraisal approaches, double-counting should be avoided, otherwise the appraisal will give undue importance (weight) to the elements that are double-counted when calculating the final outcome of the benefits assessment and reaching an appraisal opinion. Care is needed to avoid double-counting by including duplicate factors in both cost and in benefit assessments, and/or by reflecting them in more than one of the benefit criteria. Critical review, checking and rechecking for consistency, mutual dependency, redundancy, etc. of criteria is important throughout the MCA exercise.

[53] This threshold usually ensures preference independence (i.e. independence of scores). All options need to meet the minimum performance, so that the preference on any one criterion is unaffected by those on others.

11.4.2 Timing of benefits

Major infrastructure investment projects have implications for many years, generating benefits over the total operating period of the project. On the cost side of an appraisal, discounting is used to reflect social time preference expressed in a single indicator of monetary value. In the absence of such approaches when assessing non-monetary benefits, MCA alternatives include, for example:

- Where the completion date is an important consideration (i.e. the point at which project benefits will start to be generated), it can be modelled by a separate criterion within the MCA technique;
- By incorporating time in the definition of other criteria so that temporary impacts are distinguished from permanent or longer–term impact, usually by being explicit about the time horizon over which benefits will be generated;
- Using some other principle for giving less (or more) importance to long-term implications.

Whichever approach is used, it is important that appraisers ensure all assessments of criteria and options are made on a common basis. Hence, if some impacts are immediate or one-off and others are longer term, and/or occurring in variable time patterns, these differences should be recognised explicitly in the scores awarded to option criteria during the appraisal.

11.4.3 Superior/inferior or dominant/dominated options

It is possible that one or more of the investment options examined through MCA might be superior (or inferior) to the other options, as demonstrated by the attribution of highest (or lowest) scores for every benefit criterion and hence for total weighted scores. For example, a new build facility might perform better on every criterion when compared to a “do nothing/minimum” counterfactual (better access/location, better service effectiveness, more flexible, the most modern accommodation, greater acceptability to end users, etc.). If options benefits were the decision-criterion, a clearly superior investment would not need to be appraised further but could be selected as the preferred way forward and, likewise, a clearly inferior option removed from the exercise (unless it has a role as a baseline comparator).

However, even if an investment alternative is shown to be superior in terms of the benefits delivered, as demonstrated through MCA,[54] total project costs must also be factored into the appraisal opinion. The project may deliver the largest benefits, but it is also likely to be a costly – perhaps the most costly alternative. Hence, a conclusion of dominance (or dominated) should not be made until the MCA results and costs have been brought together, as outlined above.

[54] Typically (hopefully) the Project that is submitted to the Bank for funding support.

11.5 Appendix 1: Checklist for each step of multicriteria analysis

Step 1 — Decision context

Summary actions/decisions:
• Evaluate the decision context – the nature of the decision required and the resources available to address the decision.
Outputs:
• An appropriate approach to MCA within the decision context; • An agreed process for undertaking appraisal judgments/decisions.

Step 2 — Option identification

Summary actions/decisions:
• Develop an understanding and describe the realistic implications of not implementing the project (do nothing, do minimum); • Consider and explore the range of possible options capable of delivering the investment objectives (albeit to differing degrees); • Develop an understanding of the project and any other investment options in sufficient detail to undertake the MCA.
Outputs:
• Description of the options to be subjected to MCA (including a baseline, such as do nothing/do minimum)

Step 3 — Identify objectives and constraints

Summary actions/decisions:
• Identify the high-level policy aims for the sector and the promoter; • Identify and review the organisation's business aims and objectives; • Identify the objectives for the investment strategy that are SMART (specific, measurable, achievable, relevant and time-linked); • Check that the chosen objectives concentrate on results rather than the means of achieving them; • If possible, rank objectives from highest to lowest in order of priority; • Constraints.
Outputs:
• Statement of ranked/prioritised objectives for the investment; • Statement of constraints facing the investment.

Step 4 — Identify benefit criteria

Summary actions/decisions:
• Identify the benefits that will be realised by meeting the objectives set for capital investment; • Classify the benefits into groups of benefit criteria.
Outputs:
• List of benefits that the investment seeks to deliver; • Identification and definition of benefit criteria for the evaluation (comparison of alternatives).

Step 5 — Assess benefits

Summary actions/decisions:
• Give a weight (0 to 100) to each benefit criterion; • Give a score (1 to10) to each option on each of the benefit criteria; • Multiply weights and scores to provide a total weighted score for each option; • Rank options in terms of the acceptability of the cost or incremental benefits.
Outputs:
• Weights for benefit criteria; • Scores for each criterion for each alternative solution; • Total weighted scores for alternatives; • Incremental costs and benefits; • A preferred “benefits” option.

Step 6 — Undertake sensitivity analysis

Summary actions/decisions:
• Conduct sensitivity tests on the weighted benefit scores of each option; • Identify critical factors that affect the ranking/preference of options on “benefits” grounds.
Outputs:
• Sensitivity analysis on benefit criteria weights and options scores; • Switching values/crossover points that alter the preferred option; • Conclusions on the robustness of the benefits assessments.

11.6 Appendix 2: Illustrative outputs of multicriteria analyses

Table 11-2: Calculation of weighted benefit scores

Benefit Criterion	**Weight**	**Option 1**		**Option 2**		**Option 3**	
		Score	**Total Weighted Score**	**Score**	**Total Weighted Score**	**Score**	**Total Weighted Score**
Strategic fit	25	4	100	8	200	9	225
Quality	25	4	100	8	200	10	250
Equity	20	2	40	7	140	7	140
Environment	15	5	75	7	105	8	120
Flexibility	10	2	20	4	40	5	50
Implementation	5	9	45	5	25	3	15
Total	**100**		**380**		**710**		**800**
Preference rank			3		2		1

Table 11-3: Example sensitivity tests — Changes to option scores

	Weight	Option 1		Option 2		Option 3	
		Score	Total Weighted Score	Score	Total Weighted Score	Score	Total Weighted Score
			Reduced score for equity:				
Strategic fit	25	4	100	8	200	9	225
Quality	25	4	100	8	200	10	250
Equity	20	2	40	7	140	*2*	*40*
Environment	15	5	75	7	105	8	120
Flexibility	10	2	20	4	40	5	50
Implementation	5	9	45	5	25	3	15
Total	**100**		**380**		**710**		***700***
Preference rank			**3**		***1***		***2***
			Reduced score for quality:				
Strategic fit	25	4	100	8	200	9	225
Quality	25	***8***	***200***	8	200	10	250
Equity	20	2	40	7	140	7	140
Environment	15	5	75	7	105	8	120
Flexibility	10	2	20	4	40	5	50
Implementation	5	9	45	5	25	3	15
Total	**100**		***480***		**710**		**800**
Preference rank			**3**		**2**		**1**

Table 11-4: Example sensitivity tests — Changes to criteria weights

Benefit Criterion	Weight	Option 1		Option 2		Option 3	
		Score	Total Weighted Score	Score	Total Weighted Score	Score	Total Weighted Score
			Increased weight attributed to implementation:				
Strategic fit	*18*	4	*72*	8	*144*	9	*162*
Quality	*18*	4	*72*	8	*144*	10	*180*
Equity	*15*	2	*30*	7	*105*	7	*105*
Environment	*11*	5	*55*	7	*77*	8	*88*
Flexibility	*8*	2	*16*	4	*32*	5	*40*
Implementation	*30*	9	*270*	5	*150*	3	*90*
Total	**100**		***515***		***652***		***665***
Preference rank			3		2		**1**
			No importance attributed to strategic fit:				
Strategic fit	*0*	4	*0*	8	*0*	9	0
Quality	*33*	4	*132*	8	*264*	10	330
Equity	*27*	2	*54*	7	*189*	7	189
Environment	*20*	5	*100*	7	*140*	8	160
Flexibility	*13*	2	*26*	4	*52*	5	65
Implementation	*7*	9	*63*	5	*35*	3	21
Total	**100**		**375**		***680***		**765**
Preference rank			3		2		**1**

Increased weight reassigned to implementation is added to other criteria ("rounded") as follows:

Strategic fit	=> 25 x 25/95 = 7 (from 25% to 18%)
Quality	=> 25 x 25/95 = 7 (from 25% to 18%)
Equity	=> 25 x 20/95 = 5 (from 20% to 15%)
Environment	=> 25 x 15/95 = 4 (from 15% to 11%)
Flexibility	=> 25 x 10/95 = 2 (from 10% to 8%)

No importance assigned to strategic fit, reassigned to other criteria ("rounded") as follows:

Quality	=> 25 x 25/75 = 8 (from 25% to 33%)
Equity	=> 25 x 20/75 = 7 (from 20% to 27%)
Environment	=> 25 x 15/75 = 5 (from 15% to 20%)
Flexibility	=> 25 x 10/75 = 3 (from 10% to 13%)
Implementation	=> 25 x 5/75 = 2 (from 5% to 7%)

11.7 Appendix 3: Cost–benefit comparison

Comparison of Options 1 and 2:

- Option 1 has lower costs (+ve) but also offers lower benefits (-ve) than Option 2 – i.e. south-west quadrant of cost-effectiveness plane, where cost-effectiveness is questionable
- Are the additional benefits worth the additional costs?
- A lower NPC of €108 million for a higher TWS of 330 benefit points equates to a cost/benefit ratio of 0.90 (each additional €1 million NPC generates 1.1 additional benefit points).

Comparison of Options 2 and 3:

- Option 2 has lower costs (+ve) but also offers lower benefits (-ve) than Option 3 – i.e. south-west quadrant of cost-effectiveness plane, where cost-effectiveness is questionable
- Are the additional benefits worth the additional costs?
- A lower NPC of €19 million for a higher TWS of 90 benefit points equates to a cost/benefit ratio of 0.21 (each additional €1 million NPC generates 4.7 additional benefit points).

Where no intermediate option between “minimum” and “new build”, **(incremental) comparison of Options 1 and 3**:

- Option 1 has lower costs (+ve) but also offers lower benefits (-ve) than Option 3 – i.e. south-west quadrant of cost-effectiveness plane, where cost-effectiveness is questionable.
- Are the additional benefits worth the additional costs?
- A lower NPC of €317 million for a higher TWS of 420 benefit points equates to a cost/benefit ratio of 0.75 (each additional €1 million NPC generates 1.3 additional benefit points).

12. Risk analysis and uncertainty

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12.1 Risk and economic returns

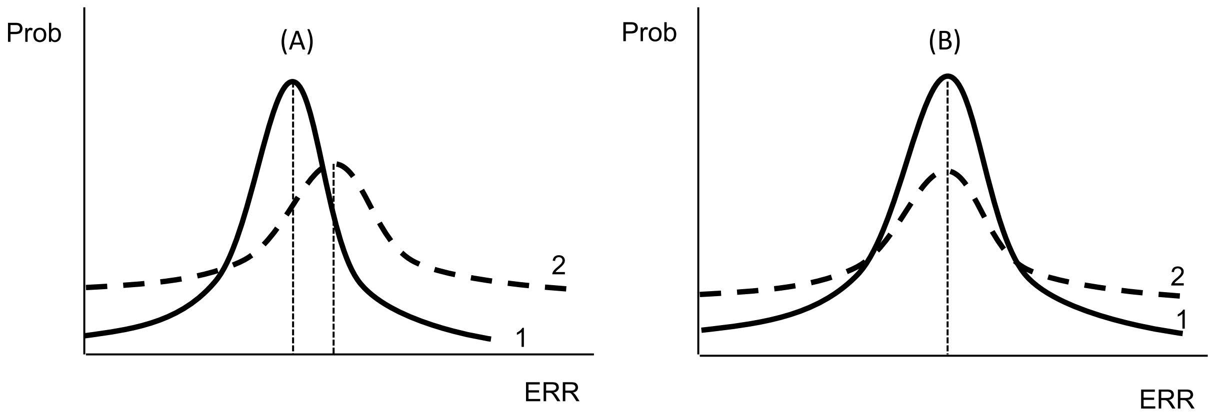
The most generally accepted means to incorporate risk into investment appraisal is through the capital-asset pricing model (CAPM). Measuring risk by volatility, the model adjusts the discount rate applied to the stream of future benefits and costs by the risk premium corresponding to their expected volatility. For any volatility level, the applied risk premium is also affected by market participants' risk aversion, the general degree of uncertainty in the economy at large, and various other factors.

Following the CAPM, the resulting NPV of the investment represents the project's value, incorporating the effect of risk. When the appraisal focuses on IRR instead of NPV, the same risk premium can be incorporated into the threshold rate of return used to judge a project's acceptability.

As seen in chapter 10, however, where the non-diversifiable risk of a project to society is small, the SDR used in economic appraisal should not incorporate a risk premium. Non-diversifiable risk to society is typically small when the project represents a small proportion of the whole economy, which is normally the case for EIB-financed projects. However, this does not imply that risk analysis is irrelevant in the economic appraisal: such analysis is necessary to gauge the likelihood of the project diverting from the expected rate of return and to provide information about possible risk mitigating conditions that could be applied to the financing.

This is illustrated in Figure 12-1, which shows probability distributions of project ERR outcomes for two scenarios (A and B) each involving two projects (1 and 2). In scenario (A), project 1 has a narrower distribution of possible outcomes than project 2, meaning that project 2 is riskier than project 1. Following the CAPM, the private sector would carry out the riskier project only if the expected rate of return (assume here that ERR = FRR) is sufficiently above the return of the less risky project, in line with the situation in scenario (A).

Figure 12-1: Probability distributions of project outcomes



In scenario (B), projects 1 and 2 have the same expected ERR but different risk profiles. Despite that difference, the two projects are equally attractive from society's perspective. The economic appraisal in effect assumes risk-neutrality. Although risk analysis appears unnecessary for determining project viability, information about riskiness is relevant to the project analyst and decision maker. As mentioned above, risk analysis can help identify project areas of particular vulnerability, and hence help in formulating risk-mitigating conditions. There may also be cases where the decision maker wants to divert from risk-neutrality, for instance where a project risks irreversible damage — often associated with climate change — or where the long-term potential benefits are hard to quantify, which is typical of highly innovative projects.

12.2 Risk analysis in the EIB's economic appraisal

What type of risk analysis can be applied to a project depends on what data are available to the analyst. The quality and availability of data vary widely among projects submitted for Bank financing. In ideal circumstances, the analyst has sufficient data to estimate the probability distribution of the key variables determining project performance. This enables a full risk analysis, including the following steps:

1. Identify the probability distribution of the main variables affecting project return. This determines the most likely range of possible outcomes for each variable and the maximum ranges that can be reasonably assumed to occur.
2. Estimate the risk-weighted expected rate of return. The resulting figure constitutes the base estimate of project returns.
3. Estimate the probability that the project's rate of return would exceed the threshold return rate determining project acceptability.
4. Estimate the "switching value" — which must be attained to meet the acceptability threshold — for all main variables affecting profitability. This should identify any necessary conditions for addressing specific project elements.

The above procedure involves performing a Monte Carlo simulation, which is only desirable if the data allow reliable estimates of each main variable's probability distribution. Though Monte Carlo simulations can also be performed with assumed probability distributions, this simply adds a new layer of assumptions, rather than information, without reducing uncertainty over the estimated project returns.

When lacking sufficiently sound data to construct probability distributions, the analyst must judge the range and likelihood of possible values for each variable. In these circumstances, it may be more transparent to base the risk assessment on scenario building, where the assumptions used are immediately apparent and visible, than to run Monte Carlo simulations with assumed probability distributions, where the underpinning assumptions are less easily appreciated by the decision maker.

In addition to a "base case" scenario, constituting the base ERR reported for the project, scenario-based risk analysis can be based on two scenarios:

- A "pessimistic scenario," including a set of values for the main input variables depicting a probable bad outcome. Neither the worst possible nor catastrophic, these intput values are commensurate with past adverse experience in the sector;
- A "switching scenario" of input values that would cause the project to miss the acceptable return threshold.

The analyst then issues an opinion on project riskiness based on the three scenarios. Inevitably, scenario-based analysis is more reliant on analyst judgement than a Monte Carlo simulation based on known probability distributions. The analyst needs to judge whether there is sufficient available information on probability distributions to merit performing a Monte Carlo simulation. Moreover, scenario-based analysis may complement or replace Monte Carlo analysis.

12.3 Uncertainty and real options

When uncertainty is particularly high and investments are irreversible, flexibility to adapt in the future is especially valuable. Moreover, if project components can be delayed and if waiting would resolve uncertainty, the promoter may design and phase the project to leave options open on future actions. Measuring the full economic value of such projects requires the valuation of such options using real options analysis (ROA).

In finance, an option is the right, but not the obligation, to take a particular action, most commonly the purchase or sale of a security. By contrast, real options involve real assets, rather than financial securities; though they may take the form of a legal right without accompanying obligation — like financial options — they more generally involve gaining the possibility but not the commitment to follow a course of action.

Examples of real options include expanding or contracting capacity, deferring or abandoning an investment, or choosing among alternative technologies in the future. Project promoters may use ROA in their decision-making process, helping to define project components and their timing and phasing. However, by the time a project is presented to the EIB for financing, it is generally already defined. Reaching an advanced stage in defining the project is usually necessary before financing can be agreed. Accordingly, ROA by the EIB serves not to assist project conception but rather to attach value to any embedded options. Since options generally come at the cost of additional capital investment, failing to value them would penalise a project's estimated economic returns. ROA is becoming increasingly relevant in the context of climate change, with growing numbers of infrastructure operators and other promoters conceiving projects with costly preventive measures giving flexibility to adapt to future uncertain climate conditions.[55] The same considerations apply to financing of innovative technologies.

ROA is also relevant when appraising the effects of new technologies on more traditional infrastructure projects. For example, before it was known whether the ultralarge A380 aircraft would ultimately be launched, some airports began designing new oversized terminal structures that could be expanded to accommodate it, with additional investment needed only in new jetties and boarding gate facilities. The alternative was to entirely ignore the possibility of the A380 being introduced, such that if the aircraft were eventually launched, the required airport investments to accommodate it would be considerably higher, perhaps with the need to build entirely new terminals. This case involved some airports committing resources to preparatory investments, giving them flexibility to accommodate an aircraft not then certain to ever enter service. This type of situation is likely to repeat in the future, given current uncertainty over new propulsion technologies in transport, particularly aviation and maritime.

If the real option value of such preparatory investments were ignored, projects may appear oversized or overly expensive, with a negative impact on their ERR. By recognising that apparent oversizing would create the option to expand and switch to an alternative technology, initial investment in such preparation can be regarded as value-creating.

The procedure for estimating value is specific to the nature of the real option considered, and can easily become complex. For some projects, calculating the real option value may require specialist advice. For others, investment in the option may be so small relative to the overall project size that its value is not worth estimating: the project may be economically justified even without accounting for the real option value. However, for projects where investment in the option is significant and the option is not complex, a simple calculation could suffice.

[55] The usefulness of ROA for climate-change adaptation investment is illustrated in the Annex of Chapter 3 of Kolev *et al.* (2012).

12.4 Calculating the real option value

There are several methods to calculate the value of a real option.[56] For complex options, the most straightforward procedure is the Black–Scholes formula.[57] The analyst should judge whether this method is valid, based on the characteristics of the option, or whether an alternative method is needed. The Black–Scholes method is illustrated here because it is the simplest to apply. For some project options it may be sufficient; for others (particularly more complex options) it may be useful as a first approximation. The formula is as follows:

$$C = N(d_1)S - N(d_2)Ke^{-rT}$$

where *C* is the option value; *S* is the value of the underlying asset, or the PV of the free cash flow generated by the project; *K* is the strike price, or the eventual investment involved in exercising the option; *r* is the risk-free rate of return; *T* is the time to maturity of the option; and *N* is the standard normal distribution. The option parameters d_1 and d_2 are estimated as follows:

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$

$$d_2 = d_1 - \sigma\sqrt{T}$$

where σ is the volatility of cash flows of the underlying asset (e.g. cash flows from operating the aircraft in the above example), estimated as follows:

$$\sigma = \frac{\ln\left(\frac{S_{opt}}{S_{pes}}\right)}{4\sqrt{t}}$$

where S_{opt} is the underlying asset value under the optimistic scenario, S_{pes} is the underlying asset value under the pessimistic scenario, and *t* is the project lifetime.

[56] For a formal explanation of real option analysis, see Dixit and Pyndick (1994) or Trigeorgis (1996). For more accessible applications see Kodukula and Papudesu (2006) or Koller et al. (2010).

[57] The Black-Scholes method is applied to European options, options that can be exercised at a pre-specified date. Alternatively, American options can be exercised at any time before the expiry date, and require other methods. Whereas real options tend to be European in nature, institutional constraints often place limits on when they can be exercised. The analyst should judge whether assuming an American option is a close enough approximation, and apply other methods if not.

12.5 Worked example of real option value

Assume the Bank is considering financing a manufacturer to build a new plant for producing product X. The plant is €30 million more expensive than what could have been expected (excluding any taxes, to reflect economic costs), as it is designed to be expandable to manufacture a new product Y. The extra €30 million therefore constitutes the price for acquiring the option to produce product Y. The prospects for product Y critically depend on future regulatory developments, which are highly uncertain but expected to be resolved in four years.

If the regulatory developments are favourable, product Y could generate a cash flow stream over the next 15 years with a PV of €300 million; after adding output taxes and removing input taxes, this implies an economic PV of €40 million. If the developments are unfavourable, the project would generate cash flows of €75 million, with an economic value of €100 million. Assuming that the favourable and unfavourable developments are equally likely, the expected value of economic benefits is €250 million (= (0.5 x €400 million) + (0.5 x €100 million)). Readying the plant to produce product Y would have an economic cost of €200 million. If the regulatory developments are favourable, the project would have an economic value of €200 million (= €400 million − €200 million). If unfavourable, however, the project's value would be −€100 million (= €100 million − 200 million). The expected NPV of the project would therefore be €50 million (= €250 million − €200 million, or = (0.5 x €200 million) + (0.5x(−€100 million))), which may be deemed too small a return for the associated risk.

If the decision to invest in capacity for product Y can be delayed until regulatory uncertainty is resolved, the negative payoff would be eliminated and investment only made following favourable developments. It may be worthwhile preparing the plant for product X to have expansion capacity for eventually producing product Y. As mentioned above, the promoter has decided to spend €30 million to hold this option, so the pertinent question is how much the option is worth.

The first step is to calculate the volatility implied by the return estimates, as follows:

$$\sigma = \frac{\ln\left(\frac{400}{100}\right)}{4\sqrt{15}} = 8.95\%$$

With this estimate of volatility, and assuming a risk-free discount rate of 5%, option parameter d_1 can be estimated as follows:

$$d_1 = \frac{\ln\left(\frac{250}{200}\right) + \left(0.05 + \frac{0.0895^2}{2}\right)4}{0.0895\sqrt{4}} = 2.4538$$

Taking this value, parameter d_2 is calculated as follows:

$$d_2 = 2.4538 - 0.0895\sqrt{4} = 2.2748$$

The formula for the real option value is then:

$$C = N(2.4538)250 - N(2.2748)200e^{-0.05x4}$$

The standard normal distributions $N(d_1)$ and $N(d_2)$ are default functions in standard spreadsheets. The resulting figures are:

$$N(2.4538) = 0.9929$$
$$N(2.2748) = 0.9885$$

The resulting value of the option is therefore:

$$C = (0.9929\, x\, 250) - (0.9885\, x\, 200)e^{-0.05x4} = 86.3631$$

With the option thus valued at €86.3 million, which is higher than its €30 million cost, investment is worthwhile. The economic appraisal, incorporating the apparent over-investment of €30 million, should also now include the €86.3 million value of the option as a project benefit.

Moreover, deducting the €30 million option price from the €86.3 million option value yields €56.3 million, which is higher than the project's NPV (€50 million). This implies it is better to keep the option alive than to invest now in capacity for producing product Y. Finally, acquiring the option is a better solution than not investing anything in preparing to produce product Y.

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Part 2:

Methodology topics: Sector-specific

13. Benefits of fixed telecommunications very-high-capacity networks

Anders Bohlin and Tobias Münstermann

13.1 Introduction

In recent decades the economic benefits of broadband networks for consumers have been increasingly emphasised by researchers. Numerous studies have evidenced the positive impact of first-generation broadband networks on employment, productivity and economic growth (Bertschek et al., 2016). Similarly, the wide-scale roll-out of fibre-optic next-generation broadband (NGB) networks is believed to spur job creation in information and communications technology (ICT) and other related industries; more generally, it is ascribed enormous potential for boosting productivity and economic growth. Besides the benefits of these technologies for process innovation and productivity, product innovations are massively impacting on consumers' social lives. In particular, the adoption of broadband technologies can create substantial consumer surplus. For labour markets, broadband internet is expected to generate new employment opportunities, particularly in remote (rural) areas, by enabling many employees to work from home (teleworking) and, thus, reducing the importance of distance and travel time. As broadband technology develops and the surrounding ecosystem grows, the positive impact on the overall economy is expected to be substantial and ongoing, particularly in completely new fields of business such as artificial intelligence and pandemic resilience/mitigation. This chapter describes the method used to estimate these benefits.

13.2 Socioeconomic and policy background

Given these advantages and promises, broadband technologies have also received attention from policymakers at the national and EU levels in the last decade. The European Commission introduced the Digital Agenda for Europe in 2010, then subsequently adopted a set of initiatives and legislative proposals to place the European Union at the forefront of internet connectivity. In 2016 the Commission defined a new set of common EU broadband targets for 2025 — the "European Gigabit Society" objectives. One objective is for all schools, transport hubs, main public-service providers, and digitally intensive enterprises to have access to internet connections with download/upload speeds of 1 Gbit/s. Another target is for all European households, rural or urban, to have access to networks offering a download speed of at least 100 Mbit/s, which can be upgraded to 1 Gbit/s. Moreover, all urban areas and major roads and railways should have uninterrupted 5G wireless broadband coverage, starting with fully fledged commercial service in at least one major city per Member State by 2020. Whereas the Digital Agenda for Europe used "NGB" to describe broadband infrastructures delivering at least 30 Mbit/s bandwidth capacity, the European Gigabit Society focused on very-high-capacity (VHC) networks, which means an electronic communications network which either consists wholly of optical fibre elements at least up to the distribution point at the serving location or which is capable of delivering under usual peak-time conditions similar network performance in terms of available down- and uplink bandwidth, resilience, error-related parameters, and latency and its variation. VHC networks are seen as critical for the Digital Decade — the EU vision for a digital world empowering people and businesses, shaped around a human-centred, sustainable and more prosperous approach. A key component of the Digital Decade is the "digital compass," which sets out objectives to achieve the envisioned digital future. The four points of the compass identify the main goals to reach over the next decade:

- a digitally skilled population and highly skilled digital professionals;
- secure and substantial digital infrastructures;
- digital transformation of businesses;
- digitisation of the public sector.

Regarding digital infrastructure, the digital compass policy targets covering all European households with a gigabit network and all populated areas with 5G by 2030. Key policy areas to ensure the goals are met include cloud computing, artificial intelligence, digital identities, data and connectivity.

The digital compass can also support the EU in meeting the objectives of the European Green Deal, helping Europe reach its goal of reducing GHG emissions by at least 55% by 2030. Digital technologies help to significantly reduce environmental impact. For example, the widespread use of videoconferencing reduces flight emissions. More generally, digital technologies support a greener approach to agriculture, energy use in buildings, and more sustainable city planning.

Many of the aforementioned new digital services and fields of businesses require an increase in broadband quality. Meanwhile, wireline broadband network operators face increasing capacity demands from mobile operators, themselves experiencing a tremendous growth in the usage of mobile broadband services (Mobile applications or "apps"). Hence, it is necessary to replace existing broadband networks with fibre-optic NGB/VHC networks, but this requires high investment volumes amounting to billions of euros for nationwide deployment. In a study initiated by the Bank,[58] the investments required to achieve European Gigabit Society objectives were estimated at around €384 billion. Private investors are ready to roll out high-speed fibre-based broadband networks only in densely populated areas. To overcome their reluctance to cover remote and unprofitable regions, public subsidies (in the form of state aid) have been considered necessary in most developed countries. The aim to enable all European households to access VHC networks is clearly the next step in digital infrastructure deployment, yet many still lack access to broadband infrastructure enabling at least 30 Mbit/s, notably those households in underserved rural areas. The Bank's study estimates at around €250 million the gap in investment needed to achieve the European Gigabit Society objectives by 2025. As expected, the gap is much higher in rural areas.

According to a recent broadband market report published by the European Commission (2020), around 40% of rural households lack access to NGB technologies and related services. This has created a new digital divide between rural and urban areas, which has become more pronounced during the global economic shutdown triggered by the COVID-19 pandemic. With daily life significantly disrupted, society has become even more dependent on good, reliable access to high-quality broadband infrastructures and related services, such as online social activities and entertainment for residential usage; e-government; e-health; e-learning; and business-specific applications such as teleworking based on video conferencing, virtual private network access and cloud computing.

At the supra-national level, the Digital Agenda for Europe has already encouraged use of national and European state aid instruments to enhance NGB deployment and meet universal broadband coverage targets for all households and firms. State aid policies are largely directed at increasing coverage on the supply side and, ultimately, raising consumers' adoption of broadband services in unprofitable "white"[59] areas, where the total societal benefits of fibre-based broadband networks are not fully reflected in customers' WTP. The vast majority of national broadband plans in developed countries target the deployment of broadband in rural (white) areas (OECD, 2018).

Although distributional concerns regarding depopulation and the digital divide are important considerations, the main justification for public intervention is the substantial positive externalities expected to accrue in major economic sectors. A mismatch between private and social benefits might also arise where consumers cannot properly value the true benefits of new broadband services, which are experience goods. Given the existence of externalities and broadband providers' low incentives to supply rural areas (high average costs per household and low revenues), public initiatives and financial aid (including subsidies) should be considered to drive broadband development, particularly in countries with relatively large rural populations.

State aid is, however, subject to comprehensive legal constraints in most jurisdictions. The European Union has established detailed guidelines on the public funding of (first-generation and next-generation) broadband infrastructure: specific state aid rules were adopted in 2009, revised in 2013 and are expected to be modified again shortly. In principle, state aid can only be granted to promote general economic development in case of market failure. Broadband-specific rules particularly caution against crowding out

[58] With support of NoonVentures.
[59] A white area is an area where no Very High Capacity Network (VHCN) infrastructure exists.

private investment or overcompensating funded network operators. Consequently, state aid in "grey" areas — where monopolistic infrastructure exists or is foreseeable — is permissible only in exceptional cases; in "black" areas, where more than one (next-generation) broadband infrastructure already exists or is foreseeable, state aid is strictly prohibited.

13.3 Estimating the benefits

The baseline approach to calculate the economic benefits of VHC network deployment follows the specifications of Koutroumpis (2009) and Czernich et al. (2011). The national aggregate economic output (*GDP*) is related to input factors, specifically *Capital, Labour*, and *Education*. Moreover, *GDP* is affected by investment in (old) *Basic broadband* and (new) *VHC* broadband infrastructures, together with the related adoption of fibre-based broadband services. The starting point of our empirical analysis is the national production function for country i (i = 1, …, N) in period t (t = 1, …, T). It reads as follows:

$$GDP_{it} = A_{it}F\left(Capital_{it}; Labour_{it}; Education_{it}; Basic\ Broadband_{it}; VHC^{j}_{it}; 3G^{+}_{it}\right) \quad (1)$$

where A_{it} represents the total factor productivity given the levels of *Capital*, *Labour, Education* and (wireline and wireless) broadband. It is considered here as the part of economic growth attributable to unobservable variables affecting overall efficiency. The superscript j denotes the level of VHC coverage and adoption, while *3G+* represents the coverage of mobile broadband based on 3G or a higher standard. Equation (1) assumes that the production function has the same functional form in each country and is separable in A_{it}. Controlling for human skills (*Education*) accounts for important externalities among input factors in terms of broadband-enabled knowledge spillovers from highly skilled individuals.

Most ICT-related empirical specifications further assume a Cobb–Douglas-type production function (Cardona et al., 2013; Briglauer and Gugler, 2019), in which all input factors are weighted by their (constant but otherwise unconstrained)[60] output elasticities. Rewriting equation (1) yields:

$$GDP_{it} = A_{it}Capital_{it}^{\beta_1}Labour_{it}^{\beta_2}Education_{it}^{\beta_3}Basic\ Broadband_{it}^{\beta_4}VHC_{it}^{j,\beta_5}3G_{it}^{+,\beta_6} \quad (2)$$

where β_i (i = 1, …, 6) represents the output elasticities of *Capital*, *Labour*, *Education* (human capital) and different quality levels of broadband. Our empirical baseline for estimating the equation further includes period effects, θ_t, to capture any common macroeconomic shocks affecting all countries alike, as well as fixed effects, α_i, to capture any time-invariant heterogeneity at the country level. Fixed effects and year period effects have been shown to capture the largest part of investment and adoption decisions (Briglauer and Gugler, 2019).[61]

Expressing equation (2) in logarithmic form and adding a constant term, β_0, together with year period and country fixed effects yields our final estimating equation:

$$logGDP_{it} = \beta_0 + \beta_1 logCapital_{it} + \beta_2 logLabour_{it} + \beta_3 logEducation_{it} + \beta_4 logBasic\ Broadband_{it} + \beta_5^j logVHC_{it}^j + \beta_6 log3G_{it}^{+} + \alpha_i + \vartheta_t + \epsilon_{it} \quad (3)$$

where $\varepsilon_{it} = \eta_{it} + log(A_{it})$ and the additive error term, η_{it}, captures unobserved variations between countries and years. From the previous discussion, we expect $\beta_i > 0$ for all values of i and that $\beta_5^{VHC\ adoption} > \beta_5^{VHC\ coverage}$. Furthermore, if the European Commission's assumptions in its gigabit objectives are correct, we should also observe $\beta_5 > \beta_4$. To test whether the estimated coefficients of our *VHC* variables differ for rural and urban areas, we also include the interaction term *Rural*VHC* in some specifications of our regression analysis.

[60] In particular, we do not impose any assumptions on returns to scale.

[61] For the case of basic broadband deployment, Akerman et al. (2015, pp. 1796–1797) concluded as follows: "We find that 84% of the variation in broadband availability can be attributed to time-invariant municipality characteristics and common time effects, while 1% of the variation in broadband availability can be attributed to a large set of time-varying variables."

For the main explanatory variables, we source from the FTTH Council Europe database the annual numbers of deployed and adopted fibre-based broadband connections, broken down by technology, and thus quality, levels.

The following fiberisation scenarios can be distinguished (FTTH Council Europe, 2018; Briglauer et al., 2020). Digital subscriber line technologies (xDSL) rely on copper lines from local exchange to customer premises. Fibre to the cabinet (FTTC) involves the delivery of more advanced DSL-based access technologies, such as VDSL/VDSL2[62]: fibre extends to street cabinets, then copper lines cover the last (several hundred) metres from street cabinet to customer premises. Fibre to the distribution point (FTTDp), supported by VDSL/G.fast[63], is another recent hybrid broadband technology, reducing the distance of the remaining copper line to below 250 metres (FTTH Council Europe, 2018). Access network topologies based on FTTC and FTTDp currently provide data rates of up to several hundred Mbit/s. Hybrid broadband technologies can also rely on the coaxial cable infrastructure originally built and used for the unidirectional delivery of cable television.

Through the complementary DOCSIS 3.0 technology, data rates of up to 400 Mbit/s can currently be provided (Zhao et al., 2014). DOCSIS version 3.1 is expected to provide data rates of up to 10 Gbit/s in the near future. Further fiberisation requires the deployment of fibre even deeper into the local access network. Fibre-to-the-building network topologies require fibre-optic cables to be located close to or inside a building.

When copper lines are completely replaced inside a building, even in-house, full fiberisation is achieved. Termed fibre to the home (FTTH), this system is considered “future proof” as the capabilities of access technologies are no longer limited by fibre infrastructure (e.g. terminal equipment or network nodes like servers and routers) and the data transmission rates are almost unlimited (FTTH Council Europe, 2018, pp. 11–12; Timmers et al., 2018; Briglauer et al., 2020).

All fibre-to-the-x access technologies (including FTTC/FTTDp) can be referred to as NGB, enabling bandwidth levels of at least 100 Mbit/s. For the purpose of this modelling approach to calculate ERR, however, and as indicated by the European Commission’s gigabit strategy (2016), VHC networks are defined as comprising FTTH/B and FTTLA technologies only (excluding FTTC/FTTDP).

The results reported in Table 13-1 are based on robust standard errors for all the regression models.

Regarding the main production function variables, *Capital* and *Labour*, the sum of both coefficients is close to 1 in models (1)–(4), suggesting constant returns to scale. This appears reasonable at the macro level. *Education,* representing human capital, has a significantly positive coefficient in all regression models, as expected. Models (5)–(6) provide robustness checks with some control variables derived from the literature added to our baseline equation. The coefficients of the control variables *Long-term interest rate* and *Investment freedom* show the expected signs and significance.

The coefficients for *Basic broadband* are about 0.015 in models (1)–(4) and slightly lower in the robustness regressions (5)–(6). The main results suggest that **an increase of 1% in the adoption of basic broadband yields an increase of 0.015% in *GDP_pc***, which is broadly in line with previous related studies (Koutroumpis, 2009; Czernich et al., 2011; Briglauer and Gugler, 2019).

Compared with basic wireline broadband, the adoption of VHC broadband services has a significant but much smaller percentage impact on *GDP_pc* (ranging from 0.0032% to 0.0061% in regressions (1)–(6)). The impact of *VHC coverage* is lower than that of *VHC adoption* as the full benefit of broadband investments is realised only when broadband services are used. When simultaneously controlling for *VHC adoption* (model (4)), the impact of *VHC coverage* even becomes zero in statistical terms. The re-estimation of regressions (1)–(6) to test for geographic heterogeneity is not significant. Finally, mobile (wireless)

[62] Very High Speed Digital Subscriber Line (1st and 2nd generation)

[63] G.fast is a digital subscriber line (DSL) protocol standard for local loops shorter than 500 meters, with performance targets between 100 Mbit/s and 1 Gbit/s, depending on loop length.

broadband coverage with 3G or a higher network standard exerts a significantly positive impact on *GDP_pc*: **a 1 percentage point increase in *3G+* coverage increases *GDP_pc* by about 0.0015%.**

Table 13-1: Results of two-way fixed-effects regressions (dependent variable: log (*GDP_pc*))

Regr. model no.	(1) Basic	(2) VHC Adoption	(3) VHC Coverage	(4) VHC	(5) VHC Controls	(6) VHC Controls
Production function vars.						
Log (Capital)	0.3229***	0.3219***	0.3217***	0.3228***	0.2476***	0.2462***
	(6.65)	(6.91)	(6.66)	(7.52)	(4.10)	(3.88)
Log (Labour)	0.6594***	0.6160***	0.6242***	0.6349***	0.4523***	0.4413***
	(3.82)	(3.69)	(3.64)	(3.72)	(2.95)	(3.05)
Log (Education)	0.1986***	0.1833***	0.1862***	0.1900***	0.2049***	0.2006***
	(5.00)	(5.25)	(4.95)	(5.43)	(4.57)	(4.38)
Log (Basic broadband)	0.0151***	0.0150***	0.0150***	0.0151***	0.0129***	0.0129***
	(4.55)	(4.40)	(4.40)	(4.97)	(4.44)	(4.40)
Log (VHC adoption)		0.0035**		0.0061*	0.0032*	
		(2.33)		(1.91)	(1.84)	
Log (VHC coverage)			0.0020	-0.0030		0.0025**
			(1.63)	(-0.94)		(2.22)
3G+	0.0014***	0.0015***	0.0014***	0.0015***	0.0016***	0.0016***
	(4.47)	(5.10)	(4.89)	(5.19)	(4.88)	(4.74)
Control vars.						
Long-term interest rate					-0.0117***	-0.0119***
					(-3.54)	(-3.44)
Investment freedom					0.0034***	0.0033**
					(3.25)	(2.93)
Internet users					0.0003	0.0004
					(0.57)	(0.77)
Age (< 15 and > 65)					-0.0015	-0.0017
					(-0.28)	(-0.34)
Period and fixed effects	YES	YES	YES	YES	YES	YES
Constant	5.8602***	6.0476***	6.0241***	5.9480***	7.0474***	6.7492***
	(6.55)	(7.06)	(6.85)	(6.96)	(7.82)	(7.85)
F	297.071	2344.092	734.572	1089.769	321119.047	386645.437
R^2 (within)	0.903	0.904	0.903	0.904	0.918	0.916
#Countries	24	24	24	24	24	24
#Observations	384	384	384	384	374	374

Notes: #Countries as depicted in Figures 1 and 2 above. All the regression models ((1)–(6)) include year period- and country-specific fixed effects for the period of analysis (2003–2018). The t statistics in parentheses are robust. The error structure is assumed to be heteroskedastic, autocorrelated up to lag 2 and possibly correlated between the groups (panels). * *p < 0.10,* ** *p < 0.05,* *** *p < 0.01.*

The estimated parameters above are used in a spreadsheet model to calculate the potential economic effects of a VHC network investment, to be considered in the economic CBA. The translation of (gross) GDP magnitudes into CBA must respect the logic of (net) opportunity cost and of CBA producing general equilibrium results in the absence of distortions.[64] The calculated ERR can be compared with the FRR to determine the broader economic and social externalities of the project.

The magnitude of the economic effects of investment in basic and VHC broadband is derived from empirical estimates in related studies and estimates.

Table 13-2 presents the key elasticities used in the current version of the spreadsheet model.

Table 13-2: Key elasticities used in the spreadsheet model

Elasticity of	Value	Interpretation
GDP with respect to VHC adoption	*0.0048*	An increase in VHC adoption of 1% leads to a GDP increase of 0.0048%
GDP with respect to FTTC adoption (incumbent operators)	*0.0012*	An increase in FTTC adoption of 1% leads to a GDP increase of 0.0012%
GDP with respect to employment	*0.66*	An increase in employment of 1% leads to a GDP increase of 0.66%
Employment with respect to NGB availability/adoption (rural areas)	*0.149*	An increase in NGB household penetration of 1% leads to a rural employment increase of 0.149%
Employment with respect to NGB availability/adoption (high-skilled employment)	*0.0098*	An increase in NGB household penetration of 1% leads to an increase in high-skilled employment of 0.0098%

[64] See Just, R, Hueth, D. and Schmitz, A. 2004. The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation.

14. Value of time in transport

Diego Ferrer

14.1 Introduction

The economic appraisal of transport projects is conducted through CBA. A common main benefit is shorter travel times for goods and passengers. Travel-time savings are measured in minutes or hours, which need to be monetised. In this context, VOT is a crucial CBA input parameter to derive the monetary expression of travel-time savings.

Since the 1990s the Bank has introduced several initiatives to define and update guidelines for consistently calculating VOT. In 1996 the EIB chose a simple methodology based on average gross wages.[65] The basis was changed to GDP per capita in 2004, when the Bank also extended the analysis to more countries and transport modes.[66] In 2013 a comprehensive meta-analysis was undertaken on numerous VOT studies from across the European Union and other relevant countries.[67] The Bank is about to begin a new initiative to update the VOT data set.

14.2 Basic theoretical considerations

The VOT concept is based on economic theory. Numerous travel-demand studies have been carried out over recent decades, many producing estimates of VOT. These studies include a rich body of largely unpublished evidence, providing valuable insights into the impact of variables such as GDP per capita, transport mode, journey purpose and travel distance on VOT. Most studies concentrate on in-vehicle travel time, but other relevant time parameters such as waiting and walking time are also covered.

VOT denotes the exchange rate at which a traveller is indifferent to marginal changes in the time and cost of travel. It is, therefore, an output of the traveller's decision-making process, not an input thereto.

In many countries, VOT has been derived using ad hoc procedures. A commonly used methodology employs percentages of the gross wage rate as the value of travel time for business and other purposes. This is sometimes called the "resource value" method. The relationship between VOT and the wage rate is based on microeconomic theory (derived from the microeconomic models for the goods–leisure trade-off and household production). In 1996 the EIB chose the average gross wage rate in a country as the VOT for business travel, 35% of that average as the VOT for commuting, and 25% as the VOT for leisure. Real wage growth projections were used to increase the VOT over time, while adjustment factors were used for different transport modes. This approach was employed until 2003.

Research has shown that many factors other than gross wage rates can affect VOT. The most recent studies have been trying to infer VOT from models of consumer behaviour, acknowledging that VOT is the outcome of a consumer-decision process. In many situations, consumers face a trade-off between time and money. These situations can be described by models, with common examples including mode choice models, route choice models or alternative choice models (different travel time and cost for the same mode and route). Data used in model estimation can be classified as revealed preference (RP) data (actual choice data) or stated preference (SP) data (choices stated by passengers in research interviews).

It is generally recognised that the best approach to estimating VOT is to conduct specific empirical research among travellers in the focal country. The preferred method is often to interview individuals using SP methods and then estimate discrete choice models using the collected data. VOT can then be derived as the ratio of travel time to travel cost. Research has shown that these methods yield similar results to RP methods using observed choices of travellers but with smaller variance (greater precision).

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[65] EIB Internal, Pierre Vilain (1996), *Harmonising Parameter Values in Transport Project Appraisal: the Values of Time and Safety*.

[66] RAND Europe and CD Delft (2004), *Value of time and Safety Guidelines for Transport Projects*. Unpublished.

[67] LEEDS University, Mark Wardman (2013), *European Wide Meta-Analysis of Values of Travel Time*. Unpublished.

14.3 The EIB value of time data set

14.3.1 The 2004 RAND Europe study

In 2004 the EIB commissioned a study to update its VOT methodology and data set for different transport modes and countries in and outside the European Union. The research started with a literature review, followed by estimating regression equations explaining VOT by mode and travel purpose in a specific country from economic and demographic characteristics. In all regressions, the wage rate was outperformed by other economic variables, notably GDP per capita. The 2004 RAND data set includes VOT values for the four main modes of transport (car, train, bus and airplane) and three main trip purposes (commuting, business and leisure).

The regressions were largely based on behavioural values, as these are reported much more in the literature than resource values The recommended VOT values were generated by applying the regression models that better explained independent variables, such as GDP per capita (2002), for 33 countries.

The values for car, train and bus travel did not distinguish between urban and interurban journeys, since there was insufficient information in the literature to make this distinction. As no values were available for maritime transport of passengers, the value of the mode used by travellers up to boarding and after disembarking (car, bus, train) was used for ferry travel. For walk-on ferry passengers, the VOT for bus travel was used.

14.3.2 The 2013 Leeds University meta-analysis

The 2004 VOT data set and methodology were considered to satisfactorily reflect good practice. Nonetheless, in 2013 the EIB decided to carry out a VOT meta-analysis to identify areas for improvement. This study of studies was among the most comprehensive VOT reviews undertaken at the time. Some 3 100 monetary values of passenger travel time were collected from 389 studies and 26 European countries. The meta-analysis included in-vehicle time valuations but also valuations of walking, waiting, headway, congestion, free flow, late arrival, departure time shift, search time and other transport-relevant time parameters.

Exploratory analysis of data sets gave interesting insights into methodological trends in travel-demand modelling. Each valuation exercise produced datapoints for variables included in a multivariate regression model to explain VOT elasticities relative to key variables.

This research shed more light on the estimated elasticity of VOT with respect to GDP per capita and other variables, notably through a meta-model equation. Headline results indicated a VOT elasticity of 0.70–0.85 relative to GDP per capita and 0.14–0.20 relative to trip distance. Other results concerned the ratio between walk and wait time and in-vehicle time, which had been commonly assumed to have a value of two. Other important results were the variations in VOT value by transport mode, travel purpose, attribute type, distance and context.

Compared to the RAND study, the Leeds study meta-model generally yielded lower valuations of VOT but with a larger spread by income and with the added feature of variations by distance.

14.4 The EIB's VOT modus operandi

In CBA of transport projects, the Bank's models use different algorithms to calculate the total time savings from traffic absorbed or induced by the project relative to the reference WOP scenario. The resulting overall time savings are monetised using the best available VOT values for the country and specific context of the project under evaluation.

The 2004 RAND methodology and VOT data set remain the key reference in the Bank's economic appraisal of transport projects. Nonetheless, the 2013 Leeds meta-analysis results are considered more adequate for some project categories, particularly for interurban road operations.

The VOT values need to be adjusted for inflation and changes in GDP per capita. By default, VOT real growth rates are generally set to null, but the analyst may change these rates depending on project specifics and available data. VOT values correspond to in-vehicle time. Some CBA models offer the possibility to define access/egress times, for which the same VOT values are used as a simplified approach. In general, CBA models include several vehicle types, so the average occupancy rates need to be included in the algorithm.

The Bank's VOT data set is particularly useful to ensure consistency and as a point of comparison relative to values endorsed by national authorities. In all cases, the appraisal team assesses the quality of available VOT data sources and considers sensitivity testing where applicable.

15. Value of transport safety

Diego Ferrer

15.1 Introduction

For changes in transport safety resulting from an intervention (project), the benefits and costs can be calculated by attaching a monetary value to fatal and non-fatal accidents, provided information is available on traffic volumes and accident probabilities.

Since the 1990s the Bank has introduced several initiatives to define and update guidelines on valuing time, safety and other key factors in transport project appraisals. A PJ paper in 1996 defined the value of safety approach subsequently used by the EIB for several years.[68] In 2003 the Bank initiated an update study, performed by RAND Europe and CE Delft and finalised in October 2004. This study has formed the basis of the Bank's valuation of safety to date.[69] In 2012 the Bank conducted a meta-study that led to a relatively minor update to the safety data set and methodology.

15.2 Basic theoretical considerations

Since 2004 the EIB has valued safety based on the WTP approach, which assesses people's WTP for risk reduction. The results of the WTP method can be translated into the value of a statistical life (VOSL), for use in CBA.

The VOSL is complemented by the costs of net lost production,[70] emergency services and medicine — none of which are captured by individual perceptions — to obtain the full value of safety.

15.3 The EIB approach to value of safety

The approach adopted in the RAND/CE Delft study and applied since 2004 by the EIB is that proposed in the EU research project "UNITE – Unification of accounts and marginal costs for Transport Efficiency, (several deliverables 2000–2003)."

At the European level, the most recent recommendations for valuing road safety were reported in the EU research project "HEATCO – Developing harmonised European approaches for transport costing and project assessment" (2006). The HEATCO study adopted the values of safety developed in the UNITE study. Hence, when they were devised, the EIB value of safety data set and methodology were considered state of the art and reflective of good practice.

Inputs for calculating the value of safety for roads are:

- Vehicle-kilometres per year with and without the proposed project;
- Accident rates per million vehicle-kilometres, using either actual project-specific values or, in their absence, standardised road-type specific accident rates;
- Average numbers of light injuries, serious injuries and fatalities per accident;
- Country-specific monetary value per light injury, serious injury and fatality occurring;
- Formulae to update the 2003 values of safety to base-year values.

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[68] Pierre Vilain (1996) *Harmonising Parameter Values in Transport Project Appraisal: the Values of Time and Safety*. Internal PJ Paper.

[69] RAND Europe and CD Delft (2004), De Jong et al., *Value of time and Safety Guidelines for Transport Projects*. Unpublished.

[70] Net lost production is the production minus the consumption. Using gross production would cause double counting, since lost consumption is assumed to be part of the WTP.

Using the above inputs, values of safety in the WOP and WP cases are computed. Project roads will typically have better safety features and, thus, lower accident rates than existing infrastructures, therefore yielding a safety benefit.

Evaluating safety for non-road projects follows the same considerations. However, accident risks and rates are far lower for air and rail than for road, so default safety impact values per passenger-kilometre are applied, which can be overridden in the appraisal. The analyst specifies factors for actualising the input data to the base year for monetary values and future growth rates.[71] The safety-benefit calculation uses the numbers of passenger-kilometres by mode and year and calculates the safety-related savings between the WOP and WP scenarios.

15.4 The 2012 De Jong meta-study

In 2012 the EIB performed a meta-study under direction from CE Delft expert Gerard De Jong.[72] An updated set of safety values were proposed based on a meta-analysis of 27 VOSL studies from across the world.

The updated average fatality values for EU countries were similar to those in the 2004 study data set. However, somewhat higher values were obtained for countries with higher GDP/capita, while somewhat lower values were found for countries with lower per capita income. These differences were attributable to two factors. First, income elasticity was found to be 1.2, and thus higher than the value assumed in 2004 (which was 1.0). Second, the larger spread was due to using market exchange rates, rather than purchasing power parity (PPP) values (as in 2004), to calculate GDP per capita.

As in the 2004 study, the recommended values for severe and slight injuries were calculated as a fraction of the value for fatalities. Monetary values for material damage were also proposed. In order to get the value of safety for future years, the recommended method was to use the consumer price indices for the EU to correct for inflation (from Eurostat HICP or from the World Bank).

For non-EU countries, the study provided a set of equations as follows:

$$\text{Value of fatality} = 0.9 \times 8.314 \times (\text{GDP per capita})^{1.215}$$

$$\text{Value of serious injury} = 0.13 \times \text{Value of fatality}$$

$$\text{Value of slight injury} = 0.01 \times \text{Value of fatality}$$

$$\text{Value of material damage only} = 0.004 \times \text{Value of fatality}$$

Finally, the study confirmed that the German guidelines for federal infrastructure were a valid source for accident rates when combined with country-specific correction factors based on relative fatality rates.

The De Jong meta-study resulted in a marginal change in the EIB's data set and approach.

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[71] Actualisation factors take into account realised and forecast development of per capita GDP and purchasing power in a country.

[72] Significance Research (2012), De Jong et al., Update of the Value of Safety methodology and dataset.

15.5 The iRAP approach

More recently, other VOSL sources have become available, notably from the international organisation iRAP (irap.org). While the scientific background of the adopted values is unclear, they seem to be credible for developing countries. The Bank has been using these values in sensitivity analyses, comparing against the EIB data set from RAND/De Jong.

Under the iRAP methodology, the costs are as follows:

- Fatality: GDP per capita x 70
- Serious injury: GDP per capita x 17.5
- Slight injury: GDP per capita x 0.7
- Material damage: GDP per capita x 0.14.

15.6 The way forward

The EIB will soon conduct a new study to update the VOSL data set and methodology. The idea is to collect and analyse the latest research on this topic. In addition to initiatives such as iRAP, the Bank notes the publication of the *2019 Handbook of external costs of transport* by CE Delft, INFRAS, TRT and Ricardo, providing the VOSL in 2016 euros. The Bank also notes the research of Viscusi and Masterman (2017),[73] providing the VOSL in 2015 US dollars. On an experimental basis, the EIB is currently considering these two recent data sets in the sensitivity analyses of road project CBAs.

[73] Viscusi, W.K. and Masterman, C.J. (2017), Income elasticities and global values of statistical life. *Journal of Benefit-Cost Analysis,* 8(2), 226–250.

16. Road vehicle operating costs

Pierre-Etienne Bouchaud

Besides time savings, another main effect of road projects is the reduction of VOCs. This outcome is especially prominent in developing countries, owing to a combination of two factors: (i) roads are usually less maintained and so in a poorer condition relative to those in developed countries; and (ii) VOT is lower, making time savings a secondary benefit.

Operating cost relationships for road vehicles are relatively generic and similar between countries. Consequently, there are numerous off-the-shelf models and computer software packages for calculating road VOCs. These models usually integrate a wide range of default data, though they must also be populated with local data. The main components of VOCs and their relative contributions are presented in Table 16-1.

Table 16-1: Vehicle operating cost components and their relative contributions

	Percentage contribution	
Component	Private cars	Trucks
Fuel	10–35	10–30
Lubricating oil	< 2	< 2
Spare parts	10–40	10–30
Maintenance (labour)	< 6	< 8
Tyres	5–10	5–15
Depreciation	15–40	10–40
Crew costs	0	5–50
Other costs & overheads	10–15	5–20

Source: DFID (1988). A guide to road project appraisal. Overseas Road Note 5.

VOCs are all distance-dependent. However, some VOCs vary linearly with distance travelled (e.g. fuel, lubricant and tyre costs) while others vary by step (e.g. vehicle purchase, maintenance schedule and insurance costs). All VOCs vary by vehicle type, road surface type and condition, road geometry and vehicle speed. Accordingly, VOCs are correlated with the project area characteristics (climate, culture, etc.), proposed design standard (e.g. bitumen, concrete or gravel surface), road maintenance strategy, traffic flow composition and road congestion level.

Among the many types of computer software that estimate VOC savings, HDM-4 is probably the most widely used. It models the relationships over time between vehicle operation and road deterioration as part of evaluating the VOC impact of road infrastructure investments. This software can, therefore, be used to illustrate the needs in terms of inputs.

HDM-4 requires input data to be defined for the following key modules, which all affect the project's impact on VOCs:

- **Vehicle fleet(s):** A number of vehicle types are identified to represent the vehicle fleet of the project area (various sizes of passenger cars, buses and trucks, as well as non-motorised vehicles if relevant). The following information is required for each identified vehicle category:
  - Basic vehicle characteristics (passenger car space equivalent, number of wheels, number of axles, kerb weight, etc.);
  - Vehicle utilisation (annual kilometres per year, average life, etc.);
  - Vehicle-related prices and costs (new vehicles, replacement tyres, fuel, etc.).
- **Road network(s):** The road sections defining the road network represent — the fundamental unit of analysis. The following parameters are instrumental in determining the project's VOC impact:
  - Speed flow types (to model the effects of traffic volumes on speeds, depending mostly on the number and width of lanes);
  - Traffic flow patterns (interurban, commuter, urban or seasonal traffic);
  - Climate zones (moisture and temperature classification);
  - Surface classes (bituminous, concrete or unsealed);
  - Pavement type and thickness (asphalt mix or surface treatment over granular, asphalt, or stabilised base);
  - Geometry (rise and fall, average horizontal curvature, design speed limit, altitude, and drain type);
  - Road condition (ride quality/roughness, surface distress and surface texture);
  - Traffic volumes (which impact on road deterioration);
  - Accident levels.
- **Type of Works Undertaken,** comprising:
  - Maintenance of the existing asset;
  - Improvement of the existing asset;
  - New construction / greenfield project (as relevant).

The basis for calculating VOCs is well-established within the model used by the Bank (Economic Road Infrastructure Appraisal Model, or ERIAM), which is based on HDM-4 outputs. The approach currently adopted in the ERIAM is based on speed-VOC curves sourced from German guidance.[74] VOCs in the WP and WOP scenarios are calculated using speed, gradient and road length variables, in combination with the relative proportions of gasoline and diesel cars.

Besides these parameters, the ERIAM user specifies the quality of the new and old roads. VOCs vary according to the baseline condition of the road, the change in quality of that road after project implementation, and the impact of the project on the overall kilometres travelled (if warranted). The ERIAM adjusts for fuel cost growth and fuel efficiency gains over time.

Once electric vehicles become more prevalent within vehicle fleets, this section should be updated to consider this new type of vehicles in the calculation of VOCs.

[74] Empfehlungen für Wirtschaftlichkeitsuntersuchungen an Straßen (EWS) by Forschungsgesellschaft für Straßen- und Verkehrswesen, 1997, vol. 132

17. Traffic categories in transport

J. Doramas Jorge-Calderón

17.1 Introduction

The main purposes of investing in transport infrastructure and operations include saving time (or time costs) for users, reducing operating costs, improving safety and reducing external costs. Also gaining prominence are factors such as comfort, reliability and punctuality, the last two being increasingly important for logistics chains. Together, these factors are the key components of the GC of transport. To the extent these costs are borne by transport users, the GC becomes the behavioural generalised cost (BGC). Any change in BGC arising from the project may elicit a user response,[75] such as switching travel route, time or mode, or adjusting travel frequency.

The user response depends on how the project changes the relative value offered by different available travel options. That value is measured by consumer surplus (change in non-monetised BGC), and constitutes a key determinant of a project's economic viability. Understanding how users respond to the project is, thus, integral to determining how much value it offers and central to measuring the economic viability of the investment.

While the types of user response are well understood, the literature is somewhat ambiguous on how to measure the value they imply. There is also some confusion over the terminology for different response types. These difficulties are explained by three main reasons. First, the importance of each type of user response varies across transport modes. For example, in passenger railway or fluvial freight projects, modal diversion from road constitutes a large proportion of expected traffic; in urban road or air transport projects, by contrast, diversion from alternative routings within the same mode tends to be more significant.[76] Second, any modelling requires restrictive assumptions, whose formulation depends on data availability and analyst judgment; their validity may vary across types of traffic. Finally, the literature on transport project appraisal has generally focused on land transport modes, particularly road and rail. The circumstances and assumptions applied to such modes are not always directly transferable to other transport modes, raising the need for additional analyst judgment.

This chapter describes how traffic response is measured in EIB investment appraisals. The chapter starts by addressing ambiguities in terminology in Section 17.2. It follows in Section 17.3 with a discussion on measuring benefits, focusing on consumer surplus, under alternative circamstances regarding capacity constraints. It ends with Section 17.4, briefly considering implications for producer surplus.

17.2 Types of traffic response

At a broad level, traffic types can be divided according to transport users' behavioural response to a project:

- Existing traffic, comprising journeys made by users with the existing transport mode or link, with and without the project. Such traffic may grow over the project lifetime if conditions support demand growth.
- Diverted traffic, consisting of users that switch route, mode or time of travel because of the project.
- Generated traffic, comprising new trips resulting from the project, either by people who did not travel at all before the project or by existing users travelling more often.

[75] Differences between BGC and GC may be accounted for by factors such as externalities and subsidies.
[76] In addition, regardless of the transport mode, the type of project concerned—whether it is opening a much improved route, entering into competition with an existing operator, or opening up access to a new destination—determines the importance of each type of user response.

Within and between academic research and practitioner studies, there is variation in the terms used and how behavioural responses are categorised. Besides the terminological inconsistency between authors, the nature of a project affects the extent to which transport demand should be aggregated in the appraisal., which has probably led to the current confused picture. Table 17-1 summarises, non-exhaustively, the frequent terminology and groupings used in both the literature and appraisal studies submitted to the EIB.

Two points should be noted. First, "deterred" and "generated" refer to the same traffic, either deterred by the absence of the project or generated by its presence. The EIB normally considers generated traffic. Second, the "time of travel change" category may be modelled as either diversion in the presence of capacity rationing or the time cost resulting from congestion. The EIB's models measure "time of travel change" in airport projects as diversion rather than congestion, since some types of airport projects, particularly adding runways to an existing airport, aim primarily at avoiding such diversion.

17.3 Consumer surplus across traffic categories

The measure of benefits yielded by a project for each traffic category may vary depending on project circumstances. Generally, there is no ambiguity regarding existing (or base) traffic and generated traffic (new trips). However, the treatment of diverted traffic, particularly when it involves diversion to other modes of transport, may depend on the extent to which the project aims to lower GC, whether it entails capacity expansion, or various other considerations. Common cases are reviewed in turn below.

17.3.1 Lowering generalised cost

Figure 17-1 (A) illustrates a hypothetical project aiming to lower the GC of travel between two destinations in the absence of capacity constraints. This could be achieved be adding bridges and tunnels to a road crossing a mountainous area, so that travel time and VOCs fall. The project causes the GC schedule to shift downwards from GC_1 to GC_2. It is unnecessary to consider the GC of alternative modes for the purposes of estimating traffic diversion from the road to the alternative mode, because there are no capacity constraints on the road — the WOP scenario consists of the road continuing to offer current travel conditions indefinitely. The analysis can, therefore, focus only on the demand curve faced by the road (assuming price equals marginal cost elsewhere in the economy), but bearing in mind that any generated traffic can consist of diversion form alternative modes to the road.

The project's benefit to existing traffic is measured by the area g_1adg_2. In addition, the project causes an increase in the number of trips on the road, from q_1 to q_2. This increase includes three traffic types: (i) current users travelling more often; (ii) previous non-users travelling because of the project; and (iii) previous users of alternative modes switching to the road. The benefit for all three categories combined is measured by the area *abd*, a component of the rule of a half.calculated as follows: (1/2)x(g_1−g_2)x(q_2−q_1). The total benefit for all traffic categories (existing trips plus new trips) consists of the area of trapezoid g_1abg_2, estimated by the rule of a half: (1/2)x(g_1−g_2)x(q_1+q_2).

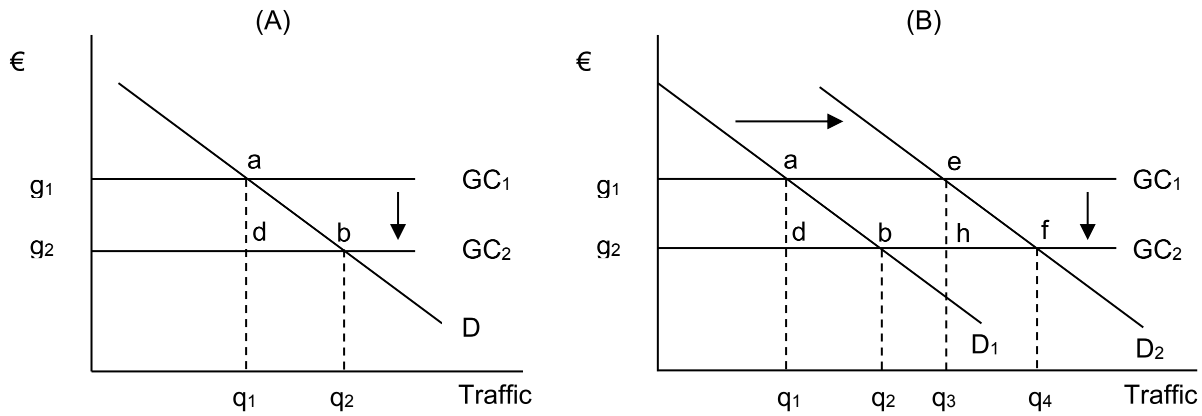
Table 17-1: Common terminology and groupings for traffic categories

<table>
<tr><td></td><td colspan="3">Project evaluation approach</td><td rowspan="3">Terminology at the EIB</td></tr>
<tr><td></td><td>Route or promoter demand</td><td>Mode demand</td><td>Transport system demand</td></tr>
<tr><td>Projects for which approach may apply (non-exclusively)</td><td>Toll road, railway line, airline, shipping line.</td><td>Road, urban rail, airport, seaport</td><td>Multimodal scheme</td></tr>
<tr><td colspan="5">Behavioural response</td></tr>
<tr><td>Same behaviour</td><td>Existing (or base) traffic</td><td>Existing (or base) traffic</td><td rowspan="4">Existing (or base) traffic</td><td>Existing traffic</td></tr>
<tr><td>Time of travel change</td><td>Diverted or reassigned traffic</td><td rowspan="3">Diverted traffic</td><td>Existing traffic (for airports only: diverted traffic, in lieu of congestion)</td></tr>
<tr><td>Route change</td><td rowspan="4">Induced traffic</td><td rowspan="2">Diverted traffic</td></tr>
<tr><td>Mode change</td></tr>
<tr><td>Additional trips by existing or diverted users</td><td rowspan="2">Induced, generated or deterred traffic</td><td rowspan="2">Induced, generated or deterred traffic</td><td rowspan="2">Generated traffic</td></tr>
<tr><td>New trips by users who did not travel previously</td></tr>
</table>

Source: adapted from World Bank. (2005). *Treatment of induced traffic.* Transport Note TRN-11. Washington, DC: World Bank.

If demand does not grow over the project lifetime, the amount of yearly benefits generated by the project will be the same every year, as measured in Figure 17-1 (A). If demand grows, however, the benefits will increase every year, as depicted in Figure 17-1 (B). Since there are no capacity constraints either with or without the project, existing (or base) traffic is accommodated either way. The benefit to existing traffic in period 2 is measured by the area g_1ehg_2, which is greater than the benefit with less demand (g_1adg_2). Benefits to generated and diverted traffic would be equal to the area *efh*, assuming VOT remains constant in real terms over time.

Figure 17-1: Illustrative project aimed at improving generalised cost of travel with no capacity constraint



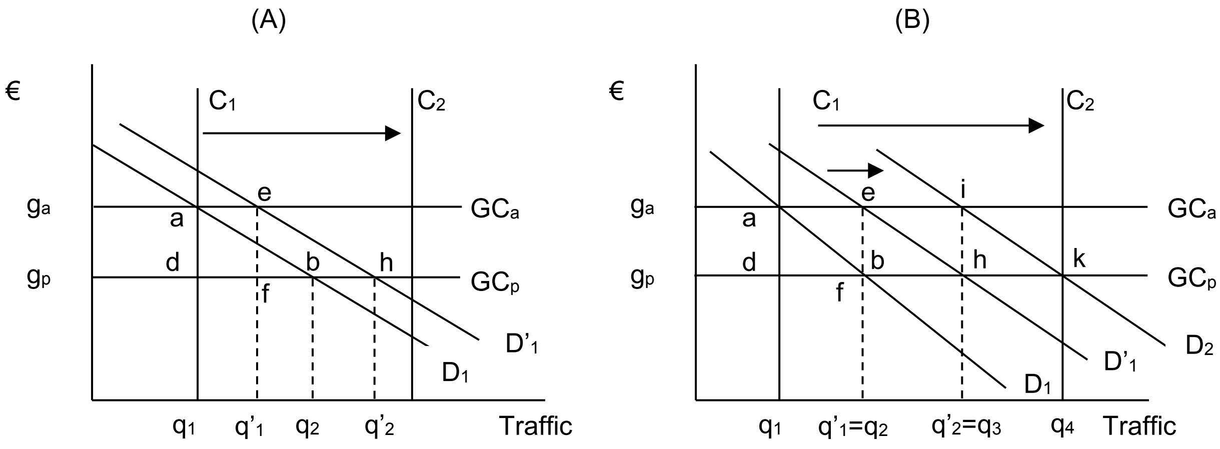
17.3.2 Capacity expansion

Figure 17-2 illustrates an alternative hypothetical project targeting an increase in capacity to alleviate a capacity constraint. This could take the form of widening from two lanes to four lanes a road currently operating at capacity. Assume that capacity is represented by the vertical lines C_1 and C_2, respectively denoting the two-lane and four-lane road, and that speeds do not change with the project.

In Figure 17-2 (A), schedule GC_p denotes the generalised cost of travelling via the road, which has capacity C_1, enabling traffic q_1. The project would cause capacity to shift rightwards from C_1 to C_2, enabling a greater amount of traffic at the same generalised cost. Because capacity is constrained, the analysis must assume what would happen in the WOP scenario if the project did not take place. In the current example, assume there is an alternative transport mode (rail) with a generalised cost of GC_a. The demand curve represents the segment of users for which both the project mode (road) is the preferred choice and the alternative mode (rail) is only accessible at an additional cost. Assuming demand does not grow and is at D_1, the project would generate traffic $q_2 - q_1$, creating a benefit measured by the area *abd*. Note that the project would not cause any traffic diversion from rail to road, since there is no decrease in generalised cost for road nor any capacity constraint for rail.[77]

If, instead, the demand curve in Figure 17-2 (A) is at D'_1 then traffic without the project would still be at q_1 (owing to the capacity constraint), while the project would cause traffic to grow to q'_2. There would also be an inter-modal diversion of traffic (from rail to road, equal to $q'_1 - q_1$), and newly generated traffic ($q'_2 - q'_1$). The inter-modal diversion consists entirely of users preferring road but forced by the capacity constraint to divert to rail: the project would cause these users to divert *back* from rail to road. Accordingly, dividing diverted traffic by two (under the rule of a half) would underestimate the benefits to these users. Diverted traffic entirely comprises users who would have used the road had capacity been sufficient, so diverted traffic is treated like existing traffic for calculating the change in consumer surplus. For this purpose, it is necessary to treat all diverted traffic as a homogeneous group, sharing an equal (perhaps average) access/egress time, operating cost saving, and comfort improvement, in addition to the normally assumed average VOT.

Figure 17-2: Illustrative project aimed at increasing travel capacity with no generalised cost improvement



[77] The alternative mode (rail) would have its own demand curve, which is not shown in the graph. If, instead, the shown demand curve represented the entire road and rail market, no-one would travel by rail in the absence of capacity constraints on the road, since the GC of rail (GCa) in the figure is drawn to be higher than that of road (GCp) for all users. Users for whom rail is the preferred choice would not contemplate changing modes to road as a result of the project, since the relative GC between the modes at no point becomes more favourable to the road relative to the situation before capacity constraints (g_a-g_p). All those who switch from rail to road as a result of the project are passengers for whom road was the preferred choice in the first place but who were forced to take the less-preferred alternative (rail) because of the lack of road capacity.

If the analysis looked only at the observed demand for road travel, the project's demand curve would be a notional line linking points *a* and *h* in Figure 17-2 (A). However, dividing by two the welfare gain from the corresponding traffic increase (q'_2−q_1) would underestimate the GC savings (reservation price) of users otherwise forced to divert to rail.

If demand does not grow throughout the project lifetime, benefits will be generated each year as depicted in Figure 17-2 (A). However, if demand grows then the situation in future period 2 will be as shown in Figure 17-2 (B), which adds a new demand schedule D_2, representing a higher level of demand in period 2. Assuming the initial demand is as denoted by D'_1, demand growth would result in higher diverted traffic from rail (q_3−q_1) than would have been the case with no demand growth (q'_1−q_1); as before, the welfare gain to these diverted users is not divided by two.

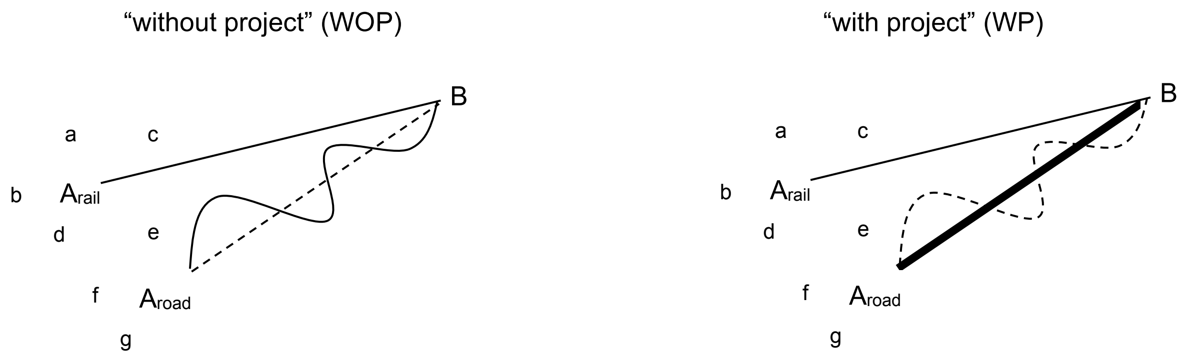
Note the contrast between the conclusions in this section and the preceding section. In Section 17.3.1, depicting a project that does not address a limit to capacity, the gains from lowering GC to diverted traffic are divided by two. While in the current section, depicting a project addressing a capacity constraint by increasing capacity, such gains to diverted traffic are not divided by two.

17.3.3 Traffic diversion with no capacity constraint

The current section adds some additional illustrative detail to the case discussed in section 17.3.1, merely for clarity. Beforehand, however, it is worth mentioning for completeness the possibility that in the situation depicted in Figure 17-1, there may simply not be any diverted traffic at all. All traffic gained by lowering GC would then consist of generated traffic. This would be the case where there is no alternative mode of transport. However, such a situation would not change the conclusions of the analysis: for any new traffic resulting from lowering GC, the improvement in GC is divided by two

Returning to the situation in Figure 17-1 as otiginally presented, where there is an alternative mode of transport, the situation could be depicted as in Figure 17-3, showing the railway and road links between A and B, along with the locations of people travelling from A to B. Travellers are based at differing distances from the beginning of the interurban road and from the rail station; therefore, their GC of access differs. Starting with the WOP scenario on the left, passengers a, b, c, d and e, travel by rail, whereas travellers f and g travel by road. In the WP scenario on the right, the tunnels and bridges built by the project make road travel faster, lowering the associated GC (as seen in Figure 17-1). Passengers f and g continue travelling by road and enjoy an equal fall in GC from the project (assuming they have equal VOT). In addition, traveller e (only marginally favouring rail before the project) switches from rail to road and benefits from a large fall in GC. Passenger d also decides to switch, though the reduction in GC is less than for passenger e, because of passenger d's higher cost to access (longer distance from) A. Even passenger b may switch to road, even though the resulting fall in GC is marginal. Diverted passenger e has a higher gain from the project than passenger d, who in turn has a higher gain than passenger d. This illustrates graphically why consumer surpluses for such diverted traffic are estimated by dividing the gain in GC by two.

Figure 17-3: Diverted traffic with different generalised cost savings



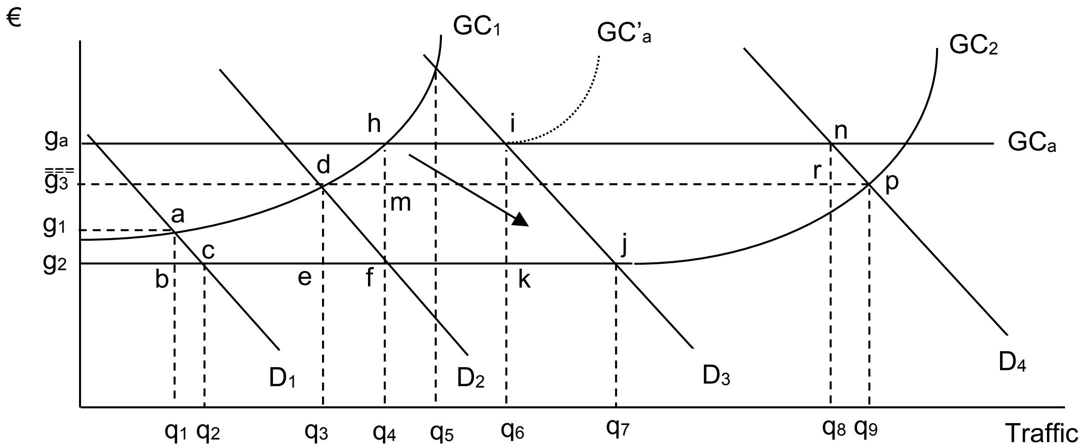
Note that it would not be correct to argue that the longer the A–B section of the trip, relative to the access/egress section, the lesser the error of not dividing the GC improvement to diverted traffic by two. Longer A-B routes may simply widen the catchment area from which observed traffic originates.[78] Also, note that Figure 17-3 would reflect poorly a situation with capacity constraints, as the preferred travel option for any given traveller may not be available due to lack of capacity.

17.3.4 Capacity expansion and lowering generalised cost

In reality, projects may combine both lowering GC and increasing capacity, while the relative prevalence of these two effects would possibly change over the project lifetime. Figure 17-4 introduces such a situation. The depicted project improves the GC and expands capacity, represented by the shift from GC_1 to GC_2., which combuines a shift downwards (improving GC) and rightwards (increasing capacity). The supply (i.e. GC) schedules curve upwards, depicting conditions of growing congestion as traffic increases for a given amount of capacity. Schedule D_1 represents demand conditions during the first year of project operation. Traffic with the project (q_2) is higher than it would have been without the project (q_1). For existing or base traffic (users travelling with and without the project), the gain in consumer surplus is measured by the area g_1abg_2, representing lower GC from improved facilities and lower congestion costs. The unit cost of congestion is measured along the horizontal axis by the difference between g_1 and the interception of the GC_1 curve with the vertical axis. The welfare gain to both diverted and generated traffic is measured by the area *acb*, calculated through the rule of a half by dividing by two.

[78] For urban travel, the access and egress section may be done walking (implying short distance), for inter-urban travel. access and egress may be done through another road (park and ride facilities, driving to the rail station, etc.); for continental trips, the access-egress section may involve hours of travel (short haul rail connecting to overnight rail) and for intercontinental trips, it may involve international travel (flying from Naples to London to connect to Shanghai).

Figure 17-4: Illustrative project that improves generalised cost and eases a capacity constraint



As demand grows to D_2, the situation is similar but with larger magnitudes. Traffic (q_4) is higher than would have been the case without the project (q_3). The benefit to existing users is represented by the area g_3deg_2, while the benefits to diverted and generated traffic are measured by the area *dfe*. The welfare gain to all diverted traffic is divided by two.

When demand grows to D_3, traffic will be q_7 with the project and q_4 without it. Without the project, some traffic that would have normally travelled by the promoter's mode will have switched to the alternative mode (q_6−q_4). The gain to such diverted traffic from the project is measured by the area *hikf,* and would not be divided by two. Division by two would be applied only to traffic q_7−q_6, comprising generated traffic and possibly some additional diverted traffic from the alternative and third modes since the project has changed relative GC in the transport market.[79] Despite the substantial difference in traffic with and without the project (q_7−q_4), which is all diverted or generated, it would be incorrect to divide by two the welfare gain to all that traffic: this would result in an estimated welfare gain of the area *hjf*, when the actual welfare gain is the area *hijf*.

By the time demand grows to D_4, congestion would already be present in the project, to the point of eliminating most of the gains from lowering GC. Existing or base traffic will have a welfare gain of g_ahmg_3. Most of the traffic difference with and without the project (q_9−q_4) is attributable to the increase in capacity. Diverted traffic (q_8−q_4) is valued as existing traffic, accounting for a welfare gain of area *hnrm*, which is not divided by two. Division by two is applied only to traffic q_9−q_8, comprising generated traffic and possibly diverted traffic from other modes.

17.3.5 Definition of counterfactual

The analysis in Section 17.3.4 assumes that the alternative mode has no capacity constraint. If it did, the scenario would change. A capacity constraint on the alternative mode is denoted by the dotted schedule GC'_a in Figure 17-4: after point *i* the mode would start experiencing congestion, trending exponentially towards full capacity. Lack of alternative capacity would mean the project brings much greater benefits than initially estimated: there would be added diversion from the alternative mode to the project mode because of relative GC change in the transport market. Alternatively, it could be assumed that sufficient investment will be made to expand the capacity of the alternative mode with or without the project. Clearly, the counterfactual can determine the viability of a project and should reflect the policy context within which the project operates.

[79] That is, diversion includes traffic *back from* the alternative mode, and may also include diversion *from* the alternative mode, as well as from a third mode.

17.3.6 The EIB's treatment of diverted traffic

As illustrated above, whether a change in BGC for diverted traffic should be divided by two depends on project circumstances. These include whether capacity increases, the potential degree of congestion as the infrastructure approaches full capacity, and the availability of alternative modes to accommodate traffic for which the project mode lacks capacity in the WOP scenario. Moreover, the extent to which such circumstances apply may change throughout the project lifetime. The key judgment to be made by the project analyst is whether diverted traffic is sufficiently homogeneous (as regards access/egress as well as other conditions.)

At one extreme, in capacity-expansion projects with constrained alternative capacity to accommodate diverted traffic, the appraisal would not divide the change in BGC for diverted traffic by two. At the opposite extreme, in capacity rehabilitation or ugrading projects with plenty of alternative capacity to accommodate diverted traffic, division by two would be applied.

17.4 Producer surplus and traffic categories

Economic appraisals address changes in societal welfare, whether affecting consumers, producers, or outsiders via externalities. Welfare changes for producers are measured through changes in producer surplus, or operating revenues minus operating costs (before depreciation). Changes in producer surplus for the project promoter must be made net of changes in the producer surplus for other modes experiencing traffic diversion due to the project. In addition, in measuring surplus changes, the analyst must recognise that changes in ticket prices constitute surplus (or welfare) transfers between the producer and existing (or base) traffic.

18. Risk-reduction analysis in the water sector

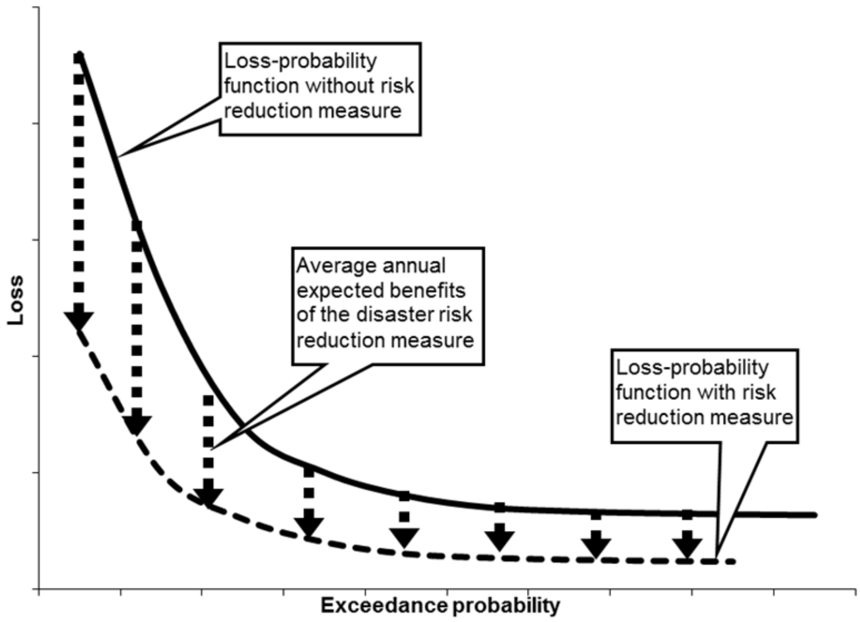
Thomas van Gilst

18.1 Introduction

Disaster prevention and post-disaster reconstruction operations follow probabilistic events, such as earthquakes, forest fires, floods, droughts, cyclones, tsunamis, landslides, volcanoes and industrial disasters. Usually such operations include a large number of urgent and less urgent projects that have to be prioritised based on available funds.

Most investments of this type generate no revenues but produce economic benefits by restoring economic activities and reducing risks and related damage (avoided cost). The approach to appraise these investments will be detailed based on flood-protection examples, which are among the most representative risk-reduction projects financed by the EIB.

Figure 18-1: Loss exceedance probability curve

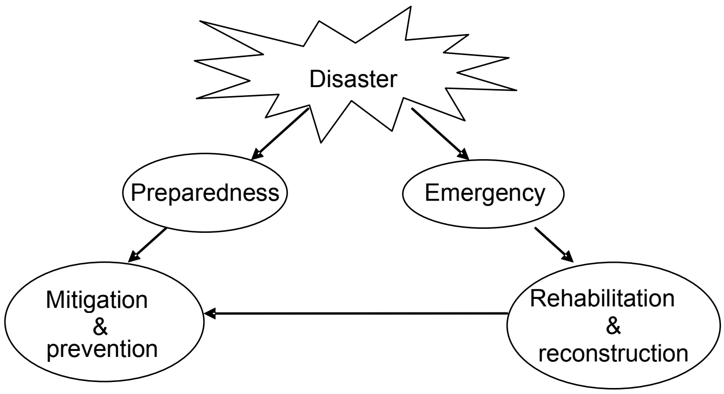


When assessing the economic efficiency of risk-reduction measures, the EIB's approach is typically based on the cost of average expected annual flood damage. This is given by the area under the loss-probability curve in Figure 18-1, which expresses losses as a function of exceedance probability: the higher the probability of annual peak flow exceeding a certain level (yearly small floods), the smaller the expected damage, and vice versa. The flow of incremental benefits (or avoided costs) expected from a measure is then given by the reduction in annual damage it is expected to generate: the analysis considers the difference between the areas under the loss-probability curve for the baseline option (upper curve) and the loss-probability curve for the "do-something" option (lower curve).

18.2 Disaster management

Before looking at a series of investment propositions, it is important to ascertain that a disaster management framework is in place. A proper disaster management process encompasses all aspects of planning for and responding to disasters, including pre-disaster (preparedness, mitigation and prevention) and post-disaster activities (emergency, rehabilitation and reconstruction). In scope, all measure are heavily interdependent. This extends even to non-physical measures such as public policies and plans, which can either modify the causes of disasters or mitigate their effects on people, property and infrastructure. With all key actions "informing" *mitigation and prevention* activities (see Figure 18-2), it is clear a disaster management framework helps ascertain the effectiveness of investments and their prioritisation. In the European Union, for example, the disaster management framework for flooding is set out legally under the Floods Directive 2007/60/EC.

Figure 18-2: Key actions should be geared to mitigation and prevention



18.3 The Floods Directive 2007/60/EC

The directive was enacted to reduce and manage the risks posed by floods to human health, the environment, cultural heritage and economic activity. It placed several key obligations on Member States:

1. Perform a preliminary assessment by 2011 to identify any river basins and coastal areas at risk of flooding;
2. For all such zones, draw up flood risk maps by 2013;
3. Establish flood risk management plans focused on prevention, protection and preparedness by 2015.

Flood risk analysis should combine (i) hydrological knowledge about the frequency of different types of flood events in an area, (ii) hydraulic modelling information about the inundation behaviour of flood water in its floodplains, and (iii) economic evaluation of flood damage linked to different types of flood events, such as snowmelt, high tides, and intense rainfall, and their joint probability.[80] The directive applies to inland waters and all coastal waters across the whole territory of the European Union.

Member Status were required to implement the directive in coordination with the Water Framework Directive, notably by coordinating flood risk management plans and river basin management plans, including public participation in their preparation.

This directive thus ensures that in all Member States and, increasingly, EU Candidate Countries, the river basin authorities are equipped to make informed decisions on how to prioritise actions, including investments. Beyond Europe, the EIB requires a similar approach to be taken.

[80] See for instance Messner, F. *et al*., 2006. *Guidelines for Socio-economic Flood Damage Evaluation*, FLOOD*site* Integrated Flood Risk Analysis and Management Methodologies, Report no.T9-06-01. Available at: www.floodsite.net

18.4 Cost–benefit analysis

The main benefit of flood risk management is the avoidance or reduction of damage or disruption from future floods — a "contingent liability" for the public authority. Measures with this as their main aim may also have secondary effects (e.g. ecological benefits and costs, or recreational opportunities), which should be considered in project appraisal. Quantifying benefits requires good knowledge and analysis of past floods, a system for modelling likely future floods, and a database of at-risk populations, properties and habitats.

Though the broad approach to carrying out CBA is well established, different methods can be used to assess costs and benefits. European countries vary in their practices for assessing the benefits of flood risk management. Different methods have particular strengths and weaknesses and are appropriate for different circumstances.

18.4.1 Estimating costs

Flood-related project costs are relatively straightforward to determine, and the approach is similar to that for other types of project. Some key principles applied are as follows:

1. Land: The cost of a project is the loss to the rest of society from using the resources for this purpose rather than something else. The opportunity cost of land is its value when put to its best alternative use. In a freely functioning, undistorted market, this is reflected in its market price. However, land is often treated in appraisals as though free to the project and useless for anything else, whereas in reality it always has an alternative use.
2. Sunk costs: Costs already incurred at the point of decision (e.g. by a partially built project) should be disregarded when making the decision, with only incremental costs factored in. If a project causes a loss of benefits, this too is a cost (e.g. building a reservoir which destroys farmland and habitats). Costs can be either tangible (e.g. wages) or intangible (e.g. loss of amenity, destruction of wildlife habitat). Techniques are available for estimating non-market values, whether costs or benefits: examples include WTP, defensive spending & avertive behaviour, hedonic pricing, travel cost, replacement cost and shadow projects.
3. Costs include internal costs (to the promoter) and external costs (borne by wider society). The private promoter would not normally factor externalities into the decision-making process,[81] but this is necessary for the public bodies usually involved in flood protection measures. Furthermore, certain financial costs should be excluded from CBA, such as taxes (generally), financial transfers and depreciation allowances.
4. There are two main types of contingency. Physical contingencies — assuming these are over and above the best possible estimate of the expected base cost — should be excluded from CBA. Moreover, price contingencies that merely aim to provide against general inflation should also be excluded as CBA is carried out in constant values.

18.4.2 Estimating benefits

The main stages involved in benefit appraisal are as follows:[82]

- Define the maximum extent of future flooding and decide on the *benefit area* for the assessment. This determines the area and populations at risk. For the environmental assessment this is important for defining the *benefits jurisdiction* — the population placing an economic value on the environmental effects concerned.
- Assemble hydrologic/hydrographic and hydraulic data defining the flood problem. Projections of future flooding based on historical data should account for climate change and its uncertainties. For instance, a 1-in-100-year flood event might become a 1-in-80-year occurrence.
- Collect data on land-use and other characteristics of the benefit area. Assessing benefits relies on detailed information about properties, infrastructure and residents' socioeconomic status.
- Assemble depth/damage data for properties in the benefit area. Relating damage costs to flood depth in previous floods allows standardised unit values to be produced for different kinds of properties. Some unit values can be downloaded from insurance company websites, though care should be taken not to inappropriately transfer costs to non-comparable situations.

[81] Unless the government *internalises* the externality by imposing a tax, or requiring polluters to clean up their processes, etc.
[82] As presented in the *Multicoloured Handbook*, by Penning-Rowsell, et al.

- Calculate the annual average flood damage expected to be avoided by the selected scheme options and the PV of this damage. This avoided damage represents the project benefits. There is still some variety among EU countries in the detailed approach to this process:[83] for example, some use replacement cost while others employ depreciated cost.

Once costs and benefits have been determined and reduced to a common price and time basis, comparison is possible. The main decision criteria between WP and WOP options include NPV, IRR, the B/C ratio and the least cost (of attaining a given objective). In some cases these criteria will give divergent rankings to alternative projects.

Notably, designing a loss exceedance probability function (as described above) is extremely laborious and difficult, while infrastructure measures are heavily affected by policy and other soft measures, and by human behaviour. Nonetheless, such a function provides for a good decision support system, particularly for ranking options.

18.5 Economic appraisal with limited available information

The above-described appraisal methods have potentially considerable data requirements, calling for resources, time and budgets that may be unrealistic in some circumstances. Alternative approaches may, therefore, be required, such as using standardised data sets and applying the method of benefit and avoided cost transfer.

- The use of *standardised data sets* and *computerised modelling* is growing. Past flood events are analysed for data on areas at risk and the damage associated with different degrees of flooding. These data can be integrated with current evidence of settlement, economic-activity distribution, etc., derived from internet-based *geowebs.* These geowebs are becoming increasingly powerful and versatile, and some leading geowebs are freely accessible.
- *Benefit and avoided cost transfer* is another method of economising on research and analytical resources. Evidence is selected from comparable situations elsewhere to indicate the size and nature of potential impact in the focal case. This approach is becoming increasingly popular for environmental–economic estimation.

Such approaches may appear less scientific, as they do not exhaustively enumerate all the building blocks, but using empirical evidence from observed floods is a valid way to investigate comparable situations. Whichever the approach followed, a preliminary analysis may indicate what the critical variables would be (if any), pointing to investigative areas where attention should be focused if resources are scarce or time constraints pressing.

[83] Meyer, Volker & Frank Messner: "National flood damage evaluation methods: a review of applied methods in England, the Netherlands, the Czech Republic and Germany." UFZ Discussion Papers, Leipzig. Nov 2005; Cihak, Frantisek, Ladislav Satrapa & Pavel Fosumpaur: "Methodology for the assessment of flood prevention measures to be included in the 2nd stage of Flood Prevention Project (2007-2010)" Czech Technical University in Prague. 2006.

Part 3:

Sector methods and cases

19. Education

Silvia Guallar Altar and Nihan Koseleci Blanchy

19.1 Introduction

The EIB has been financing education projects since 1997, following the adoption of the Amsterdam European Council Resolution on Growth and Employment. Between 2000 and 2020, the Bank's total lending to education was around €47 billion, mainly concentrated in EU Member States but increasingly focused on countries beyond Europe. EIB-financed projects cover all educational levels: pre-primary, primary, secondary and tertiary education; technical and vocational education and training; and cultural and adult learning. These investments are mostly directed at physical infrastructure and equipment, not staff salaries.

The impact of education infrastructure on learning outcomes has been widely debated.[84] Despite the importance of spaces where education is provided, there has been chronic underinvestment in school infrastructure in Europe and elsewhere. The often sizeable benefits of improving the quality of teaching and learning spaces include energy savings, safer and healthier environments for children, and better learning outcomes (Barrett et al., 2019; Duthilleul et al., 2021).[85] In Spain, for example, exposure to a green environment within and around educational institutions led to improved working memory and reduced inattentiveness in primary school-aged children (Dadvand et al., 2015).[86] In Northern Italy, tripling school infrastructure spending in the aftermath of the 2012 earthquake increased students' test scores, particularly in mathematics and for low-achieving students (Belmonte et al., 2020).[87] Studies in developing countries have reported similar findings. Across Latin America and the Caribbean, insufficient physical learning spaces in schools are strongly associated with violence, discrimination and limited opportunities to learn (Duarte et al., 2017).[88]

This chapter outlines key aspects considered by the EIB when appraising education infrastructure projects. The Bank's economic appraisal of such projects follows a methodology similar to those of other multilateral development banks, such as the Asian Development Bank[89] and the World Bank.[90]

[84] There are two central difficulties in accurately identifying the impact of public infrastructure investments in education. First, there is a problem of endogeneity. This means that variation in capital spending is typically confounded with other factors such as the state of the local economy or the socio-economic status of students that also determine outcomes. Second, even causal estimates of the effects of investments may overlook benefits that do not appear in measured output. This is likely to be a particular problem for school infrastructure, which may yield difficult-to-measure non-academic benefits such student well-being, health and safety.

[85] Duthilleul, Y., P. Woolner, and A. Whelan. (2021) "Constructing Education: An Opportunity Not to Be Missed." Thematic Reviews Series Council of Europe Development Bank, Paris.
Barrett, P., A. Treves, T. Shmis, D. Ambasz, and M. Ustinova. (2019). "The Impact of School Infrastructure on Learning: A Synthesis of the Evidence." International Development in Focus. Washington, DC: World Bank.

[86] Dadvand P., M. Nieuwenhuijsena, M. Esnaolaa, J. Fornsa, X. Basagañaa, M. Alvarez-Pedrerol, I. Rivasa, Lopez-Vicente M., De Castro Pascual M., Su J., Jerrett M., Querol X., and Sunyer J. (2015). "Green Spaces and Cognitive Development in Primary Schoolchildren" in the Proceedings of the National Academy of Sciences of United States of America. Volume 112 no. 26.

[87] Belmonte, A., V. Bove, G. D'Inverno, M. Modica. (2020). "School infrastructure spending and educational outcomes: Evidence from the 2012 earthquake in Northern Italy," Economics of Education Review, Elsevier, vol. 75(C).

[88] Duarte, J., F. Jaureguiberry, M. Racimo. Mariana (2017). Sufficiency, equity and effectiveness of school infrastructure in Latin America: UNESCO Office Santiago and Regional Bureau for Education in Latin America and the Caribbean; Inter-American Development Bank.

[89] Asian Development Bank (2017). "Guidelines for Economic Analysis of Projects." Manila.

[90] Tan, J, J. Anderson, Jock R.; P. Belli, H. Barnum, J. Dixon. (2002). "Economic analysis of investment operations analytical tools and practical applications." WBI development studies Washington, D.C.: World Bank Group.

19.2 Establishing the economic rationale and justification of education projects

Economic appraisal aims to assess the quantitative and qualitative contribution of an education project to a country's development. Accordingly, the project is analysed in its broader sectoral and country setting, encompassing micro and macro aspects and effects. This is in addition to the CBA of non-revenue generating components (presented in detail in section 19.3). The below list of areas analysed is not exhaustive and depends on the specific project circumstances.

Policy framework: For education projects, the EIB's appraisal methodology assesses the extent to which:

- the project scope is consistent with relevant EU policy and actions on education provision;
- the project is aligned with the EIB's public policy goals;
- the project objectives are consistent with the sectoral policy, objectives and priorities of the project country;
- there is complementarity between the projects' components/activities and the projects of other donors.

Country context analysis: An education project cannot be appraised without considering the broader context in which it will be implemented. A country's overall economic performance and outlook, alongside other macroeconomic factors, may affect the performance of an education project. Accordingly, this part of the appraisal overviews the socioeconomic conditions of the project country/region, such as demographic dynamics, current and expected GDP growth, labour market conditions and unemployment trends. It also examines how these conditions are likely to evolve over the project lifetime and how any changes in key indicators may influence the appraised project.

Sectoral review: A diagnostic analysis at the sector level seeks to identify key problems in the focal education system, including their causes and consequences. It also evaluates the rationale for the potential project and its objectives. Collected and analysed data cover, for example, the rates of enrolment, attendance and completion of studies; learning outcomes, as measured by national, regional and international assessments; the quality of pedagogical material; the suitability of equipment and its rate of use; and the level of preparation of teaching staff.

Overall trends in these indicators are presented in the analysis. Depending on data availability, information is disaggregated by geographic region and sociodemographic group (e.g. age, gender, socioeconomic status, and population minority). It is also useful to compare the education profile with those of other countries in the same region or of similar income levels. Public spending is analysed to assess the share of the education sector in the overall budget and to identify current and future priorities.

Demand analysis: The needs analysis is integral, providing the basis for identifying the educational spaces needed by beneficiaries and estimating a project's economic benefits. Specifically, it assesses current demand based on statistics from central and/or local authorities and from national and regional statistical offices, and estimates future demand based on reliable forecasting models. For investments in higher education and in technical and vocational education and training institutions, the analysis also includes labour market forecasts for various sectors, which may reveal the growth of new professions and the decline of others.

Intervention rationale: The economic rationale for EIB intervention in the education sector can be formulated on efficiency and equity grounds. Market failures related to public goods and externalities, informational imperfections in decision-making on further schooling, and constraints in capital markets are all recognised as logical bases for public investments in education (Poterba, 1996).[91] Public intervention is also required when the current distribution of resources denies equal opportunities to socioeconomically disadvantaged groups. The Bank's appraisal methodology assesses whether equity considerations and market failures provide a rationale for education-sector intervention and a justification for EIB financing.

[91] Poterba, J. (1996) Government Intervention in the Markets for Education and Health Care: How and Why?, in Individual and Social Responsibility: Child Care, Education, Medical Care, and Long-Term Care in America, Fuchs

19.3 Measuring the benefits from education projects

Education projects generate a wide range of benefits that can be classified into three main categories: monetary, social and environmental.

19.3.1 Monetary benefits at the individual level

If reliable data are available from relevant sources, it is possible to estimate the likely monetary impact of education investments. While various interrelated economic benefits may be observed, the quantification of monetary benefits usually assumes that the upgraded learning environment will improve education quality. This will then translate into increased educational attainment for students benefitting from the project: some children who would otherwise have dropped out will now complete their schooling, and effective learning will improve for many students. In turn, the beneficiaries' higher educational attainment will increase their productivity and earnings over their lifetime. Other quantifiable project benefits include the cost savings from investments in education infrastructure, such as lower maintenance costs and lower operational costs due to efficiency improvements in the education system (leading, for instance, to lower repetition rates).

19.3.1.1 Case study

The following approach was employed to calculate potential monetary benefits. The example project comprises new construction and major renovations of lower-secondary public infrastructure, including the extension and replacement of existing obsolete facilities, in a cohesion region. The public authorities propose investments of €194 million with the aim of raising schools to state-of-the-art standards, adapting infrastructure to changes in local demand and pedagogy, and thus compensating for chronic underinvestment over the last two decades. The project is expected to generate multiple socioeconomic benefits, including improvement of the country's human capital and economic competitiveness.

The construction works are expected to take place between 2021 and 2025. The project will benefit around 3 500 students every year, representing 5% of the student population in the region's lower-secondary education institutions. The new and renovated schools have an estimated useful economic life of 25 years, and the accumulated infrastructure maintenance costs over the buildings' life span amount to 25% of the total investment cost, at a rate increasing with the buildings' age.[92] In the WOP scenario, maintenance costs are considered to start at a higher level (equivalent to costs at the end of the new infrastructure's economic life) and increase progressively.

We make the conservative assumption that investments financed by the project will lead to 0.1 additional years of education[93] per student, on average. Combining this value with the country's statistics on earnings by educational level, the project is estimated to have an NPV of €41.6 million and an FRR of 6%. These calculations only include the project benefits that can be monetised. The appraisal also considers the social and environmental benefits considered below.

[92] Based on an expert study elaborated by Sorbonne University in 2021.
[93] Analysing test scores from 16 Latin American countries, Treviño et al. (2010) found that one additional element of infrastructure, such as a sports field or dining room, corresponds to between a 0.05 and 0.20 additional year of education. In Peru, Paxson and Schady (2002) found that spending on school infrastructure corresponded to a 14.5 percent increase in attendance, or a 0.145 additional year of education. Similarly, in the United States, poor ventilation in classrooms was found to reduce class attendance by 10 to 20 percent (Shendell et al., 2004). Therefore, the expected increase in 0.1 years of education as a result of this project is considered to be a conservative estimate.

19.3.2 Social benefits of education

Education provides social benefits for individuals and society at large, including a better way of taking care of ourselves and, consequently, creating a better society to live in. Supporting economic growth, increased educational attainment in the population potentially leads to an overall increase in productivity.[94] Additionally, there are non-monetary social benefits that transcend income differentials. For example, in terms of nutrition and disease prevention, education can help people maintain good health or become more healthy. Education has large intergenerational benefits in many areas of children's lives, and these payoffs persist over time. Educated parents, especially mothers, are better able to feed their children properly and keep them in good health (Mensch et al., 2019).[95] Furthermore, education is linked to increased female labour force participation (Heath and Jayachandran, 2016).[96] Other social or equity-related benefits of education may include increased and more active participation in political processes, lower crime rates, and behavioural changes necessary for a carbon-neutral economy, innovation and technological adaptation. However, most of these intangible benefits are inherently difficult to measure in monetary terms, so they are not considered when calculating the monetary benefits presented in the previous section.

19.3.3 Environmental benefits of education

The EIB's appraisal methodology also quantifies the positive and negative effects of an education infrastructure project on the environment, such as:

- more efficient and cost-effective energy use in new and renovated educational facilities;[97]
- improved environmental sanitation in educational institutions (water supply, sanitation, drainage);
- promotion of environmental enhancement (e.g. site enhancement and environment-friendly architectural design) and environmental awareness (e.g. introducing organic solid waste recycling in schools).

19.3.4 Qualitative analysis

With some project proposals including information of limited quality and quantity, and given the difficulty of quantifying the social and environmental benefits attributable to a project, there is merit in qualitatively analysing an investment's socioeconomic benefits.

All Bank investments in public education are qualitatively considered to have a good ERR,[98] as they are expected to translate into better learning outcomes for the beneficiaries. From an individual perspective, students who benefit from improved learning will have better employment outcomes and, therefore, higher earnings throughout their life cycle. From a public policy viewpoint, having a well-educated labour force has significant positive externalities for society as a whole, such as higher social cohesion and civil engagement and improved health outcomes.

Some project-specific features might modify the expected ERR of a particular project. This is illustrated by Table 19-1, which presents a qualitative assessment for the case study project introduced above, assessing the project's expected performance by subcategories and their relative importance in qualitative terms.

[94] Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, *98*(5), S71–S102.
[95] Mensch, B. S., Chuang, E. K., Melnikas, A. J. and Psaki, S. R. 2019. Evidence for causal links between education and maternal and child health: systematic review. Tropical Medicine and International Health, Vol. 24, No. 5, pp. 504–22.
[96] Heath, R. and Jayachandran, S. (2016). The Causes and Consequences of Increased Female Education and Labor Force Participation in Developing Countries. Cambridge, Mass., National Bureau of Economic Research. (Working Paper 22766.)
[97] See chapter 26. Energy efficiency for more details
[98] Between 7% and 9.9%

Table 19-1: Qualitative assessment of case study project

ERR components and externalities	Underlying measurements		Project performance	Score
Project's propensity to improve access to good quality education	• Capacity increase *(% of places created*): positively correlated with the project's propensity to improve access • Learning outcomes (*share of underachievers in maths in PISA*)[99]: the assumption is that when learning outcomes are low, the project's propensity to improve access to good quality education is higher • Components on digitalisation or flexible and innovative design elements (*very substantial, substantial, some, none*) • Inclusion of a teacher training component (*yes/no*)		The project addresses a situation of suboptimal investment in education infrastructure: in terms of public investment in education CAPEX. the region remains well below countries with similar economic and demographic characteristics. The EIB-financed new and upgraded infrastructure will accelerate the modernisation of teaching and learning environments in terms of functionality, green spaces, energy efficiency and safety, making lower-secondary education institutions better places to learn.	Excellent
Project's propensity to improve equity	• Socioeconomic status (SES) parity index at country level (*SES PISA index*)[100]: the assumption is that if inequalities are high in the country, the project has a higher propensity to improve access to good quality education • Inclusion of investments for students with special needs (infrastructure, digital equipment, etc.) and/or provision of special programmes for socioeconomically disadvantaged students (*very substantial, substantial, some, none*)		Investments in education are key to promoting equality of opportunities. Given that this project targets a cohesion region, it will foster the economic growth of a less-developed European region, promoting its convergence towards the EU average. Additionally, the works will improve schools' accessibility, ensuring that students with disabilities can access good quality education.	Excellent
Project's propensity to promote job creation, productivity and economic growth	• Project's contribution to closing the skills gap at national/regional levels (based on projects' team assessment)		The project has strong employment effects as it is expected to provide 3 400 person-years of employment during construction. Additionally, students who benefit from the improved learning environment will most likely have better learning outcomes, which will then translate into higher employability.	Excellent
Project's propensity to protect and enhance environmental sustainability	• Project's Climate Action &Environmental Sustainability contribution (EIB internal methodology)		80% of the project investment cost contributes to the climate action cross-cutting objective.	Excellent
National education System's efficiency to translate inputs to outputs (rule of law, meritocracy, etc.)	• Rule of law (*Rule of Law Index, World Justice Project*): the assumption is that when the rule of law is stronger in a country, the rating will be higher.		The rule of law is high in the project country.	Very good
Economic rate of return				Excellent

[99] The **Program for International Student Assessment**
[100] PISA's socioeconomic **index** of the student's family (**ses**)

20. Power generation

Dominik Ruderer

20.1 Introduction

The EIB is active in financing a large variety of power-generation projects, in principle including those based on firm renewables (e.g. biomass, geothermal, hydro), fossil fuels (e.g. abated natural gas),[101] and variable renewables (e.g. solar photovoltaic, on-/offshore wind). The Bank also invests in cogeneration projects producing heat and power. Projects can include new-built facilities and the rehabilitation or modernisation of existing power plants. To assess the economic viability of a power-generation project, its economic benefits and costs need to be compared against those of a "do-something (else)" counterfactual scenario.[102]

A project's economic costs are determined by its design characteristics (as detailed in the engineering analysis), investment[103] and annual O&M costs, fuel and air pollutants costs and grid-connection costs. The economic benefits may differ significantly depending on the project type. Benefits could be associated with a project's power production (MWh), the capacity (MW) it provides, or various other factors.

The Bank applies different analytical approaches for different technologies. Accordingly, section 20.2 covers the economic appraisal of firm power-generation projects, then section 20.3 details how variable power-generation projects are appraised.

20.2 Firm power generation

Firm power generation projects involve power plants that can be dispatched, reliably and as needed, to increase and decrease generation so as to balance electricity supply/demand. Examples include thermal power plants (e.g. fossil fuel, nuclear, biogas/biomass and geothermal power plants), hydropower plants with reliable water flow or a dedicated reservoir, pumped storage hydropower or batteries.

Because of market failures or distortions, the economic costs may differ from the financial costs, requiring dedicated estimates. For instance, in many power-generation projects, the economic costs associated with environmental externalities — GHG emissions and other airborne pollutants — are greater than their value in financial terms. The most notable dedicated estimates of economic costs are the following:

- Fuel costs. These are typically estimated by the Bank's own fuel price scenarios, but reverting to the expected/contracted locally sourced fuel prices (e.g. for biomass) might be warranted. Transport costs are included whenever relevant.
- GHG emission costs. The economic analysis uses the Bank's shadow cost of carbon to value changes in CO_2 emissions associated with the project (see chapter 4).
- Airborne pollution costs (NOx, SO_2 and particulates). The Bank uses its own database on the economic cost of such pollutants (see chapter 6).

Economic benefits are highly project-specific, depending on not only the underlying technology but also the specific project context and rationale. Frequently observed project rationales include meeting growing demand; providing low-carbon or carbon-free electricity; ensuring security of supply (resource adequacy) and reliability; replacing obsolete capacity; and providing backup capacity with flexibility to integrate variable renewable generation.

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[101] The Bank's Energy Lending Policy sets detailed criteria that need to be fulfilled for a Bank to support a project. Stringent emissions thresholds are set, limiting the Bank's financing of fossil-fuel generation to projects including carbon abatement and highly-efficient co-generation assets. The Bank no longer finances CCGTs based on natural gas alone, nor oil- or coal-based plants unless these are fitted with CCS technology.
[102] The power sector is characterised by a highly inelastic demand. Therefore, it is typically safe to assume that power demand is met under all reasonable scenarios, and the economic analysis will then assess how cost efficient the project is.
[103] This should also include any cost related to environmental and social compensation measures if applicable.

It is first necessary to fully understand the project rationale and its underlying economics, and to ensure that the project is technically suitable to meet the associated objectives. For this purpose, detailed analysis is undertaken of the relevant power sector, including supply/demand balance (short/long term), capacity adequacy, generation costs, the project's competitive position and the potential existence of long-term offtake arrangements.

Once a project's economic rationale is understood, its economic benefits are estimated based on either the cost of the best available alternative or the avoided system costs, depending on the specific project context.[104] These estimates are typically made on a levelised basis (euros per MWh) using the LCOE approach. For this approach to be meaningful, the project's estimated load factor[105] must be correctly assumed. A comprehensive analysis of the electricity market (and the heat market for cogeneration projects) is thus performed. This includes a comparison of the plant's short-run marginal cost (SRMC) — including fuel, CO_2 and variable operating costs — against historic and projected electricity prices for base load, mid-merit and peak power, as appropriate to the project.

With the share of renewable in total power generation continuing to grow, many thermal power plants are expected to operate with lower and lower load factors. The load factor must be carefully analysed for each market in relation to the expected share of renewable power. As this share grows, wholesale electricity prices become more volatile, which needs to be accounted for. There is concern in many EU countries that wholesale prices could become insufficient to fully repay investments in new generation capacity. This has triggered the development of several national capacity remuneration mechanisms to select and incentivise investments that ensure security of supply. For projects whose main purpose is providing services in the balancing market and/or system services market, analysis of those markets may be needed.

20.3 Variable power generation

20.3.1 Introduction

Variable power-generation projects involve a renewable energy source of an intermittent nature, the main types being solar photovoltaic and on-/offshore wind. Assessment of the economic benefits follows different approaches depending on the maturity of the underlying technology.

20.3.2 Characterisation of renewable technologies

Variable renewable power projects involve various technologies at different stages of technological maturity. This section focuses on technologies that have reached the commercial stage, and so does not include those at the RDI stage. The Bank categorises projects based on their technological maturity, with each category based on distinct economic considerations. Such divisions reflect not only the maturity of the technology itself but also its stage of deployment in a certain geographical market.

- ***Mature technologies*** have been in use long enough and deployed at sufficient scale so that most of their technical and operational faults have been addressed. They are competitive against alternatives, and their costs are expected to fall only relatively modestly in the future. Examples include onshore wind, large-scale ground-mounted solar photovoltaic, hydropower, geothermal and solid biomass.
- ***Technologies at an early stage of deployment*** are already commercially proven. They are characterised by potential for substantial cost reduction through large-scale deployment in the future, which will make them competitive against alternatives over a reasonable timeframe. Costs that may be reduced include those of manufacturing the technology, delivering it to project sites, and implementing and operating the project. While the technologies included in this category evolve over time, a current example is fixed-bottom foundations for offshore wind.

[104] For electricity, the "no project" scenario is equivalent to the "avoided system costs" scenario (i.e. increased generation from existing power plants connected to the grid). The "no project" scenario of "no electricity" is almost never used. An important exception is when connecting customers who do not have access to electricity and instead are using other sources of energy (lanterns, batteries, etc.). In this case, the costs and benefits of electricity are compared to the alternative energy source. If alternative new generation is possible and more cost effective than "no electricity," this option is used for the economic analysis.

[105] The load factor of a plant is the ratio of the actual generation during a given period of time to the total theoretical generation that the plant would have produced if it had run at full capacity through the whole period.

- ***Innovative technologies*** demonstrate significant innovation compared to the state of the art (not just incremental improvement). While these technologies are no longer at the RDI stage, their commercial deployment is only just beginning. Their stage of development also entails significant uncertainty with regards ot the timing and scope of technological progress. For the Bank to consider investing in projects based on these technologies, there needs to be a tangible prospect of material cost decline through major technological improvements and large-scale deployment. A current example is floating offshore wind.

The Bank conducts regular technology reviews to assess maturity.

20.3.2.1 Mature technologies

With mature technologies, a project's economic benefits are driven by its power production.[106] Secondary benefits, such as their contribution to technological progress, typically play a smaller role. In a system requiring additional generation capacity to meet demand growth, the value of power is usually determined by the LRMC of the system. By contrast, in a system with surplus generation capacity, the value of power is set by the SRMC. Accordingly, for projects located in EU markets with excess capacity, the Bank uses the system's SRMC over a project's economic lifetime to approximate the value of power-generation . Marginal costs of power generation (SRMC and LRMC) are based on the Bank's fuel-price scenarios, the shadow cost of carbon, and technology-specific standardised CAPEX and OPEX profiles.

The economic analysis also considers specific factors that are frequently relevant to renewable energy:

(i) Costs related to the intermittency of renewable energy sources. It is typically necessary to consider balancing and profiling costs. Balancing costs arise because intermittent renewables do not provide firm capacity (i.e. capacity on demand), which limits a project's contribution to covering peak demand. Profiling costs reflect the different output profiles of plants, depending on the technology and location. The correlation of a project's output profile with residual demand in the system significantly impacts on the economic value of its power production.
(ii) The cost of connecting a project to the electricity grid. This should be considered a project investment cost. There may also be investment costs at the wider power system level for integrating the project. These are assessed on a case-by-case basis. The additional costs are generally limited when the penetration of intermittent renewables into the electricity system is low; in some cases, they may not be attributable to a single project. If networks are not upgraded, curtailment and system management costs will eventually rise as renewable energy penetration increases. The economic analysis must include these costs whenever clearly attributable to and caused by the appraised project.

To determine whether a project is economically viable, the economic costs and benefits are compared over its economic lifetime. The Bank uses market-specific technology cost benchmarks to ensure that every financed renewable energy project is cost-effective in comparison to similar projects.

20.3.2.2 Technologies at an early stage of deployment

Early-stage technologies cannot yet compete with alternatives because they have not fully realised their significant potential for cost reductions. Accordingly, the industry have yet to improve overall efficiency through general learning by doing and other knowledge spillover, streamlining the supply chain and raising operational efficiencies. However, the declining trajectory of costs of early-stage technologies justifies the expectation of becoming competitive over a reasonable period.

[106] This includes environmental externalities associated with carbon emissions and other pollutants.

Supporting early-stage technologies has a dual purpose: to produce electricity in the shorter term, thus leading to similar benefits as mature technologies, and to generate cost reductions (mainly via learning by doing) in the longer term. Because the learning benefits of these technologies are not internalised and cannot be quantified for an individual project, the Bank does not run the standard economic test; instead, it presumes in favour of their economic case. Whether a technology can be considered in the early stage of deployment is determined on an individual basis considering the technological and market potentials, including the extent of likely cost reductions. The Bank's appraisal tests whether a project's costs are reasonable and consistent with the technology's overall declining trend. If the project costs appear significantly higher than for other uses of the same technology, or if the project could significantly raise local electricity prices, the Bank may decide not to support it.

For comparative purposes, the Bank qualitatively assesses any wider benefits from advancing knowledge of the technology. Besides learning by doing effects, such benefits particularly include vertical and horizontal knowledge spillovers and wider environmental benefits.

20.3.2.3 Innovative technologies

The Bank's economic appraisal of innovative technologies focuses on their future potential, in terms of scale and cost, and is conducted on a technology-specific rather than a project-specific basis.

As for early-stage technologies, the Bank may decide not to support a project if the costs appear significantly higher than for other uses of the same technology, or if local electricity prices could be significantly affected.

20.4 Case study: Onshore wind

The case study concerns an investment in constructing and operating a large onshore wind project in Northern Europe. The new plant will have a total capacity of 240 MW. The estimated economic life of the plant is 20 years, with annual O&M costs typical for this kind of project. The project's unit investment cost is somewhat lower than the European average, and includes grid connection costs. The plant will make a very limited contribution to firm capacity. Based on the total volume of wind generation expected from other sources in the system, some output from the project is assumed to be curtailed, initially at a low level but rising over the project's economic lifetime.

The project enjoys a high load factor given its good location and site/turbine optimisation. According to a long-term wind resource assessment conducted by reputable international consultants, a 35% net load factor at the metering point is expected under P75[107] conditions. This level is high but not unusual for the region. Output is thus expected to average between 680 GWh and 770 GWh per year.

Analysis reveals a reasonable correlation between the system's winter demand and the wind farm's seasonal output. However, with an estimated increase in wind generation over time, the economic value of the project's electricity production during winter is expected to decline.

The SRMC in the European power system, including externalities, is estimated at €89 per MWh on a levelised basis over the project's economic lifetime. This value is already adjusted for balancing and profile costs, reflecting the rising share of wind power in the system.

According to data from several publicly available databases, the economically justified LCOE in Northern Europe should be €37–48 per MWh, mainly depending on site conditions. The project's LCOE (NPV total cost/NPV net sales) is €41 per MWh — within the expected range for new generation and substantially lower than the SRMC of power production. The calculation is illustrated in Table 20-1. As the project is deemed competitive with the analysed alternative, it is therefore economically justified.

[107] P75 corresponds to the annual power generation, or the corresponding load factor, that a plant expects to achieve with 75% probability.

Table 20-1: Calculation of the economic rate of return for an onshore wind project

		Units		NPV*	-1	0	1	5	10	15	20
	Economic Assumptions										
(1)	Installed capacity	MW	240								
(2)	Project cost	MEUR	261								
(3)=(1)*(4)*(5)*8,76	Net power production		714								
(4)	Load factor	%	35%								
(5)	Turbine Availability	%	97%								
(6)	Economic Value of Power	EUR/MWh	86								
(7)	Curtailment		low/rising								
(8)	O&M	%	2%								
	Capital Expenditures										
(9)	Investment cost			240	87	174					
	Physical output			-							
(10)=(3)	Production	GWh		8.068	-	-	714	714	714	714	714
(11)	Curtailment	GWh		718	-	-	7	36	71	107	143
(12)=(10)-(11)	Net sales	GWh		7.350	-	-	707	678	642	607	571
	Expenditures										
(13)=(9)	CAPEX	MEUR		240	87	174					
(14)=(9)*(8)	OPEX	MEUR		59	-	-	5	5	5	5	5
(15)=(13)+(14)	TOTEX	MEUR		299	87	174	5	5	5	5	5
	Revenues										
(16)=(6)*(12)	Economic Value of Power	MEUR		632	-	-	61	58	55	52	49
(17)=(16)	Total revenues	MEUR		632	-	-	61	58	55	52	49
(18)=(17)-(15)	**Economic Cahsflow**	**MEUR**		**333**	**-87**	**-174**	**56**	**53**	**50**	**47**	**44**
(19)	**Economic Rate of Return**	**%**		**18%**							
	LCOE (5%, 15 years)	EUR/MWh		41							
	Unit cost	EUR/kW		1,1							

*) NPV is the net present value at year -1 using the applicable social discount rate i.e. 5% for Europe at the time of writing

21. Energy networks

Eugene Howard, Federico Ferrario and Manuel Baritaud (electricity networks)
Susana Lagarto (low-carbon gas networks)

21.1 Electricity networks

21.1.1 Project types

The electricity network projects submitted for Bank financing include individual investments and multi-scheme, multiannual investment programmes. They mainly concern:

Interconnectors;
Transmission network infrastructure;
Distribution network infrastructure;
Smart meters.

21.1.2 Project objectives and benefits

For electricity network projects, the promoter prioritises investments based on capital and operating costs, operational targets, implementation periods and other technical requirements. The economic analysis focuses especially on infrastructure costs and the project's effects on the network, such as network losses, network congestion, ancillary services and curtailment risks. Generally, electricity network investments aim at delivering one or more of the following objectives:

a) Increasing electricity flows between areas or markets (e.g. interconnectors);
b) Reducing congestion on transmission networks;
c) Maintaining or improving the quality and security of supply;
d) Reducing OPEX and network losses;
e) Avoiding present or expected curtailment, particularly of variable renewable generation;
f) Meeting electricity demand growth from existing and new customers;
g) Improving resilience to climate change;
h) Increasing digitalisation and the real-time monitoring and energy-management capabilities of network operators and consumers (e.g. supervisory control and data acquisition systems, smart grids, smart meters).

The economic analysis accounts for the uncertainties regarding costs, benefits, and market fundamentals. Sensitivity analyses are carried out to explore uncertainties and test for the impact of deviations in key inputs. The project's economic life depends on the type of asset; for a multi-asset investment, a weighted average life is applied.

21.1.3 Economic analysis

Electricity networks are universally considered natural monopolies, which justifies their regulation. They are natural monopolies because one power network over one geographic area involves fixed costs that would be inefficient to duplicate, and serving additional consumers has a relatively low incremental cost. Network monopolies are regulated to ensure in theory their service level maximises welfare — providing universal access to electricity at affordable rates — subject to the financial budget constraints of network companies. Energy sector regulators, whether government ministries or independent bodies, guide or approve the investment of network monopolies in terms of obligations to connect customers, provide quality of service (reliability).

The regulators generally determine the income of monopoly providers by setting network tariffs as close as possible to least cost — sufficient to cover investment depreciation and the operating and remunerate the capital[108] needed to meet service obligations. The cost of capital is usually determined using the WACC or other methodologies incorporating the cost of debt and the risk-adjusted return on equity. A benevolent regulator would not allow "super-normal profit," which exceeds recovery of the costs of capital, operations and maintenance. In practice, the regulated FRR for electricity networks in the European Union is currently 2–5% (in real terms, post-tax), depending on the country; this is in the same range and can be interpreted for the purpose of EIB's economic appraisal of electricity networks as a proxy for the SDR.

The starting point for economic analysis is evaluating the effectiveness and efficiency of the regulatory framework. In practice, regulation remains imperfect because of information asymmetries: there is inevitably a trade-off between regulating down to the tiniest detail and having manageable and effective regulation). Cost-plus regulation can have the unintended consequence of incentivising potentially unnecessary investments, which translates into higher costs for consumers and higher company profits. To address this, existing regulation of electricity networks ranges from the traditional cost-plus approach (cost of good/service, including cost of capital) to various incentive-based approaches, such as a revenue cap or price cap.[109]

At the unit-investment level, a dedicated CBA can be used to assess economic profitability before the investment obtains regulatory approval (either before the investment is implemented or after). In practice, regulators often require a CBA for large transmission investments, with the analysis usually performed by the regulated companies themselves. It is also best practice for electricity network companies to perform CBA for smaller individual schemes, comparing project benefits and costs to prioritise investments of highest economic value using a discount rate equal to the SDR. In a well-regulated system, the EIB assumes that an investment's ERR is at least equal to the regulated rate of return and can be significantly higher when accounting for quantifiable benefits such as avoided costs and externalities.

To the extent possible, the Bank's standard economic profitability analysis comprises a simplified CBA for the different components of an investment programme.

<u>Interconnections and large-scale investment schemes</u>
For large transmission projects, such as interconnections, detailed and tailored network studies are performed. CBAs undertaken by promoters, industry associations like ENTSO-E, or consultants are usually available. A quantitative CBA reflecting the Bank's assumptions is in general possible and based on a critical review of the available material.

<u>Investment programmes for electricity transmission and distribution networks</u>
Network investment programmes normally comprise many (up to several thousand) geographically dispersed components. For electricity networks, the average revenue collected through tariffs (allowing for cross-subsidisation) suffices to cover the cost of delivering electricity to new and existing customers. The first step of the economic assessment is evaluating the effectiveness of the regulatory framework. As appropriate, this may include verifying whether existing network metrics for quality/reliability of supply, or network losses, exceed the targets set by the regulator, and comparing the project with networks in other areas or with different operators.

It is data intensive and costly to economically appraise the many small-scale individual investment schemes that combine to form a standard network investment. The economic cost of not meeting customers' electricity demand is so high that a "do-nothing" scenario is generally not considered a least-cost option. Therefore, most network investment programmes do not use that scenario in analysing quantified costs and benefits. Instead, the counterfactual is generally defined as the most cost-efficient investment for provision of a given service level.

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[108] Note that the "cost of capital" feeding into the WACC calculation is composed of the cost of acquiring debt capital, and the opportunity cost of employing equity in another investment. As such, the WACC includes (indirectly) the remuneration of the capital provided as debt (through interest payments) and embeds a remuneration of equity.
[109] Incentive regulation has been introduced in some countries or for specific projects. However, its scope remains relatively limited and has a marginal impact in practice on the returns on the specific investment or on the overall aggregated revenues of regulated entities.

There are several main categories of investments in a network programme, for which the economic appraisal differs. These include the following, also listed in
Table 21-1:

- refurbishment or renewal of ageing assets;
- reinforcement of the network;
- implementation of new regulatory requirements;
- connection of new consumers and new generators.

Refurbishment entails renewing ageing assets when the risk of failure begins to increase tangibly — usually when equipment has reached a certain operating life or when service quality begins to deteriorate. A welfare-maximising network operator will identify and prioritise the refurbishment or replacement of assets using a techno-economic analysis applied to individual schemes. This analysis will consider investment costs, the life of existing assets, and quantifiable benefits such as reducing O&M costs, technical losses and unserved energy. In general, if refurbishment is not undertaken, the risk of equipment failure and its subsequent costs to customers increase over time.

The investments are selected using sound techno-economic criteria, focused on preserving supply at the quality, reliability and other service levels metrics set by the regulator. This ensures the Bank finances economically justified, cost-efficient investments. For networks already benefitting from good reliability, refurbishments ensure that the level of service remains high and the ERR is assumed to be at least equal to the regulated rate of return. For refurbishments resulting in more significant quantifiable service improvements, these benefits can increase the ERR.

Network reinforcements are necessary improvements in a specific network section or a geographic area (e.g. new industrial zone or dynamic urban area) to adapt the network to new supply/demand patterns, address new regulatory requirements, or achieve significant improvements in service quality (e.g. following previous underinvestment). Without these reinforcements to overcome constraints, new customers could not be connected and/or network reliability would fail to meet the required level. Electricity network companies usually establish network development plans to define the long-term structure of the electrical network. Their objective is to find the most efficient solution to modernise and reinforce the network, accounting for consumption growth (and/or distributed generation) over time. Such investments are often associated with quantifiable improvements in service quality or avoidance of economic costs, which typically lead to an ERR higher than the regulated rate of return assumed for pure refurbishment.

For connecting new customers to the network, economic benefits depend on the counterfactual scenario.

In countries where the regulatory framework obliges the network operator to connect new customers, the counterfactual is a least-cost connection to the network. The costs associated with connecting new customers are typically a very small proportion of the total investment in customer activities (residential, commercial and industrial). Accordingly, the economic benefits of customer activities are usually excluded from the economic analysis.[110] In such cases, the ERR of the connecting infrastructure is assumed to be at least equal to the regulated rate of return.

While consumers may increasingly fulfil part of their consumption needs through self-generation (if they can install solar PV and batteries), this choice is usually neither least-cost nor feasible at all times; therefore, where networks are accessible, almost all consumers choose to remain connected to the grid.

In countries where the regulatory framework does not require the network operator to connect new customers, particularly those located in isolated areas, the counterfactual may differ from a least-cost connection to the grid. Key considerations are whether the customers are already using alternative energy sources (lanterns, batteries, portable generators, etc.) and are likely to adopt a self-generation solution in the absence of a grid connection (e.g. solar PV plus batteries). In such cases, the counterfactual is an alternative energy source, with the cost of lanterns for instance) or self-generation, with the cost of self-generation translating into a cap on the economic benefits of connecting a new customer to the grid. Further analysis may conclude that the counterfactual is a mixture of self-generation types for different consumption

[110] EV charging stations are a notable exception due to their higher network connection costs. In this or similar cases, an approach analogous to the connection of new generation is used.

levels. A quantitative CBA is then carried out, and the ERR of the investment to connect new customers is based on the avoided costs of the counterfactual.

For connecting new power generation to the network, the economic analysis is similar to that for connecting new customers, except that it includes some benefits and externalities associated with new generation. Network companies are usually legally obliged to connect the new power plant, but the initial connection charge paid by the new generation plant does not always fully cover the connection costs. Unlike for new customer connections, the infrastructure for connecting new power plants usually represents a more significant share of the total investment cost. Therefore, the economic analysis typically accounts for part of the benefits and externalities (e.g. avoided emissions) of the newly connected power plants. Consequently, at least for renewable power generation, the ERR of the connecting infrastructure is higher than the regulated return.

Smart grid infrastructure, smart metering and other demand-management investments contribute to decarbonising the electricity sector by providing flexibility and improving energy efficiency. As in the analysis of connecting new generation to the grid, the ERR of these investments includes a share of the avoided cost of externalities, and tends to be higher than the regulated rate of return.

Adapting the network for climate change helps avoid outages due to extreme weather events, which can have a significant economic impact on consumers. The requirement to adapt infrastructure may be regulatory with unquantified benefits, but reasonable assumptions can often be used to quantify them. A case-by-case analysis is required to estimate these benefits and any associated costs.

In conclusion, when quantitatively analysing the benefits of investment in electricity networks, the Bank adjusts its approach according to project circumstances. When the regulatory framework is reasonably efficient and effective in avoiding situations of over- or underinvestment, all investments approved by the regulators are generally considered economically justified and assumed to have an ERR no lower than the regulated rate of return.

When the information needed for quantifying the ERR is unavailable or not provided by the promoter, the Bank may refer to default ERR values for each type of investment, enabling the calculation of an ERR weighted by the share of investment costs associated with each investment type. Table 21-1 provides an indicative breakdown of the ERR considered for the different components of a typical electricity network investment programme. The latter is adjusted upwards or downwards according to the conclusion of the economic analysis, the sector review, and evaluation of the regulatory framework.

Table 21-1: Indicative economic rates of return for different project types

Indicative economic benefits	ERR
Refurbishment for maintaining the quality and reliability of supply	3.5–5%
Network reinforcement	5–7%
Connecting new consumers in countries/regions with connection obligation	3.5–5%
Connecting low-carbon/renewable power plants or new innovative infrastructure	7–10% (or depends on CBA)
Connecting new consumers in countries/regions with no connection obligation	> 10%

21.2 Low-carbon gas networks

21.2.1 Project identification

The low-carbon infrastructure projects submitted for Bank financing include individual investments and multischeme, multiannual investment programmes. They mainly concern:

- Transmission and distribution pipelines or other infrastructure for transporting biomethane, green hydrogen or CO_2;
- Underground Storage (US) for low-carbon gases or CO_2.

The EIB will support the gas industry only to advance its decarbonisation. As such, to be eligible for Bank financing, gas network investments must be planned for the imminent transport of low-carbon gases, which may require the rehabilitation and adaptation of existing gas infrastructures when part of this goal.

For all types of infrastructure and associated technologies, there are three main steps to be taken for the project definition. First, the project scale and dimension must be stated, accompanied by analysis of the market where the low-carbon gas will be placed, with credible projections for the future uptake of low-carbon/renewable gas voilumes. Second, a market and/or technical study must establish the need for additional or upgraded infrastructure, evaluating whether it is needed to connect new low-carbon gas supply sources, store CO_2 or retrofit facilities incompatible with hydrogen. Third, the main features of the infrastructure must be described, including:

- Physical features:
    - *Networks*:
        - Nominal load (volumes per hour);
        - Amount of low-carbon gas to be transported annually over the lifetime of the asset (millions of cubic metres);
        - Number of customers served (demand and/or supply points);
        - Pipeline route (attaching pertinent maps) and length (kilometres);
        - Nominal diameters (mm or inches) of pipelines;
        - Evidence of overall future savings in GHG emissions due to the project (including no increase in transmitted or distributed natural gas volumes);
    - *Underground storage*:
        - Type of storage site (e.g. depleted field);
        - Site dimension (volume);
        - Injection capacity (cubic metres per hour);
        - Associated pipeline route (attaching pertinent maps) and length (kilometres);
- Characteristics of the national and regional gas system, and the locations of internal nodes and links with other transmission pipelines/networks/gas facilities;
- Building techniques and technical features of the main project elements;
- Contractual features:
    - Eviden*ce of contractual commitments for low-carbon/renewable gases or CO2 supply/demand (e.g. capacity bookings or supply agreements); and/or*
    - *Evidence of investments in projects to produce low-carbon/renewable gases, in facilities to be physically connected to the financed gas infrastructure;*
    - *The blend*ing rate required by the applicable national regulatory framework, if any.

The key information for feasibility and options analysis includes the following:

- Energy demand forecast (average and peak);
- Seasonal and long-term trends, and demand curve for a typical day;
- For underground storage, injection rate projections;
- If volumes have a single off-taker/supplier, main features of the contractual relationship and pricing;
- Price scenarios, if project-specific. The EIB considers its own pricing scenarios for avoided natural gas consumption.

The analysis should consider possible realistic alternatives, including:

- Within the same gas system: alternative routes or smaller capacity for gas pipelines; different materials for networks (steel, polyethylene, etc.);[111] different locations and/or capacities for underground CO2 storage sites;
- Alternative ways for providing the energy required: actions and policies aimed at energy savings instead of maintaining the intenting gas delivery capacity; using other energy sources instead of gas, such as electricity, district heating (DH), and mixed alternatives; using other types of low-carbon gas (e.g. hydrogen produced on site, instead of transported via pipelines).

[111] All project elements must be fit to transport high volumes of hydrogen.

21.2.2 Economic profitability analysis

Economic **benefits** are generally quantified as the value of the energy supplied, valued wherever possible by estimating the country/region's WTP for that energy. Typically, WTP is estimated by quantifying the costs of the project's counterfactual — a best available alternative scenario in which users would incur costs (direct and via externalities) by using an alternative energy source/mix (e.g. avoided natural gas consumption; avoided emissions from that fossil gas use; directly producing the energy on site). Evaluation of the project's benefits accounts for the load factor (utilisation rates) of the pipelines, networks and other facilities under consideration and their avoided costs.

For underground CO_2 storage, the economic analysis identifies and quantifies the main roles for storage and its associated benefits (or avoided costs), particularly the avoided emissions externalities of releasing CO_2 into the atmosphere. The economic profitability assessment includes an evaluation of the best viable alternative to the project.

There are two main relevant **externalities** in low-carbon gas network projects. The first is the environmental externality, i.e., the cost of the measures necessary to neutralise possible negative effects on air, water, land and health. The EIB uses its own economic price scenario for CO_2 and other non-GHG emissions (see chapter 4). Since the Bank will only finance gas network projects with evidence of overall future savings in GHG emissions, this externality is expected to always be a benefit for such projects. The second externality is the security of supply, which could be positive (benefit) or negative (cost), depending on the project's use and purpose. This externality aims to reflect, for example, the value (e.g. measured as an impact on GDP) of supply disruptions that could occur without the project.

The project **costs** are provided by the sum of CAPEX (land, buildings, licences, patents, civil works, materials, etc.) and OPEX (personnel, raw materials, energy use, etc.).

The economic return is then calculated based on the net stream of costs and benefits over the project's economic life.

Finally, a sensitivity analysis is conducted by adjusting key variables, particularly for utilisation rates and the evolution of low-carbon gas blending rates.

21.3 Case study: Regional electricity distribution network

This project concerns investments in an electricity distribution network to improve the reliability and quality of electricity supply to end customers. The review of the regulatory framework confirmed that the national regulator has implemented a well-designed framework to guide regulated entities on making cost-efficient investments in the interest of society. Accordingly, the risk of under- or over-investment can be considered negligible. The investments are remunerated at a regulated rate of 5.0% (real, post-tax). The promoter identifies and selects each investment following sound techno-economic criteria and procedures.

The project will reduce the duration of unplanned outages in the network, resulting in a drop in unserved energy of 0.04 GWh per year compared to the counterfactual. This is monetised at the value of lost load. Considering the assets to be developed, the project's weighted average economic life is estimated at 23 years.

The counterfactual scenario is the least-cost investments needed to maintain the reliability and quality of supply at current levels.

The CBA of the project calculates an ERR of 5.5%, as shown in Table 21-2. The benefits are represented by the avoided cost of the counterfactual investments and by the monetised improvements in supply reliability for end customers.

Table 21-2: Calculation of the economic rate of return for a, electricty Distribution System Operator (DSO) project

	DSO INVESTMENT PLAN *Economic Analysis* (2020 Constant Prices)											
	General Assumptions	Units										
(1)	Regulated rate of return	%	5.0									
	Start Year	-	2021									
	Weighted average economic life of project	yrs	23									
(2)	Cost ENS (VOLL)	EUR/MWh	6,228									
			NPV	**2021**	**2022**	**2023**	**2024**	**2025**	**2030**	**2035**	**2040**	**2044**
	Project Costs											
	CAPEX per item of investment											
(3)(from promoter)	Investments to improve quality and reliability of supply	EUR m	65	65.0								
(4)	*(share of investments still within the defined economic life // NPV of life)*	*%*	13		*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
(5) = (3)	**TOTAL**	**EUR m**	**65**	**65**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(6)(from promoter)	**OPEX**	EUR m			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
(7) = (6)	**TOTAL**	**EUR m**	**13**	**0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
(8) = (5) + (7)	**TOTAL COSTS**	**EUR m**	**78**	**65.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**	**1.0**
	Project Benefits											
(9)(from promoter)	**Avoided ENS thanks to network reinforcements**	GWh		0	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
(10) = [NPV((1); row (5)) + NPV((1); row(7))] / [NPV((1); row (4)]	**Avoided costs of the counterfactual**	EUR m	78	0	5.79	5.79	5.79	5.79	5.79	5.79	5.79	5.79
	Summary - Monetary Benefits											
(11) = (10)	Avoided costs of the counterfactual	EUR m	78	0	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
(12) = (9) * (2) /1000	Reliability benefit	EUR m	3	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
(13) = (11) + (12)	**TOTAL BENEFITS**	**EUR m**	**81**	**0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**
(14) = (13) - (8)	**PROJECT NET CASH FLOW**	**EUR m**	**3**	**-65.0**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**	**5.1**
(15) = IRR (14)	**EIRR (23y)**		**5.5%**									

22. Energy efficiency

Isidoro Tapia, Francesco Angelini and Davide Sartori

22.1 Methodology

22.1.1 Introduction

The economic appraisal of energy-efficiency projects is conducted through CBA. Energy consumption depends on the use of scarce resources. Projects focused on energy efficiency result in the reduction of consumed energy compared to the counterfactual scenario. Examples include building renovation projects; new constructions exceeding minimum regulatory requirements; energy efficiency investments in public lighting, industrial facilities, and small and medium-sized enterprises. Society gains the energy saved by these projects (valued at opportunity cost) plus the reduction in externalities. Energy efficiency is a core component of the EU decarbonisation strategy, and requires sustained investment in buildings and industrial processes and plants.

Buildings are responsible for approximately 40% of energy consumption and 36% of CO_2 emissions in the European Union. Globally, industry accounts for one-third of final energy demand.[112] Energy-efficient buildings result in lower energy bills and reduced energy demand. Moreover, increased use of on-site renewable, non-emitting energy sources leads to better air quality and improved health. Energy-efficiency investments in industry also support core business activities by helping to reduce costs, increase value and mitigate industrial risks; simultaneously, they contribute to achieving Paris Agreement targets.

The low uptake of energy efficiency, particularly in buildings, is a longstanding paradox largely discussed in the economic literature and often termed "the energy-efficiency gap." This gap is usually attributed to incomplete information, price volatility and intrinsically random factors such as weather determining energy needs. Another major challenge is asymmetric-information problems such as moral hazard and price discrimination, magnified by the high upfront costs and multiplicity of stakeholders involved in energy-efficiency investments. Also typically problematic is the fragmentation of projects across multiple small beneficiaries, which penalises individual investments given the large economies of scale of energy-efficiency investments, particularly in buildings.

22.1.2 Basic theoretical considerations

The economic impact of energy-efficiency projects is diffuse and often captured by multiple users individuals, making estimation of impact a technically complex exercise. The multiplicity of benefits generated by such projects is widely recognised in academia[113] and by regulatory bodies, such as the European Commission,[114] the United States Environmental Protection Agency,[115] and the International Energy Agency.[116] In a 2014 study, the International Energy Agency identified no fewer than 15 different benefits deriving from energy-efficiency projects, and even recommended performing multiple-benefit analysis.

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[112] 'Capturing the Multiple Benefits of Energy Efficiency', IEA Study, 2014.

[113] See, for example:
Matthias Reuter, Martin K. Patel, Wolfgang Eichhammer, Bruno Lapillonne, Karine Pollier. Energy Policy, Volume 139, April 2020, A comprehensive indicator set for measuring multiple benefits of energy efficiency.
Thema, J.; Suerkemper, F.; Couder, J.; Mzavanadze, N.; Chatterjee, S.; Teubler, J.; Thomas, S.; Ürge-Vorsatz, D.; Hansen, M.B.; Bouzarovski, S.; Rasch, J.; Wilke, S. The Multiple Benefits of the 2030 EU Energy Efficiency Potential. Energies 2019, 12, 2798. https://doi.org/10.3390/en12142798
Joyce, A.; Næss-Schmidt S.; Bo Hansen, M.; Monetising the multiple benefits of energy efficient renovations of the buildings of the EU. ECEEE SUMMER STUDY proceedings

[114] Art.3.3 of the proposal amendment to the Energy Efficiency Directive EU 2018/2002. COM(2021) 558 final 2021/0203 (COD)

[115] https://www.epa.gov/statelocalenergy/quantifying-multiple-benefits-energy-efficiency-and-renewable-energy-guide-state

[116] 'Capturing the Multiple Benefits of Energy Efficiency', IEA Study, 2014.

Academic research has extensively analysed the informational barriers erected by the multiplicity of investment costs and benefits,[117] which impede the implementation of energy-efficiency projects. Beyond theoretical considerations, some practical implications are gaining attention. The EU Energy Efficiency Directive[118] establishes that Member States, in applying the energy efficiency first principle, shall ensure the application of cost–benefit methodologies that allow proper assessment of wider benefits of energy-efficiency solutions from the societal perspective. The challenges associated with multiple benefits have been examined by a specific working group of the Energy Efficiency Financial Institutions Group, which has advised financial institutions "to collect wider data sets and capture wider benefits beyond energy efficiency." A large number of industry studies seek to quantify the wider benefits of energy renovations. Examples include the Energy Efficiency Data Protocol and Portal, part of the Energy Efficiency Mortgages Initiative, and the study carried out by BPIE[119] to measure improvements in the performance and productivity of schools, offices and hospitals (similarly to the Mbenefits.eu study funded by Horizon 2020). The increased value of renovated properties and the impact of energy-efficiency investments are also receiving attention from the real estate industry[120] and regulators.[121]

Building refurbishments and investments in industrial facilities are typcail examples in the broader discussion of multiple benefits from energy-efficiency projects. Typically, building renovations entail interventions such as installing insulation, replacing windows and improving the building envelope or heating and cooling systems. Meanwhile, refurbishments often imply other upgrades unrelated to buildings' energy performance and intended to improve the comfort and quality of working and living environments. Similarly, energy-efficiency projects in industry can be designed and implemented in several ways, from replacing one piece of equipment to carrying out a full facility retrofit and modernisation. Alternatively, they may involve demand-side interventions resulting in facilities running at higher capacity, which tends to be less energy-intensive. Often, energy-efficiency measures (e.g. thermal insulation, boiler replacement, refrigeration) are integrated within larger renewal schemes to generally modernise a facility.

The multidimensional benefits of building renovations and industrial projects include energy savings, reduced GHG emissions and other economic benefits, such as extending the economic life of building elements or reducing maintenance costs. Other, more diffuse, benefits include improving the comfort and quality of working and living environments, enhancing productivity and competitiveness, reducing the costs of environmental or building compliance; reducing wastewater and solid waste disposal, saving resources (water and raw materials), and improving process and product quality.

22.1.3 The EIB's modus operandi for economic appraisal of energy efficiency

On the cost side of the CBA, the key challenge is separating the energy-efficiency component from the overall capital investment. On the benefit side, the economic value of energy (including externalities) is accounted for based on expected annual savings in electricity and heat, as compared to the baseline scenario. The challenge is how to account for other benefits.

In 2017 the EIB updated its CBA methodology for energy-efficiency projects to partially consider the multiple benefits they generate. In particular, the Bank identifies three tiers of economic benefits:

- **Tier 1:** energy savings, including externalities (e.g. emissions of CO_2 and airborne pollutants);
- **Tier 2:** extension of the economic life of building elements, reduction in maintenance costs and increases in property value. These are tangible benefits created by energy-efficiency projects;

[117] Energy efficiency as a credence good: A review of informational barriers to energy savings in the building sector Louis-Gaëtan Giraudet. Energy Economics, 2020, vol. 87, issue C
[118] Directive (EU) 2018/2002 of the European Parliament and of the Council of 11 December 2018 amending Directive 2012/27/EU on energy efficiency
[119] "Building 4 People: Quantifying the benefits of energy renovation investments in schools, offices and hospitals" (https://www.bpie.eu/publication/building-4-people-valorising-the-benefits-of-energy-renovation-investments-in-schools-offices-and-hospitals/)
[120] Cushman Wakefield (2021) Europe, The DNA of Real Estate, Fourth Quarter 2020 (https://cw-gbl-gws-prod.azureedge.net/-/media/cw/emea/a-emea-shared/insights/pdf-reports/2020-q4-dna-real-estate-europe-cushman-wakefield.pdf?rev = 971ffbb2c52c4a878215bed223859ba8)
Jones Lang LaSalle (JLL) (2020). "The impact of sustainability on value." (https://www.jll.co.uk/en/trends-and-insights/research/the-impact-of-sustainability-on-value)
[121] Benjamin Guin and Perttu Korhonen (January 2020). Does energy efficiency predict mortgage performance? Staff Working Paper No. 852. Bank of England.

- **Tier 3:** improvement of the comfort and quality of working and living environments, enhanced industrial productivity and poverty alleviation — all difficult to quantify and estimate.

For instance, installing new, higher-performing windows (e.g. double-glazed) not only generates the Tier 1 benefits of energy savings but also brings the Tier 2 benefits of extending the building shell's economic life.

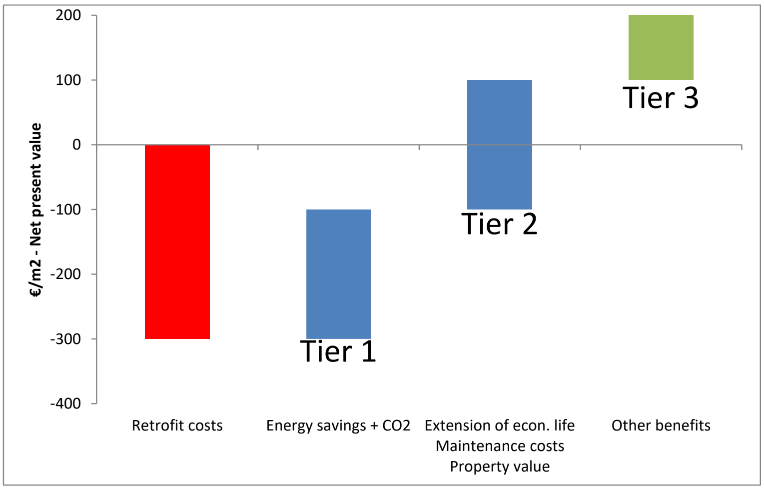
In some cases, each tier of benefits accrues to different categories of stakeholder. This is typically the case for building refurbishments: tenants capture Tier 1 benefits through reduced energy bills, whereas property owners capture Tier 2 benefits through the longer economic life of building elements — a situation commonly described as "split-incentives."[122] Regardless of who profits from these benefits, they all contribute to the project's overall economic return.

The investment costs and three benefit categories are shown on an NPV basis in Figure 22-1. The split-incentives problem illustrates why refurbishment projects may be deemed non-viable when only Tier 1 benefits are included. Returning to the new windows example, tenants estimating the financial viability would compare the red bar (investment costs) with only Tier 1 benefits, and so would be reluctant to approve the installation. The owners would reach the same conclusion by comparing the red bar with only Tier 2 benefits. However, the project is actually economically viable as the sum of Tier 1 and Tier 2 benefits exceeds the investment costs.

Generally, Tier 1 benefits are systematically included in CBA, since the methodology used to estimate them is well documented and the necessary information tends to be available. The EIB uses shadow prices for electricity and heat to monetise the energy savings generated by the project.

Currently, the EU ETS covers only around 30% of building emissions from heating and cooling,[123] encompassing only DH and electricity used for heating purposes. Despite generating 75% of heating and cooling in the European Union (Eurostat, 2019), heating from fossil fuels is excluded from the EU ETS. As regards industry, the sectors currently covered by the EU ETS include power and heat generation and various energy-intensive sectors (e.g. production of steel, iron, aluminium, cement, paper and glass).

Figure 22-1: Economic benefits of energy-efficiency projects



[122] Academic literature has found strong empirical evidence of the split incentives problem, as documented by McCoy (2019). Brechling and Smith (1994) find lower ownership of energy-efficient assets in rented properties than in owner-occupied ones in the United Kingdom. Scott (1997) finds similar results in Ireland. Gillingham et al. (2012), using U.S. Residential Energy Consumption Survey (RECS), report that owner-occupied dwellings in California are 20% more likely to be insulated in the attic or ceiling than rented ones. Melvin (2018) extends the result to water heating, window thickness and weatherisation. Myers (2015) finds that energy price movements cause shifts in rents of energy-efficient units when rents include utilities, but not otherwise, suggesting the market does not convey information about energy use. In Europe, Krishnamurthy and Kriström (2015) report that owners are more likely to have energy-efficient appliances, better insulation and heat thermostats than tenants.
[123] https://ec.europa.eu/commission/presscorner/detail/en/qanda_21_3542

Estimating Tier 2 benefits is more difficult given the limited available information. A general approximation is not feasible because many idiosyncratic factors are at work, such as the real estate market and maintenance costs, which are normally larger for commercial than for residential buildings. Consequently, the Bank's methodology incorporates Tier 2 benefits on a case-by-case basis and only when the available information is reliable and sufficient to produce robust estimates. Based on experience to date, the Tier 2 benefits most likely to be robustly estimated (and thus included in the analysis) are the extended economic life of building elements and the reduced maintenance costs. For the extension of economic life, the EIB calculates the difference in value between the new building elements (excluding the Tier 1 benefits of energy savings and externalities) and the remaining economic value of replaced building elements. Only exceptionally, the increase in the property's market value is included, when robust evidence proves this is directly linked to the energy refurbishment and beyond other benefits.

In industry-based projects, by contrast, the extension of the economic life of elements is excluded following a conservative approach. While replacement of a given equipment item can definitely extend its useful life, in industry these interventions are not carried out to increase/preserve value. Instead, they are used as inputs of the production process, with the overall aim of improving the plant's productivity and the efficiency of its processes. Therefore, the multidimensional Tier 2 benefits in industry — ranging from reduced material costs to additional revenues from increased production and efficiency — cannot be captured by energy-efficiency measures only. Tier 2 benefits can be included in the CBA provided the full investment cost of the renewal is also included, so as to avoid overestimating benefits.

In summary, the Bank's CBA incorporates Tier 1 benefits and, on a case-by-case basis, Tier 2 benefits. It thus produces a lower-bound estimate of the project's real economic return.

22.2 Case study 1: Energy efficiency in buildings

All CAPEX for energy-efficiency improvements to the building envelope and systems are eligible for Bank financing if (i) in line with national energy performance standards (cost-optimum levels as required by the Energy Performance of Buildings Directive) or (ii) included in a list of measures defined by the EIB energy lending policy (2019).

This project involves the energy-efficiency renovation of a series of buildings, including over 9 000 apartments, in a European city. The renovation works mostly focus on the building envelope: upgrading insulation (walls, roof and floors); replacing existing windows with PVC double-glazed windows; and other energy-efficiency measures targeting heating, domestic hot water, and lighting systems. The energy-efficiency investment costs total €94.6 million. This project is part of an overall programme supporting the refurbishment of around 30 000 city apartments.

The thermal rehabilitation of residential buildings is a main measure of the national energy efficiency action plan. There are approximately 5.6 million buildings in the country, representing around 644 million m^2 of heated useful area. Residential buildings account for 90% of the entire building stock.

The specific unit costs for this project are €110/m^2 including value-added tax (VAT). These are in line with equivalent costs in previous operations and the actual price cost trends observed in the country's construction sector. The targeted buildings have an average primary energy consumption of around 205 kWh/m^2/year, on which savings of 40% are expected (based on the previous experience). Overall, the post-renovation energy savings for heating are estimated at 53 GWh/year.

Final beneficiaries benefit from a grant covering most of the investment costs. Owners' contribution is limited to 20% of eligible expenses, collected through a thermal rehabilitation tax levied for ten years (following a five-year grace period).

The vast majority of dwellings in the project buildings are connected to the DH network. Heat tariffs for households are subsidised by the national government and vary by region. The actual energy costs are €87.9/MWh, but subsidies limit the tariff paid by homeowners to €36.7/MWh.

Following the Bank's methodology, the shadow price for heat is used to monetise the thermal energy savings generated by the project. This value integrates financial cost components (fuel and transport costs avoided) with economic cost components, including reduced CO_2 and air pollutant emissions (monetised using the

Bank's estimated value for externalities). The investment grant and the subsidised component of the heating tariff are excluded from the calculations, since they are transfers of resourcse cancelling each other out in societal terms.

The (discounted) economic value of the achieved thermal energy savings amounts to €93.1 million (see Table 22-1). Energy savings are the main benefits generated by the project. In addition, the analysis considers the life extension of the building elements, with a (discounted) value of €19.2 million based on the difference between the investment costs and the remaining economic value of replaced building elements. The promoter could not quantify the reduction in O&M costs resulting from the project.

In total, the benefits generated by the project amount to €112.3 million, against (discounted) investment costs of €90.2 million, resulting in a project ERR of 7.4% and a project FRR of 5.1%.

Table 22-1: Calculation of the economic rate of return for an energy efficiency in buildings project

	Economic Analysis	
	Investment costs	**NPV**
(1)	Investment cost	-90.17
	Financial benefits	
(2)	Tier 1 - Energy savings	74.43
(3)	Tier 2 - Reduction O&M	0.00
(4)	Tier 2 - Extension economic life	19.23
(5) = (2)+(3)+(4)	Total Financial Benefits	93.66
	Economic benefits	
(6)	Tier 1 - Energy savings	93.12
(7)	Tier 2 - Reduction O&M	0.00
(8)	Tier 2 - Extension economic life	19.23
(9) = (6)+(7)+(8)	Total Economic Benefits	112.35
(10) = IRR{(1)+(5)}	**FIRR**	5.1%
(11) = IRR{(1)+(9)}	**EIRR**	7.4%

22.3 Case study 2: Energy efficiency in industry

Investments in renewing existing production facilities may be considered as energy-efficiency projects, provided (i) they are primarily motivated by energy savings and (ii) the project will not increase the facility's overall GHG emissions (EIB energy lending policy, 2019).

This project involves the modernisation of a bioethanol production plant. It currently produces approximately 240 000 m^3 of bioethanol per year, mainly sold for industrial uses and as a substitute transport fuel. The plant also contains a CO_2 liquefaction facility, which captures CO_2 from the fermentation process for use in the food industry.

The proposed investment amounts to €28.2 million and will finance the improvement of existing production processes through the following measures: a) general modernisation of plant infrastructure, including utilities and automation systems; b) rehabilitation of the wastewater treatment plant; c) expansion of existing cleaning-in-place systems; d) introduction of efficiency measures for process heat recovery and reuse; and e) improvement of the by-product production lines.

The project will produce significant gains in energy and resource efficiency, and expand the bioethanol capacity from 240 000 m^3/year to 250 000 m^3/year. It will also improve product quality and processing of by-products, and add a production line for a new bio-fertiliser generated at the facility.

Energy efficiency is the predominant component of the overall investment. Measures of energy efficiency for process heat recovery and reuse (heat exchangers) in different steps of bioethanol production (such as distillation, sieving, and mash preheating) amount to €10 million (36% of the total cost). Elements of improvement were identified in an energy audit carried out under article 8 of the EU Energy Efficiency Directive 2012/27/EU, as transposed into national legislation.

Overall, the energy-efficiency measures will generate thermal energy savings of 36 GWh/year relative to the pre-project scenario, i.e. around 20% of energy saved.[124] These energy savings will lower the plant's natural gas demand by about 3.2 Mio Nm^3 per year. In particular, the additional CO_2 emitted because of the capacity expansion will be more than offset by the reduced emissions achieved after project implementation, thanks to the thermal energy savings. In incremental terms, the project will save approximately 7 300 tons of CO_2 per year.

The shadow price for gas is used to monetise the thermal energy savings. This value integrates financial cost components (fuel and transport costs avoided) with economic cost components, including reduced CO_2 and air pollutant emissions.

The reference period is set at 17 years, including 2 years of implementation and 15 years of operations, calculated as the weighted average economic life of the renovated assets.

The results of the economic analysis are displayed in Table 22-2. The (discounted) economic value of the achieved thermal energy savings amounts to €30 million. The project's ERR is estimated at 8.5% and its ENPV at €20.7 million, taking into account the benefits from energy efficiency only. Therefore, the investment meets the EIB's eligibility criteria for energy-efficiency investments in industrial facilities. The inclusion of other benefits, such as resource (water) savings and additional revenues from increased bioethanol production, would further increase the overall project's economic performance.

Table 22-2: Calculation of the economic rate of return for an energy efficiency in industry project

	Economic Analysis - Energy efficiency in industry			
	constant 2020 EUR		**Total**	**Discounted (5%)**
(1)	Investment cost	EURm	10.0	9.3
	Energy savings	GWh	540.0	338.9
	Avoided CO2 emissions	tons	109058.4	68449.8
	Avoided NOx emissions	tons	73.9	46.4
(2)	Avoided fuel costs	EURm	18.0	11.2
(3)	Avoided social cost of carbon	EURm	31.3	18.2
(4)	Avoided cost of air pollution	EURm	0.9	0.6
(5) = (2)+(3)+(4)	**Total economic benefit**	**EURm**		**30.0**
(6) = (5)-(1)	**Economic Net Present Value**	**EURm**		**20.7**
	ERR - EE only	**23.5%**		
	EE capex/total capex	**36.0%**		
	ERR	**8.5%**		

[124] Electricity savings from the rehabilitation of the wastewater treatment plant are not included in the CBA model.

23. Heat supply

Susana Lagarto

23.1 Introduction

Projects in the DH sector include measures leading to improved efficiency of heating systems in the following areas:[125]

- DH, including extension or densification and rehabilitation of networks;
- Centralised combined heat and power generation (CHP, or cogeneration), heat-only boilers and heat storage;
- Buildings, with measures such as replacement of heating options and installation of energy management systems (e.g. remote metering);
- Industry, such as introducing waste heat recovery.

This chapter showcases the methodologies applied to economically appraise projects involving heat networks (section 23.2) and heat generation (section 23.3).

23.2 Heat networks

23.2.1 Project identification

To be eligible for Bank financing, investments in heating network infrastructure (e.g. pipes and substations) must meet the efficiency criteria for DH systems as prescribed in the Energy Efficiency Directive 2018/2002/EU.[126] The directive classifies these DH systems as those using at least 50% renewable energy, 50% waste heat, 75% cogenerated heat, or 50% of a combination of these energy sources. The project must also be forecast to lower or at least maintain the system's annual GHG emissions. Heat generation is assessed separately, applying the eligibility criteria defined in Annex 2 of the CBR.

If the DH system is already efficient pursuant to the Energy Efficiency Directive, it is important to evaluate whether this situation will likely continue in the medium and long term, or whether the current favourable situation risks becoming unsustainable. For example, an existing fossil-fuel-fired CHP plant may have to shut down for age or policy reasons, or waste heat from industry may cease to be available after a certain point. Therefore, even when the current DH system is considered efficient, it may not satisfy long-term decarbonisation objectives.

In this context, the demand outlook for the DH system should be substanciated by assessing:

- Current demand, based on statistics provided by the promoter;
- Future demand, based on reliable demand-forecasting models that consider macro- and socioeconomic forecasts, alternative supply sources, elasticity of demand to relevant prices and income, energy-efficiency goals, climate change impact, and other factors.

The estimation of future heat demand is crucial for identifying DH decarbonisation options. Energy demand estimates are key parameters in the financial and technical design of DH systems, thus also affecting the economic assessment.

[125] The same rationale generally applies to cooling networks as well, with the appropriate adaptations.
[126] For existing DH systems, eligibility is also met if there is a viable decarbonisation plan for the DH/DC system that ensures that the definition of efficiency is met within an acceptable timeframe.

The following main features are necessary for describing a project to extend or rehabilitate a DH system:

- Details of the planned investments (components, CAPEX, OPEX, etc.) and characteristics of the DH system in the “with” and “without” project scenarios, including:
  - Supplied capacity and annual volumes (divided by user type);
  - Heat production types, capacity and mix, generation efficiency;
  - Losses (production and distribution);
  - New/replaced pipe routes (attaching pertinent maps) and length (kilometres);
  - Other measures aiming to reduce heat losses (e.g. pump replacement, heat storage upgrades);
  - Measures aiming to reduce water losses through improved water management;
  - Measures aiming to optimise operating regime: supplying heat for space heating only versus space heating and domestic hot water, supply/return temperatures, pressure, hydraulic balancing, automatic control;
  - Replacing heat substations and/or installing smart metering;
- Building techniques and technical features of the main project elements;
- Contractual features:
  - Pricing/tariff arrangements for heat;
  - Evidence of heat generation investments/capacity, to be physically connected to the financed heat infrastructure, thus ensuring demand coverage and (if necessary) progress towards classification as an efficient DH system.

Economic life depends on the type of project components. Networks have an expected life of 25 years.

23.2.2 Economic profitability analysis

The economic profitability analysis of DH systems is based on their overall economic competitiveness compared to alternative individual heating systems. This is quantified by the savings in energy (volume and cost) and emissions (GHG, air pollutants) derived from the project and, where relevant, the improvement in security and quality of supply. To assess these projects, information is needed on the investment cost; the energy savings to be achieved (relative to the “without project” or baseline scenario) from connecting new users or reducing losses through renovations; and the impact of the investment on operating costs. If the DH system includes heat supply via a CHP, the benefits also include the value of additional cogenerated electricity.

A long-term analysis of heat demand is the starting point for ensuring the DH system is sized correctly and will be sustainable over the lifetime of its assets. This is particularly important given the focus on and expected investment in energy efficiency over the coming years, which must be reflected in demand forecasts.

The economic analysis is normally based on comparing the discounted heat supply costs of the project with the costs of the best alternative. This comparison considers the costs of investment, fuel (when applicable), O&M, heat losses and environmental externalities. For network refurbishment projects or components, the benefits are estimated by comparing the “with” and “without” project scenarios. There may also be benefits related to the reduction of heat supply disruptions. In addition to evaluating the incremental economic profitability, the analysis tests whether the refurbished system (“with project” scenario) is competitive when compared with the best alternative individual heating solution.

Like for electricity, two types of levelised cost can be estimated: financial and economic. The financial levelised cost should be based on observed market prices and related forecasts of the future costs and prices to be borne by the owner(s) of the heat generation/distribution assets, including grants, tariff subsidies and taxes, as applicable. The economic levelised cost should be complemented with the assessment of external costs be borne by society at large: for example, the value of damage caused by airborne pollutants and GHG emissions. For CHP options, the value of power generation is netted out from the heat generation cost, where appropriate (e.g. when the primary project objective is to deliver heat). To estimate the levelised cost, the NPV of the different cost components over the project lifetime is divided by the NPV of the total generated/supplied heat over the same period.[127] Table 23-1 summarises the elements typically considered in the economic and financial levelised cost of heat (LCOH).

[127] Using the Bank’s social discount rate.

Table 23-1: Levelised cost of heat (LCOH) elements

Economic LCOH	Financial LCOH
CAPEX	CAPEX (net of grants)
+ O&M costs (benchmark)	+ O&M costs
+ Fuel costs (if relevant)	+ Fuel costs (if relevant)
+ Social cost of CO_2 emissions **+ Social cost of SO_2, NO_x and/or particular matter (PM)**	+ CO_2 (Emissions Trading Scheme) allowance costs or carbon tax (as relevant)
– Economic value of power sales (if relevant)[128]	– Revenue from power sales (if relevant)
= Net LCOH (economic)	= Net LCOH (financial)

Box 23.1: The economic value of heat

An investment programme for extending DH to new residential dwellings is compared with the best individual alternative to the project. To estimate the economic value of the annual benefit associated with centralised DH supply, the economic LCOH for domestic heat pumps is generally used to proxy for consumers' maximum WTP. The estimation assumes average weather conditions.

Air-to-water heat pump
Capital cost
Electricity cost[129]
O&M costs
Social cost of CO_2 emissions
Social cost of airborne pollutants
Economic LCOH (in €/MWh)

The LCOH is derived from detailed calculations using data for different climatic conditions[130] and for buildings of varying size and quality.[131] This data is updated as needed, for instance to adapt to the project's base year or to climatic conditions in the project location, as the load factor influences the levelised cost. The electricity cost/source and associated externalities are also adapted to fit the project location and market.

The competitiveness of the DH system is evaluated by comparing its costs against those of alternative individual solutions. Given the Bank's carbon externality cost, the cheapest economic alternative to a centralised DH system is currently the individual air-to-water heat pump. Therefore, this solution is the counterfactual scenario generally used, as individual boilers (using natural gas or gas-oil) — in many locations the "do-nothing" scenario — are neither competitive nor viable given their incompatibility with global decarbonisation goals and the growing carbon externality cost. Domestic biomass-based heating is also more expensive and far less convenient for users compared to DH. If the price of heat from DH is significantly higher than that of the best alternative option, the DH is likely unsustainable in the medium to long term, or dependent on regulatory measures that restrict consumer options.
It is also important for the related financial cost to be competitive and affordable for users. The financial LCOH can be considered a rough approximation of a cost-covering heat tariff (e.g. if regulated on a cost-plus basis).[132]

[128] To be estimated based on the methodology presented in the 'Power generation' section.
[129] To be estimated based on the methodology presented in the 'Power generation' section.
[130] Which effect heat demand, but also the average coefficient of performance of heat pumps, i.e., the amount of heat output per electricity input. The need for heating was captured through the use of "heating degree days" (HDD). HDD is an index designed to describe the need for the heating energy requirements of buildings depending on the weather conditions.
[131] As heat pumps are a high investment cost solution, the installation in larger buildings allows the initial costs to be shared among a larger number of households.
[132] Differences could, for example, stem from: (i) differences between the *ex-ante* cost estimates and the actual costs incurred; (ii) differences in the related depreciation period included in the heat tariffs by the regulator; (iii) differences between the return on capital embedded in the discount rate used in the LCOH and the allowed profit included in the regulated tariffs; (iv) in the case of co-generation assets, differences between the cost allocation method to transfer common heat and power costs to the heat tariff and the residual net LCOH after deduction of power sales revenue.

23.3 Heat generation

23.3.1 Project identification

The following main features must be included in the description of a heat generation project (new or upgraded):

- Location, scale and purpose of the project (e.g. to meet demand growth, enhance reliability and security of supply, replace obsolete capacity, or “decarbonise” existing supply);
- Basic functional data:
  - Type of plant and technology (heat only or CHP);
  - Fuel mix used, which must comply with the EIB’s emissions threshold (e.g. a combination of fuels including green hydrogen, biomethane and/or natural gas meeting the energy lending policy emissions limit; biomass; geothermal; solar);
  - Connecting facilities to heat, power and/or gas/hydrogen grids;
  - Installed capacity (MW);
  - Fuel and/or heat storage capacity;
  - Carbon capture facilities (if any);
  - Expected fuel efficiency, plus envisaged operating mode and load factor;
  - Expected share of electricity versus heat output (for CHPs);
- The full investment cost (for land, buildings, equipment, licences, patents, etc.), including relevant investment needed to connect electricity/gas/hydrogen/heat transport infrastructure (even if implemented by a third party);
- The phasing of the investments;
- O&M costs;
- An analysis of the relevant heat market, indicating:
  - the supply/demand situation and expected development;
  - main customers and competitors;
  - average and peak demand;
  - position of the investment project in the merit order;
- Building techniques and technical features of the main project elements;
- Contractual features:
  - Long-term offtake arrangements;
  - Pricing/tariff arrangements for heat (and power, if relevant).

23.3.2 Economic profitability analysis

The technical assessment of heating plants should focus on four key areas:

- Adequacy of the heat production capacity to meet actual demand without interruption (using a combination of base load and peak load production facilities);
- Compliance of the heating plants with environmental requirements and criteria for efficient DH systems, as defined in the EU Energy Efficiency Directive;
- Compliance of biofuels (if used) with applicable sustainability criteria;
- Energy efficiency of the heating plants, calculated as net heat production per fuel input.

Available heat production capacity should be sufficient to cover all customers' heat demand during normal steady-state operation and in emergency situations. Heat production costs and efficiency should be optimised to ensure that security and quality of supply are acceptable and in accordance with the contractual and heat delivery requirements. The maintenance of heat plants should also be analysed, keeping in mind the objective of minimising supply interruptions.

The economic profitability analysis is based on a least-cost assessment of the project in terms of the heat produced/supplied (LCOH, in euros per MWh of heat (MWh_{th})). The LCOH approach compares the project's discounted generation cost (LRMC) — including the costs of investment, fuel, operations and all relevant externalities — to the costs of viable alternative options (the "do-something (else)" scenario) or to the avoided individual heating costs (the "do-nothing" scenario).

The discounted cost of heat production, including economic externalities, is calculated based on a 5% discount rate (within the European Union) and an economic life of 15 years.[133] Economic costs typically include:

- **Capital investment costs**: these cover the plant and direct connection infrastructure;
- **Fixed O&M costs:** these are generally estimated as an annual expenditure equal to a percentage of the investment cost, varying per technology type;
- **Fuel costs:** the Bank uses its own set of fuel price scenarios or the expected/contracted locally sourced fuel price (e.g. for biomass). Transport costs are included whenever relevant. Low-carbon gases are considered using their contractually committed volumes and pricing methodology;
- **Greenhouse gas emission costs**: the Bank's shadow cost of carbon is used to value changes in CO_2 emissions associated with the project (see chapter 4);
- **Airborne pollution costs (nitrogen oxides (NO_x), sulphur dioxide (SO_2) and particles):** their estimated impact on the environment and health has been valued by an external study (ExternE), and the Bank applies these externalities as applicable to the technology and fuel type of the generation plant (see chapter 6);
- **Load factor/operating regime:** the estimated utilisation of the plant will affect the project's capacity to recoup the investment and fixed O&M costs, affecting its economic viability in the long run.

Heat generation is among the most important elements for the viability of DH systems. Cheap and efficient heat supply is essential to overcome the inherent losses and compensate for the high capital costs of the distribution network. The key factors in determining whether a heat source is cheap are the investment and O&M costs, fuel cost, environmental cost, and plant efficiency. Renewable heat sources, such as geothermal or biomass (for heat only), are regularly the most competitive (from an economic point of view) when compared with decentralised heat supply options, due to their limited environmental impact. They are, however, dependant on local availability conditions. Other important elements for determining the competitiveness of DH are the level of heat losses, the cost of rehabilitation, and O&M cost-efficiency.

[133] Which can be reduced/extended depending on project specifics, e.g., if ELP compliant fuel supply is only ensured for 10 years.

For CHP plants designed to maximise heat supply, overall annual production efficiency of 80–90% is considered reasonable. Such plants should aim to meet the requirements for high-efficiency cogeneration, as defined in the Energy Efficiency Directive. In these cases, the value of cogenerated electricity is considered as an additional benefit in LCOH calculations.

The Bank's CBA of heat generation projects is based on a similar conceptual framework to that applied for power generation (see chapter 20). For DH projects, as consumers' maximum WTP is valued at the point of heat consumption (as the LCOH for individual heating solutions), the analysis must also include the costs and losses associated with heat distribution, in addition to the project's heat generation costs.

It is also necessary to conduct a sensitivity analysis by adjusting the key variables, particularly CO_2, fuel prices and the load factor.

23.4 Case study: Extension of a DH network in the European Union

The project concerns the extension of a small DH network in an EU country, including the refurbishment of existing gas boilers and the construction of a new geothermal plant to cater for the additional heat demand.

The promoter's demand studies concluded that approximately 100 buildings can be connected, resulting in 150 GWh of additional heat demand. The proposed investment will be realised within three years. The additional heat demand from new users will mainly be met by geothermal energy, a renewable source available in the area. Peak and backup demand will be catered by natural gas boilers (approximately 25% of annual supply after project completion). Extending the DH service (production, pipes and substations) will result in energy and emissions cost savings. No network refurbishments will be carried out since the level of losses in the existing network is low; this is primarily a network-extension project.

According to the promoter's statistics, the residential sector accounts for a substantial portion of total heat demand (70%). The counterfactual WOP scenario assumes that, economically, the best alternative heat-supply solution for those residential users would be individual heat pumps, with an LCOH of €110/MWh_{th} (including all externalities associated with the required electricity generation). The larger public buildings being connected have their own large gas hot water boilers as the best viable alternative, estimated to have an economic LCOH of €100/MWh_{th}.

The economic cost of heat supply is estimated at approximately €82/MWh_{th}, including CO_2 and other external environmental costs (i.e. NOx, in relation to the use of peak gas boilers). The calculation of the economic profitability is presented in Table 23-2. Based on the economic cost of the energy saved, including environmental external costs, the project has a positive NPV and an ERR of 14%.

Table 23-2: Calculation of economic profitability for a district heating network extension project in the European Union

Economic Analysis

(2020 Constant Prices)

	General Assumptions	Units	
	Discount Rate (SDR)	%	5
(1)	Alternative Cost (LCOH large gas hot water boilers, incl. externalities)	Eur/MWh	100
(2)	Alternative Cost (LCOH indiv. heat pumps, incl. externalities)	Eur/MWh	110
(3)	Alternative Cost (LCOE of CCGT w/o capex, incl. externalities)	Eur/MWh	147
(4)	Peak gas hot water boiler (LCOH w/o capex, incl. externalities)	Eur/MWh	94
(5)	Geothermal hot water boiler (assumed opex cost)	Eur/MWh	10

	DH Extension Project in the EU	Units	PV @ 5%	Y1	Y2	Y3	Y4	Y5	Y10	Y15	Y20…
	Project Costs										
	CAPEX per item of investment										
	Heat Generation (Gas boiler)	MEUR	5	0	5	0					
	Heat Generation (Geothermal)	MEUR	23	0	25	0					
	Network Extension	MEUR	36	10	20	10					
(6)	**TOTAL CAPEX**	**MEUR**	**64**	**10**	**50**	**10**	**0**	**0**	**0**	**0**	**0**
(7) = (5)*(12)*RE Share	**Cost of additional heat supplied from Geothermal**	MEUR	13	0	1	1	1	1	1	1	1
(8) = (4)*(12)*Gas Share	**Cost of additional heat supplied by peak Gas boilers**	MEUR	48	1	2	4	4	4	4	4	4
(9) = (6)*3%	**Other OPEX (3% of Capex)**	MEUR	3.0%	0	2	2	2	2	2	2	2
(10) = (7)+(8)+(9)	**TOTAL OPEX**	**MEUR**	**87**	**2**	**5**	**7**	**7**	**7**	**7**	**7**	**7**
(11) = (6)+(10)	**TOTAL COSTS**	**MEUR**	**150**	**12**	**55**	**17**	**7**	**7**	**7**	**7**	**7**
	Project Benefits										
(12)	Additional heat consumption catered by Project (sales)	GWh	1,834	50	100	150	150	150	150	150	150
(13) = (12)*Resid Share*(2)	Savings in Residential+Commercial share in additional demand	MEUR	70%	4	8	12	12	12	12	12	12
(14) = (12)*Ind Share*(1)	Savings in Industrial/Large building share in additional demand	MEUR	30%	2	3	5	5	5	5	5	5
(15) = (13)+(14)	**Savings from additional heat supplied**	**MEUR**	**196**	**5**	**11**	**16**	**16**	**16**	**16**	**16**	**16**
	Electricity saved from conventional generators (avoided generation)	GWh	0	0	0	0	0	0	0	0	0
	Savings in elect. generation (per alternative SRMC)	MEUR	0	0	0	0	0	0	0	0	0
(16) (Not applicable, no CHP)	**Savings from avoided electricity generation - N/A**	**MEUR**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Heat generation saved from refurbishments	GWh	0	0	0	0	0	0	0	0	0
(17) (Not applicable, new network)	**Savings from reduced losses - N/A**	**MEUR**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
(18) = (15)+(16)+(17)	**TOTAL BENEFITS**	**MEUR**	**196**	**5**	**11**	**16**	**16**	**16**	**16**	**16**	**16**
(19) = (18)-(11)	**PROJECT ECONOMIC CASH FLOW**	**MEUR**	**46**	**-6**	**-44**	**-1**	**9**	**9**	**9**	**9**	**9**
(20) = IRR (19)	**ERR (over average economic life of project components)**		**14%**								
	Discounted DH Distribution Cost (network + heat generation)	**EUR/MWh**	**82**								

24. Health

Dorothee Eckertz

24.1 Methodology

24.1.1 Introduction

Since the EIB started lending to the health sector in 1997, there has been steady growth in the range of health projects benefitting from Bank funding, within and beyond the European Union. For many years, investments in physical hospital infrastructure received the bulk of investments. Yet this portfolio structure has been shifting over recent years. Amid the rapid digitalisation of healthcare, demographic and socioeconomic challenges, climate change and — most recently — the SARS-CoV-2 pandemic, the role and value of the health sector for society is profoundly changing. Consequently, the Bank's health sector portfolio is expanding rapidly to include more comprehensive, sector-wide projects in response to short- and long-term financing needs. The EIB is thereby helping to make health systems in Europe and throughout the world more resilient to future threats.

EU policy on health is complex and evolving, with responsibilities still divided between the European Union and Member States — individual countries continue to lead on healthcare delivery. Reflecting subsidiarity, the policies and objectives of Member States normally underpin healthcare investment decisions, and therefore the projects submitted to the Bank for funding.

The methodology described in this chapter focuses on evaluating the appropriateness and robustness of a project, together with the net value it will bring to society within the strategic context (see Chapter 1). However, in view of the changing needs from the EIB's and society's point of view, an expanded methodology will be developed for cases where the Bank may seek to prioritise projects across settings and sectors explicitly and on the grounds of comparative economic return or other quantitative decision criteria for health-sector investments. This methodology will include the established principles of CBA, CEA and other acknowledged valuation tools for health projects (such as MCA). It will outline their application in a sector-specific context and reflecting the Bank's evolving role in financing such projects following the COVID-19 pandemic.

24.1.2 Economic appraisal of health projects

The Bank adopts a multiple-stage economic appraisal for all health projects:

- **Stage 1:** Evaluate the strategic context, rationale for investment and general feasibility;
- **Stage 2:** Evaluate the project's economic aspects in comparison with the alternative(s), using an appropriate quantitative method to obtain numeric values whenever feasible;
- **Stage 3**: Compare the benefits of the chosen alternative to its costs, by estimating the project's FRR where possible and meaningful;
- **Stage 4**: Assess the project's contribution to social welfare (over and above returns to investors), expressed as the spread between the project ERR and project FRR, as applicable;
- **Stage 5**: Evaluate the project's contribution to key public policy objectives for health sector investments (in particular achieving Universal Health Coverage,[134] the Sustainable Development Goals (SDGs), and main EU policies[135]).

[134] This refers to the conceptual framework of Universal Health Coverage, as defined by the World Health Organisation.
[135] As reflected in, among others, the Bank's framework for Additionality and Impact Measurement (AIM)

24.1.3 Main appraisal aspects

The context for, and nature of, health projects appraised by the Bank varies widely in numerous regards:

- Country/regional context, including:
    - The relative development of health systems and the availability of resources to deliver healthcare;
    - National policies, strategies and plans for improving health services;
- The nature of projects for which EIB funding is sought, including specialist centres, university and general hospitals, primary care centres, public health schemes (such as large-scale prevention and vaccination campaigns), health technologies, R&D, e-health/digital health, and medical (professional) education;
- Promoters of health projects:
    - Public-sector entities and private-sector providers;
    - Differential development of healthcare planning and investment appraisal techniques, and variable availability of relevant and reliable data, information and analysis;
- Timescale for project implementation and return on investment:
    - Emergency interventions;
    - Fixed-term individual projects;
    - Longer-term strategic investment programmes, often with a phased approach.

Because of this variability and material differences in the information supplied by promoters, the Bank cannot generally use a single analytical framework or appraisal methodology for all health sector appraisals. Therefore, the Bank's approaches vary with respect to the assessment and evaluation of investment benefits. Moreover, it is often not feasible to calculate the ENPV or ERR for health projects, and thus perform a full-fledged CBA (although approximation efforts are being undertaken), given the significant difficulties of measuring and valuing the health benefits expected to arise from investments in healthcare infrastructure. A main challenge is the lack of reliable outcome information for the wide variety of services delivered via EIB-financed infrastructure. Where standard CEA is relevant and feasible, the Bank seeks to use this method. For the rare cases in which outcomes are not expected to materially differ following a project's delivery, least- cost analysis is used. In most cases, however, the Bank appraises health projects using MCA, undertaken to different levels of sophistication, quantification and qualification. This involves relying on the informed professional judgment of sector experts to value healthcare benefits, compared with total project costs. These judgments are supported by the analysis of key project variables and informed by the collective knowledge and experience of the Bank's health economists.

24.1.4 Valuation of costs and benefits

With no universal approach for determining the monetary value of costs and benefits in health projects, the Bank may employ established valuation methods as and where appropriate. The two main methods involve establishing shadow prices by estimating ***WTP*** and/or the ***VOSL***.[136]

A shadow price is a monetary value assigned to currently unknown or difficult-to-calculate costs in the absence of explicit or undistorted market prices. It is based on the estimated WTP of end-users. For most EIB-financed hospital infrastructure projects, the main element requiring shadow pricing is differential service quality, e.g. in a new, modern hospital versus old premises, if it is a replacement construction. In the healthcare sector, it is challenging to distil end-users' WTP because payment is often intermediated through insurance policies, and there is a strong principal–agent relationship, particularly for complex healthcare services.

The VOSL focuses primarily on valuing averted mortality, which is especially difficult to measure in EIB-financed hospital infrastructure projects, again because these generally involve modernising or relocating existing hospitals. Yet these benefits are often the central focus and main objective in EIB projects, particularly in the more complex cases of investing in common goods for health. Therefore, while the Bank is devising a consistent approach to address these challenges, it continues to assess the use of VOSL and WTP methods on a case-by-case basis. It may be necessary to employ other methods for appraisal, such as MCA, particularly when there is no empirical evidence for a country or service to enable estimation of the VOSL, or in the absence of a suitable proxy for WTP.

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[136] Including value of a statistical life-year.

Building on the principles of MCA set out in chapter 11, this chapter outlines a systematic approach to using MCA to assess project benefits, thereby facilitating consistency and transparency in the Bank's appraisal of healthcare investment without a full CBA. The method builds primarily on the Bank's practice and experience in appraising public sector health projects in EU countries, and is illustrated in the accompanying case study (see section 24.2).[137] This chapter also highlights some specific issues encountered while undertaking the economic evaluation of health projects.

24.1.5 Strategic context and investment rationale

Where healthcare markets are not efficient, we cannot rely on market forces alone to deliver allocative efficiency for the country/region or sector/subsector as a whole. It is, therefore, critically important for the EIB to appraise health projects within the context where the investment and subsequent healthcare operation will function. Hence, the Bank evaluates the strategic context and project rationale before, and as a precursor to, examining the project in more detail. For countries where the Bank has not previously lent to the health sector, or for new and innovative healthcare concepts, a full sector study will ideally be performed; in other cases, the investment context and project rationale are fully evaluated.

Key assessments include:

- Independent, critical examination of the strategic context:
  - International, EU, and/or relevant regional, national and local health and healthcare policy context, and the economic importance of health and the healthcare system;
  - Health and healthcare strategies and plans that provide the framework for delivering health improvements;
  - The current position from a system-wide perspective, including healthcare capacity, distribution, utilisation and performance, the need to invest in public goods as well as human, infrastructure, financial and information resources;
  - Future healthcare needs (health needs, healthcare demands, service workloads and capacities) and anticipated resources available to meet them;
  - Key issues arising from the above, including strategic responses to international, national and local pressures for change that require health infrastructure investment in several dimensions, such as climate change adaptation and mitigation, improving health system resilience, pandemic preparedness and essential public health functions;
- Assessment of the project's consistency with, and support for, implementing:
  - Relevant EU policy and actions on health and healthcare delivery;
  - National and local policies, strategies, trends and plans;
  - Internationally recognised policies, treaties and best-practice approaches;[138]
- The robustness of the rationale for investment, expressed in policy, strategic, service and resource terms.

Unless and until a robust strategic context and underlying project rationale justifies investment (where such rationale is taken as a proxy for the allocative efficiency test that would be offered by CBA), the Bank will not proceed to full appraisal of a health infrastructure investment project.

[137] Though most of these principles also apply to economic evaluation of private sector health projects and projects outside the EU.

[138] This has become especially important in the context of the pandemic caused by SARS-CoV-2, for which a key evaluation criterion is alignment with international agreements and evidence-based best practice

24.1.6 Demand analysis

A rational, appropriate and well-planned healthcare investment project assesses the future need, demand, resource availability, technological development and service capacity in the planned catchment area, based on the demographic situation and forecast trends. These factors are also key cost drivers and represent healthcare inputs and outputs that generate health benefits — and, hence, facilitate assessment of relative costs and benefits. Project promoters examine these factors with varying degrees of rigour and precision, lacking a common approach. Given this variability, to judge the robustness of healthcare and infrastructure planning for a project, the Bank assesses the promoter's forecasting methodologies (if any) and examines the related planning processes and their outcomes with reference to internationally accepted best practices. The Bank's comprehensive, multidimensional approach considers the international context, the expected evolution of the burden of disease, and key externalities that may affect future demand for healthcare services, such as climate change and socioeconomic determinants of the population's health status.

24.1.7 Evaluation of alternatives

The Bank also examines the process by which promoters have identified the investment project within the strategic healthcare context, including how they developed and evaluated strategic and other alternatives and selected the project submitted to the Bank for funding. The EIB also seeks to ascertain the specific health, healthcare and related objectives of the project and what constraints may impede their achievement. Each project is evaluated against a single counterfactual or a range of options for delivering the promoter's objectives (see chapter 3 on counterfactuals). At a minimum, comparison should be made against a "do-nothing"[139] or a realistic "do-minimum"[140] option — not simply the static situation before and after the project, which assumes implicitly that "before" is a realistic and continuous state, neither deteriorating nor improving. For each counterfactual, the total discounted cost (typically NPC) is compared with the expected benefits.

24.1.8 Appraisal of benefits using multicriteria analysis

The Bank uses different forms of MCA to assess the benefits of health projects. The systematic approach outlined below (and illustrated by a simple case study) enables comparison of the project with alternatives and facilitates the ranking of multiple options. The purpose of MCA is to compare the project's benefits with those of other options for meeting the investment objectives. When combined with the total discounted costs of each option, MCA enables assessment of the comparative economic case for the project. Accordingly, the economic decision-criterion is the incremental "cost–benefit effectiveness" of the project and other options, as represented by the incremental discounted cost per benefit point.[141] This indicator is useful where the Bank's appraisal analyses two or more options for delivering the project objectives.

Depending on circumstances, the Bank's health project appraisal involves examining and evaluating the analyses undertaken by promoters, conducting analysis of the key economic parameters or, more commonly, a combination of both approaches. For MCA, this appraisal process involves:

- Drawing from the healthcare policy and strategic objectives and, within this context, the specific objectives of the investment[142] to establish:
    - The benefit criteria to be examined and evaluated in the MCA;
    - The relative importance (weight) of each benefit criterion;
- As far as possible based on quantitative indicators, examining the extent to which each option ("do nothing," "do minimum" and the project) delivers the expected benefits, criterion by criterion;
- Calculating the total weighted scores for each investment option;
- Where required, undertaking sensitivity testing with respect to criteria weights and option scores.

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[139] A full understanding of the implications of no change at all to the current situation, which in some circumstances could have important consequences for the continuation and quality of healthcare.

[140] The minimum change and investment required if the Project is not implemented, incorporating the costs of maintaining the current service over the lifetime of the proposed Project. This may include significant costs just to maintain the status quo—buildings and plant may have come to the end of their useful life and may need replacing or upgrading and where patient workloads are increasing, maintaining the service may require additional staff, energy and other operating expenses.

[141] The implicit assumption is that all "benefit points" are of equal value. Where there is a concern this might not be the case, the scaling or weighting of the attributes may need modifying and different weights/scores may need to be tested through sensitivity analysis.

[142] Typical criteria might include, for example, improvements in clinical quality, access, scope and level of service, and performance (not already reflected in costs) and ease of staffing, ease and/or timing of implementation, etc.

Without actual valuation, project benefits cannot be discounted for easy comparison with discounted costs. Nevertheless, the timing of benefits may be an important factor in the promoter's investment decision-making, and so should be reflected in the MCA. Benefit timing can be captured within the benefit scores (benefits are "soft" time-weighted); more commonly, though, a time-related criterion is explicitly included in the benefits appraisal.

24.1.9 Wider (displacement) impact

Strategic changes to healthcare delivery, including those facilitated by major capital investment, frequently have knock-on implications for other parts of the health sector. For example, a hospital relocation will improve access for some of the population but may worsen it for others, who will consequently attend a different hospital; relatedly, the successful delivery of changes to a hospital function will often require support from complementary services outside the project. Drawing from the strategic context and project definition, and where material to the appraisal, these wider implications are incorporated into the economic evaluation — whatever form that takes. This enables an appropriate like-for-like comparison of alternatives (e.g. on the cost side, by incorporating the costs/savings accruing elsewhere in the healthcare system).

24.1.10 Equity and inequalities

There remain wide variations in health status and differential healthcare access within countries, across the European Union and beyond. Accordingly, the Bank endeavours to assess a project's contribution to reducing healthcare inequities and health inequalities in accordance with EU health policy, as well as in the context of attaining universal healthcare. In particular, whether, to what extent and for whom healthcare access is improved and/or worsened by the project's implementation is an important factor in the Bank's appraisal. This issue is examined at different stages of the appraisal, including when evaluating the strategic context, the investment rationale, the objectives set and constraints upon them, the options examined, the overall project design and the anticipated outcomes. Whenever equity concerns are an important consideration, an appropriate benefit criterion is explicitly included in the MCA exercise.

24.2 Case study: New-build replacement hospital

24.2.1 The hospital project

At an initial total investment cost of almost €211 million, the project comprises a new-build replacement acute hospital of 295 beds, which will facilitate and support the transformation of local healthcare services. The two existing acute hospitals will be merged into a single service and relocated to a new, purpose-built facility on a greenfield site. The new hospital will be complementary to and networked with other local health and social care services in the area.

24.2.2 Strategic context and project rationale

Based on publicly available documents and material from the promoter, the strategic context is a national and local policy of modernisation to deliver safe, accessible, sustainable, equitable, affordable and high-quality health services. This is reflected in a range of strategies for transforming and developing health and social care, including standards for service access, new models of service delivery, effective networks with other acute services nearby, and integration with other forms of care (primary, community and tertiary healthcare, and social care). Within this context, the current hospital configuration does not and increasingly will not adequately meet the population's healthcare needs or public expectations. It faces challenges in terms of clinical risks/safety, adequacy of human resources, service cost and value for money; current infrastructure is inappropriate for modern healthcare delivery and not easily accessible to the local population.

24.2.3 Market analysis

In the context of demographic change, a new service delivery model and national assumptions on the redistribution of services, the promoter developed a number of workload scenarios for the local area and for the hospital project in particular. The promoter concluded that a 12% higher hospital inpatient caseload is expected by the end of the decade, in eight years time, compared to current caseload at the time of appraisal. Combined with improvements in hospital throughputs, this workload increase generates a total requirement for 337 beds across the area: 295 acute beds in the new hospital and 42 intermediate care beds in different settings. Having examined the promoter's methodology, the Bank considers this approach a reasonable basis for planning infrastructure investment; given future uncertainties, it provides some flexibility for later changes to service levels and mix (by varying throughputs).

24.2.4 Option evaluation

The promoter's option identification and evaluation process involved three stages: developing models for delivering acute hospital services; identifying site options for a new acute hospital; and evaluating the costs and benefits of shortlisted options. From a longlist of eight service configurations and three possible sites, three options were selected for full appraisal: the "do-minimum" option, refurbish and extend an existing acute hospital, and construct a new-build hospital on a (specific) new site. The "do-minimum" option represents a realistic baseline for comparison, involving investment in existing hospital facilities to meet statutory standards on health and safety through ongoing maintenance and equipment replacement (i.e. minimum investment to maintain the status quo), but without delivering the improvements generated by the new service model and hospital reconfiguration. The other comparator (refurbishment and extension) was designed to deliver the service strategy by utilising and adapting one existing hospital.

24.2.5 Wider (displacement) impact

The current service configuration (and the "do-minimum" option) comprises two small acute hospitals with a combined total of 365 beds. Through the transformation of local healthcare services, a proportion of the workload currently undertaken in these acute hospitals will be shifted to intermediate care settings (i.e. displaced). To ensure a like-for-like comparison, the discounted costs of the new-build and refurbishment/extension options were supplemented by the Bank to include an estimate of the cost of workloads to be delivered in alternative local settings.

24.2.6 Equity and inequalities

The key equity consideration for the project is access to healthcare services overall and for different groups of the local population. The drivers for change in local healthcare policies and strategies primarily concern: equity of access to an appropriate range of good quality clinical services and healthcare facilities, helping to reduce inequalities in health outcomes; improved access to services, especially for rural populations and the disabled; the availability of alternatives to acute inpatient care (ambulatory, intermediate care, etc.); and integrated models of care delivered by multidisciplinary, multiprofessional teams across the local healthcare system and within the new hospital. The healthcare transformation plan and the future model of care for hospital services are designed to address these considerations. In addition, the relative accessibility of appropriate services is appraised explicitly in the MCA summarised next, in section 24.2.7.

24.2.7 Economic evaluation — Net present cost and multicriteria analysis

The costs of the three options evaluated are set out in Table 24-1.

Table 24-1: Total option costs, € million

Costs & Benefits	Minimum	Refurbish/Extend Existing Hospital	New Build Hospital (the Project)
Initial investment costs	47.6	206.8	210.7
Life-cycle investment costs*	13.2	34.1	38.4
Annual operational cost (once complete)	43.9	44.3	44.2
Net Present Cost (at 4%[7], 30 years)	**885**	**993**	**1 015**
Rank	1	2	3
Advantage over minimum option	-	+12%	+15%

* The investment costs incurred throughout the life of the Project (excludes annual maintenance)

Drawing from the strategic context, change drivers and investment objectives, the promoter defined seven benefit criteria and weighted them by relative importance. Wherever possible, taking advantage of supporting data and analyses, the Bank evaluated the ability of each option to deliver the project benefits. The total weighted benefit scores were calculated for each of the three options, as outlined in Table 24-2. Given the relatively large differences in expected benefits between the three options, the Bank's limited sensitivity testing demonstrated that the MCA outcome was insensitive to the weights assigned as part of the appraisal criteria and to individual option scores.

Table 24-3 compares the costs and benefits. At a 4% discount rate (the discount rate for the country) and a 30-year discount period, the new build hospital project generates an average cost (NPC) per benefit point 30% lower than the "do-minimum" option and almost 15% lower than the refurbishment/extension alternative. The incremental cost per benefit point is lower for refurbishing and extending an existing hospital than for the "do-minimum" option (0.4), and even lower for the new-build solution compared with the refurbishment/extension option (0.16). This shows that refurbishment/extension is more cost-beneficial than minimum change and that the new-build replacement hospital (selected by the promoter) is even more cost-beneficial in circumstances where major investment is desirable and affordable.

Table 24-2: Weighted benefit scores (multicriteria analysis)

Benefit Criteria	Criteria Weights (%)	Option Scores			Weighted Option Scores		
		Minimum	Refurbish/Extend Existing Hospital	New Build Hospital (the Project)	Minimum	Refurbish/Extend Existing Hospital	New Build Hospital (the Project)
High quality care	20	5	8	9	100	160	180
Service synergies	17	3	7	10	51	119	170
Accessibility	17	6	7	9	102	119	153
Patient/staff environment	15	3	7	10	45	105	150
Statutory requirements	10	8	9	10	80	90	100
Ease/timing of implementation	8	6	8	1	48	64	8
Future flexibility	13	2	5	8	26	65	104
Total Weighted Scores	**100**	-	-	-	**452**	**722**	**865**
Rank					3	2	1
Advantage over minimum	-	-	-	-	0	+60%	+91%

Table 24-3: Cost–benefit comparison of options

	Minimum	Refurbish/ Extend Existing Hospital	New Build Hospital (the Project)
Costs and benefits:			
NPC at 4% TDR*, 30 years (EUR m)	885	993	1 015
Cost rank	1	2	3
Total Weighted Score	452	722	862
Benefits rank	3	2	1
Average NPC/benefit point (EUR m)	1.96	1.38	1.18
Rank	3	2	1
Incremental costs and benefits:			
NPC minimum	885		
NPC refurbishment vs. minimum.		+108	
NPC new build vs. refurbishment			+22
TWS minimum	452		
TWS refurbishment vs. minimum		+270	
TWS new build vs. refurbishment			+140
NPC/TWS minimum	1.98		
NPC/TWS refurbishment/min		0.4	
NPC/TWS build/refurbishment			0.16
Overall preference rank	3	2	1

* Cost/benefit points at the alternative social discount rate of 5.5% for a Convergence Region: EUR 1.66m for the minimum option, EUR 1.18m for refurbish/extend and EUR 1.02m for new build, retaining the original ranking and broad relativities across options

25. Private Sector Research, Development, Innovation and Digitalisation (RDI)

Antonello Locci and Tom Andersen

25.1 Methodology

25.1.1 Purpose of RDI projects

The EIB's financing of Research, Development, Innovation and Digitalisation (RDI) entails investments in tangible and intangible assets.[143] RDI financing is not sector-restricted, with only EIB excluded activities ineligible for support.[144] In recent years, most projects financed have been in the automotive, pharmaceutical, med-tech, clean-tech, industrial engineering[145], ICT and energy-intensive industries[146]. The Bank's financing for RDI covers various eligible costs, such as salaries of researchers and technical/engineering staff, RDI consumables and materials, RDI equipment, outsourced RDI, costs for prototypes, and investments in RDI facilities. Typically, the Bank limits its financing to activities up to the pre-commercial stage, However, it also supports pilot demonstration projects and first full-scale commercial production lines for breakthrough technologies, other Key Enabling Technologies and digital transformation projects Moreover, for small and medium-sized enterprises and mid-caps, the EIB funds investments to scale up innovative technologies and introduce them to market.

The EIB generally focuses on identifying and prioritising projects leading to societal benefits where investment levels are adversely affected by material market failures, whether in the form of knowledge or environmental externalities, imperfect competition or incomplete markets.

Innovative private firms, especially smaller and younger ones, may be particularly exposed to information asymmetries that inhibit their access to financing. Consequently, they face a higher cost of capital, making their RDI projects less profitable, though such projects may bring important societal benefits and externalities. This market failure can be avoided or mitigated if such firms can signal their quality (e.g. through patents) to poorly informed third parties such as commercial banks, and if these parties can correctly interpret such signals.

RDI projects primarily (but not exclusively) support the creation of promoter knowledge and know-how and, thus, of intangible assets expected to generate benefits for the promoter and wider society in the medium to long term. This new private knowledge will usually generate spillovers, contribute to the diffusion and further creation of knowledge and, in line with EU policy objectives, incentivise further private-sector RDI investments in Europe.

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[143] Examples of tangible assets are the construction of a new research centre or the investments in testing and validation equipment, while examples of intangible assets are the development of a new drug, a new software, a new vehicle technology, a new manufacturing process.
[144] Military projects, projects resulting in limitation of people's individual rights and freedom, ethically or morally controversial projects, projects that are unacceptable in environmental and social terms, projects prohibited by national legislation.
[145] E.g. industrial machinery and equipment, electrical and electronic equipment, etc.
[146] E.g. steel, glass, materials processing

25.1.2 Market

R&D, technology and product innovation, and the digitalisation of manufacturing and business processes are often core to a promoter's competitive advantage and its market and technological leadership. In many cases, RDI projects play a strategic role for a promoter by helping them stay ahead of competition, anticipate market or technology trends and regulation, enhance productivity, withstand price pressure and sustain long-term growth and profitability. Investments in research, development, innovation and digitalisation certainly contribute to creating private and public knowledge and advancing science and technology. However, particularly for private-sector promoters, such projects are intended to find viable commercial applications and yield investment returns for the promoter. RDI projects typically help promoters address the demand and requirements of their customers: examples include demand for mobility from private or commercial/industrial customers; demand for medicinal products and medical technology from patients and/or healthcare providers; demand for industrial tools, machinery or technology systems for industrial or service processes; and demand for software systems for industrial or service applications. RDI projects therefore help promoters accelerate the introduction of innovative, enhanced, higher value products and services, offering greater efficiency in terms of energy, natural resources or productivity. These projects help to meet customer demand, society requests and government requirements, frequently by exceeding regulations, setting industry standards and further incentivising investments in research, development, innovation and digitalisation.

25.1.3 Costs and benefits

The cost and benefits of RDI projects are assessed by the EIB in relation to two different agents: the promoter and European society. Regarding the promoter, the Bank typically considers the project's financial profitability, whereas economic profitability is the main consideration regarding society. An RDI project's economic profitability is normally calculated in a two-step approach: after first assessing financial profitability, the analytical scope is enlarged from the promoter to society.

25.1.4 Financial profitability

Assessment of financial profitability evaluates in advance the soundness of the project and the extent to which it rationally allocates the promoter's resources. Financial profitability indicates the project's capability to generate future cash flows, thus allowing repayment of the investment undertaken by the promoter and compensating for the cost of capital invested.

The EIB's approach to calculating the FRR for RDI projects does not generally differ by industry or service (sub)sector. Instead, it depends on: (i) the size of the promoter and its specific RDI management processes; (ii) the size and scope of the RDI project relative to the promoter's total RDI investment; (iii) the importance of the RDI project and its potential impact on the promoter's business; and (iv) the data and information available to the promoter or provided to the Bank during project appraisal.

Typically, the FRR is calculated by assessing the expected incremental discounted cash flows from the commercial application of the RDI project outputs. The project's FRR is then compared with the promoter's opportunity cost of capital (WACC or specific hurdle rate). Alternatively, the project's financial profitability may be assessed by considering the promoter's entire portfolio of RDI projects. In this case, it is assumed that the commercial application of outputs from all RDI projects will yield a rate of return at least equal to the hurdle rate used by the promoter in the selection process. An RDI project's rate of return could also be assessed by considering its expected impact on the firm as a whole in the medium term. This approach is typically used when a large portfolio of RDI projects — representing most of the promoter's RDI investments — will be carried out over several years. In the "with project" the firm's future return on invested capital (ROIC)[147] is first estimated over a sufficiently long period for the RDI to unfold its potential; the "with project" scenario's ROIC is then compared with a "without-project" scenario (estimated) ROIC in which the promoter would not invest in RDI and with the promoter's (firm-level) WACC.

[147] ROIC measures the return generated on the capital being actively used and invested in the company's business activities. Sometimes, depending on the data provided by the promoter or its specific scope of business activity, ROIC could be substituted with ROCE (Return on Capital Employed). The latter is a broader measure; it considers the total capital employed by the company including the capital for financing non-operating assets (e.g. cash-equivalents, financial assets, minority participations).

25.1.5 Economic profitability

The assessment of economic profitability evaluates the benefits of a project for society. The financial soundness of a project, though neither a necessary nor sufficient condition, nonetheless gives an initial indication of positive economic impact. A project whose resources are properly allocated and expected to yield a positive return will likely support the promoter's long-term competitiveness and sustained profitability, thus advancing wider economic growth, welfare and employment. Some projects, however, may not be financially viable for the promoter in the medium term but are still expected to generate positive developments in the long term (e.g. "option" value), and have positive economic profitability because of their expected socioeconomic benefits (e.g. environmental protection and enhancement, climate adaptation and mitigation, and knowledge externalities).

An RDI project's costs and benefits for society are, therefore, explicitly assessed by considering the project's externalities (positive or negative). These represent positive or negative effects on third parties (benefits or costs, respectively), which do no have monetary compensation; they are not reflected in financial accounts and not included in the project's financial profitability calculation.

The positive externalities typically associated with RDI projects in industrial or service sectors include:

i. the increased consumer surplus associated with the market introduction of innovative technologies and products developed as RDI project outputs;
ii. the knowledge creation, sharing and spillovers, which are greater when the technologies developed are less appropriable, imitation or incentive to further innovate is easier, the innovator's competitors are numerous and equipped with adequate absorptive capacity, innovators collaborate with other firms, academia, partners along the supply chain and collaboration fosters knowledge flows to and knowledge absorption by innovators' partners;
iii. environmental, safety and/or human health benefits, resulting from deployment of the technologies developed as RDI project outputs.

Such positive externalities and wider socioeconomic effects are uncompensated benefits to society from the project. An example of the second category of externalities listed above is the dissemination and generation of knowledge through linkages (inter-industry, intra-industry and geographic) and collaborations among industry participants, academia and research institutes, which could, in turn, incentivise further private RDI investments. RDI projects may lead to the build-up of intellectual stock in a defined geographical region or area, creating cluster effects.[148] Other socioeconomic effects frequently considered by the Bank include the project's impact on advancing the technology leadership and competitiveness of EU industries and businesses, and thereby supporting long-term economic growth and employment in the European Union.

The externalities of RDI projects may however also be negative.

i. It could be the case of innovative technologies leading to a number of benefits in their field of primary application, but resulting in some kind of negative environmental, human health or safety impact — as unintended consequence— in some other adjacent fields or in other stages of the supply chain, e.g., upstream or downstream.
ii. Alternatively, it could be the case of innovative technologies introduced by a promoter and resulting in reduced competition, thus preventing knowledge diffusion and sharing and further innovation. As an example, it could happen in an oligopolistic industry, where a promoter may develop a radically new technology making competitors' technologies obsolete, somehow limiting further knowledge creation and therefore leading to a (likely temporary) monopoly. It could also be the case of newly developed proprietary technologies blocking further innovative developments in the industry.

Detailed measurement of externalities is not easy for private-sector RDI projects. However, some indicators of innovation outcomes or inputs can be used as a proxy for likely externalities, if the promoter operates in a competitive market, rather than a monopolistic or oligopolistic market, where their RDI investments could limit or reduce other firms' innovation.

[148] A business cluster is a geographical location where enough resources and competences gather together and reach a critical mass, giving it a competitive advantage in a given sector, by contributing to increase the competitiveness of the companies in the cluster, by driving innovation in the sector, and by stimulating new entrants in the sector.

Assuming a competitive market, outcome indicators signalling knowledge creation could include: the patents and publications expected to result from project implementation; the promoter's involvement in collaborative projects with inter- or intra-industry partners and academia; the share of revenues from new products/technology applications introduced in recent few years; and other indicators of RDI input (intensity, quality management, and track record of invention disclosures and patent applications). Empirical evidence supports the idea that knowledge creation, and associated spillovers, indicating enhanced competitiveness of the industry or service sectors, stem from increased private and public RDI investments.

The approach to assessing a project's economic profitability ultimately depends on (i) the data and information supplied by the promoter, (ii) the possibility to define the project's externalities in monetary or quantitative terms, and (iii) the importance and number of spillovers and other socioeconomic benefits.

When a project's externalities can be translated into monetary terms and assigned market or shadow prices, their net monetary value can be added to the project's incremental financial cash flows, netted of subsidies and other public transfers, and the ERR is explicitly calculated.

For example, the CO_2 and NO_x exhaust emissions eliminated by installing a full electric powertrain in new vehicles can be monetised through market or shadow prices.[149] Similarly, a market price can be applied to the energy savings from integrating a newly developed technology into new products or existing industrial processes. The analysis also lists the main non-quantifiable spillovers and other socioeconomic effects.

When a project's implementation leads directly to reduced (or increased) CO_2 emissions, such data (relative emissions vs. the identified baseline) can be consistently drawn from calculations following the EIB's carbon footprint methodology. The monetary valuation of such emissions uses the shadow cost of carbon as defined in the CBR (and successively updated) — netted of those carbon costs accounted for in the project FRR — if the promoter or project is located in a country or sector subject to a carbon tax or other carbon pricing mechanism.[150]

Otherwise, the analysis develops qualitative considerations to take into account the project's externalities and socio-economic effects in qualitative terms, by using qualitative scoring criteria, based on the number and intensity of externalities involved in the project, which help to assess the wedge[151] between the financial and economic profitability of the project. The project's economic profitability is therefore assessed in qualitative terms in such situations and the qualitative scoring leads to a quantitative assessment of the wedge between the financial and economic profitability.

For projects in competitive markets, the analysis will state the alternatives the promoter may have considered or the most appropriate counterfactual defined by the Bank's economist, and highlight whether the project represents — based on industrial sector knowledge — the most efficient allocation of resources compared with other alternatives.

[149] Shadow cost of carbon as defined in the EIB Climate Bank Roadmap 2020 and successively updated

[150] For greenfield projects, if no carbon price mechanism is applied in the country where the project is implemented (for example projects outside the EU), it could be possible—if data are available—to calculate an "adjusted" FRR to define how the facility/plant performs compared to the respective EU ETS benchmark. It will be necessary to estimate the equivalent carbon cost that the company would have to pay under EU ETS and it would be applied for the FRR calculation. The ERR would then be calculated as indicated above, by considering the shadow cost of carbon as defined in the EIB Climate Bank Roadmap netted by those carbon costs already accounted for in the financial profitability.

[151] As a difference in terms of percentage points.

25.2 Case study 1: Portfolio approach

The promoter is a provider of industrial solutions including compressed air and gas equipment, construction equipment, industrial tools and assembly systems. It is a leader in technology and sets standards in all segments where it competes. Substantial investments in RDI are, therefore, critically important for the promoter to keep its innovative edge; continuously enhance productivity, environmental impact, and the quality of products and systems; and widen the product range offered to customers by investing in first-mover technological developments.

The project considered for financing by the Bank concerns the promoter's investments for advanced research and development of technologies and highly innovative products in the fields of compressor and construction equipment solutions. The promoter's RDI activities are essentially driven by the need to develop enhanced product solutions, which allow its customers to increase levels of productivity, energy efficiency and recovery, safety and ergonomics, while also reducing the environmental impact of their production processes. The promoter's market and technological leadership is based on R&D, technology and product innovation as well as market introduction of new, more energy-efficient and productive equipment. Accordingly, this project has a strategic role: it is expected to help the promoter stay ahead of competitors and anticipate trends and regulation, thereby ultimately supporting its long-term growth and profitability.

The selected project's costs include operating expenditures (primarily salaries for internal staff and consultants, materials and other R&D costs) and capital expenditures (pre-commercial stage, including prototyping and tooling investments) to be incurred over a period of 4 years.

25.2.1 Financial profitability

The project includes spending on RDI initiatives at different development stages, many still at an early stage and involving technology concepts still far from market launch. For RDI initiatives with a longer-term perspective, the promoter follows a rigorous qualitative screening and selection approach, assessing the innovation level (for promoter and the market), strategic attractiveness and fit, consistency with the promoter's core competences, and ease of implementation. This process leads to the definition of a long-term technology roadmap consistent with the promoter's strategy and its customers' needs. For RDI initiatives closer to the market stage, in addition to verifying strategic fit and potential benefits for the final customer, and therefore market attractiveness, the selection and investment decision is carried out based on expected profitability. The investments submitted for approval with a business case must have a positive NPV, with cash flows discounted at the promoter's opportunity cost of capital, set at 10% (pre-tax). It can, therefore, be assumed that the promoter's RDI project, at portfolio level, will have a profitability exceeding its average cost of capital and yield an FRR of at least 10%. Moreover, reassurance that the project's resources are properly allocated can be derived from the promoter's high-quality RDI management and project-selection procedures, stringent budget accounting, evaluation and monitoring of project progress, patent portfolio, track record of invention disclosures and patent applications, and close attention to customers' needs. This is further confirmed by the level of the promoter's sales from new products, which is between 20% and 40% depending on the business area, confirming that RDI has a long-term strategic importance for the promoter.

25.2.2 Economic profitability

In terms of economic contribution, the benefits of this project for society are identified by considering: (i) the positive environmental effects (energy efficiency) and the contribution to increased levels of productivity, safety and ergonomics arising from the application of the promoter's RDI results to its customers' industrial processes and operations; (ii) the knowledge externalities from joint R&D collaboration with universities, research institutes and customers, as well as from patenting, and therefore through direct and indirect knowledge dissemination, contributing to increasing the public stock of knowledge, while creating an incentive for further R&D, innovation and digitalisation[152]. The extent of the knowledge externalities depends on the market structure of the industry and the innovator. As a quantification of one of the project's positive environmental benefits, it may be mentioned that the promoter is targeting the development of compressors featuring an improvement of several percentage points in terms of energy efficiency in each new product generation. The project's ERR is therefore expected to exceed the FRR (higher than 10%).

[152] Such extent of knowledge externalities is supported by the fact that the firm concerned operates in competitive markets rather than in monopolistic or oligopolistic markets.

25.3 Case study 2: Discounted cash flow approach

The promoter is a small company and a new entrant in the field of Li-ion battery technology. The project aims to demonstrate the viability of the promoter's innovative battery cell technology and proprietary manufacturing process. Bank financing is sought to support some of the promoter's RDI investments and the construction and operation of an innovative, first-of-a-kind demonstration plant for manufacturing advanced Li-ion cells, for battery applications in transport, stationary storage and other industrial applications.

The project represents a first step. If successful, it will enable the scale-up of the promoter's technology into larger scale production plants. The demonstration plant is not primarily intended as a commercial operation: it is too small to achieve the necessary economies of scale, and will be over-dimensioned in terms of equipment and workforce. Nonetheless, it will be operated to be financially viable on its own.

The project costs will cover RDI investments, construction of the demonstration facility, installation of its specific infrastructure, acquisition and installation of relevant equipment, other project planning, and setup and implementation.

25.3.1 Financial profitability

The Bank estimated the project's expected rate of return based on data from the promoter and further estimates using industry information. Under these assumptions, the project is expected to yield an FRR of 7%. This is low for a normal industrial manufacturing capacity scheme but explained by the project's strategic objective (for the promoter), demonstration purpose and size. The project FRR is not very sensitive to increased material input costs but more sensitive to construction period delays and a decrease in the unit sales price.

25.3.2 Economic profitability

The ERR was calculated by taking into account the project's direct positive environmental externalities, specifically the reduced CO_2 emissions expected to result from the setup of this facility as compared to the most likely alternative (producing the same battery cells with a less efficient manufacturing process in a different region). This calculation uses the project's relative emissions according to the EIB's carbon footprint methodology, employing the shadow cost of carbon as defined in the CBR.[153] The calculated project ERR is 8.3%.

The project is also expected to lead to additional positive environmental externalities: the battery cells produced through the project will ultimately be installed in new electric vehicles, which will replace an equivalent number of vehicles powered by internal combustion engines. More generally, the project will help create the conditions for deploying electromobility and developing a more efficient and sustainable transport system in Europe.

Finally, the project is expected to generate additional benefits for society. First, it will lead to the transfer, further development and dissemination of important knowledge throughout Europe. These benefits are attributable to the project's high R&D intensity and propensity to disseminate knowledge throughout European industry and academia (via research and commercial partnerships and collaborations). Second, the project will contribute to preserving and strengthening R&D and advanced manufacturing activities and related jobs in several industries in Europe.

Taking into account all these additional externalities, which are difficult to quantify and monetise, the project ERR is uplifted by 2 percentage points based on qualitative scoring of the number and intensity of externalities. Therefore, considering all the quantitative and qualitative effects of externalities, the project ERR is estimated at 10.3%, which is expected to be higher than the FRR.

Table 25-1 summarises the approach followed, with the numbers altered for confidentiality reasons.

[153] EIB shadow cost of carbon from the EIB CBR 2020, for the period 2020-2050. No adjustment was needed, as the promoter and the project are not subject to the EU ETS scheme.

Table 25-1: Calculation of the economic rate of return for a private-sector RDI project

	m EUR	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
(1)	Contribution profit (cash contribution)	0	0	-1	3	5	18	20	20	20	20	20	20	20	20	20
(2)	Change in Working Capital			-0.2	-1	-2	-3	-2	-1	0	0	0	0	0	0	0
(3)	Project Investment Cost	-10	-75	-20	-4	0	0	-3	0	0	0	0	-3	0	0	0
(4)=(1)+(2)+(3)	Net Incremental Cash Flow	-10	-75	-21.2	-2	3	15	15	19	20	20	20	17	20	20	20
	IRR	**7.0%**														
(5)	CO2 reductions (kt)	0	0	0.4	1.3	2.1	7.6	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
(6)	EIB shadow cost of carbon (EUR / ton CO2 eq)	80	80	80	80	165	165	165	165	165	250	250	250	250	250	390
(7)=(5)*(6)	Environmental benefits	0.0	0.0	0.0	0.1	0.3	1.2	1.4	1.4	1.4	2.1	2.1	2.1	2.1	2.1	3.3
(8)=(4)+(7)	Net Incremental Cash Flow for ERR	-10.0	-75.0	-21.2	-1.9	3.3	16.2	16.4	20.4	21.4	22.1	22.1	19.1	22.1	22.1	23.3
(9)	ERR	**8.3%**														
(10)	Additional uplift (qualitative, p.p.)	2%														
(11)=(9)+(10)	ERR (total)	**10.3%**														

Assumptions
- Contribution profit estimated by the EIB
- CO2 reductions estimated by considering as a baseline the most likely alternative to the project, i.e. a plant in a different region, with a less efficient process technology and sourcing energy with a higher CO2 grid factor.
- Environmental benefits (CO2) valued on the basis of EIB shadow cost of carbon (CBR 2020 for the period 2020-2050).
- All the number s have been altered for confidentiality reasons

25.4 Case study 3: Proxy of project profitability approach and quantitative non-monetary benefits

This project concerns the EU-based part of the promoter's corporate RDI programme for discovering and developing innovative enzymes, novel proteins and microorganisms, whose purpose is to enhance product quality and process/energy efficiency in industries such as detergents, agro-food, pharmaceuticals, fibres and textiles. As such, the project is well in line with Horizon Europe objectives of supporting industry research and innovation, particularly for technologies enabling and accelerating green transition. The project also corresponds to the Bank's "Innovation, Digital and Human Capital" policy objective and qualifies under the Climate Action and Environmental Sustainability policy objective.

The promoter is a research-based biotechnological company with a world-leading position in production and sales of industrial enzymes. It specifically targets the segments of microorganisms, biofuels and biopharmaceutical ingredients.

25.4.1 Financial profitability

The Bank evaluated and accepted the promoter's internal RDI investment evaluation and approval procedures, which aim at ensuring that the company continuously optimises the use of its resources. This project groups together and includes a large number of R&D projects with different duration times and objectives, with an uncertain outcome in terms of deliverables and timing. The sub-projects are pursued as part of the promoter's ongoing RDI, and are indispensable investments to a biotechnology-based research company like the promoter. They aim at safeguarding and expanding the company's future position by strengthening its knowledge base and ensuring competitiveness, growth and eventually revenues.

This promoter sets particularly high standards for past project performance indicators and future project return indicators (e.g. NPV/IRR). The success of the promoter's RDI efforts is reflected by annual increases in the product portfolio value, which have exceeded 20% per annum in recent years, measured by the probability-adjusted NPV of new products entering the portfolio.[154] The probability-adjusted NPV of the entire portfolio has exhibited annual growth of around 14–15% in the last five years.

Alternatively, as the promoter seeks Bank financing for a large number of RDI projects with different durations and objectives, the overall performance of this research-based company could be considered. The ROIC provides an estimate of the success of past RDI spending and a proxy for the project's expected impact.[155] The promoter's ROIC shows an upward trend over 10 years, staying well above 15%. Comparing the ROIC with the promoter's WACC (8%), it is clear that the company has been creating significant value. The consistency between the company's product pipeline and current strategy, as well as its historical performance, suggests a high likelihood of the promoter being able to defend its market shares in the important mature enzyme segments, as well as in the key growth segments (biopharmaceuticals, microorganisms and biofuels). As such, over the next three years, the promoter is expected to maintain financial profitability on a par with the average of the last three years (e.g. 20% profit margin, > 18% ROIC).

[154] NPV (Net Present Value) is calculated based on future probability-adjusted discounted cash flows (the financial discount rate used is 15%). The probability is differentiated based on the different segment according to market prospects, competition, degree of uncertainty, etc.

[155] ROIC (Return On Invested Capital) is defined as operating profit, before or after tax, as a percentage of average invested capital. Operating profit is adjusted for net foreign exchange gain/loss.

25.4.2 Economic profitability

Demand is increasing for enzyme-assisted products and processes because they typically replace more environmentally intrusive conventional chemicals, or more energy-intensive processes. For example, because enzymes are effective at a lower temperature, using them to wash clothes can reduce household electricity consumption per wash by around 30%. Furthermore, the increased use of enzyme-driven industrial processes has been calculated to facilitate large reductions in CO_2 emissions: i.e., 1 kg of enzyme product will cause CO_2 emissions of 10 kg, replacing CO_2 emissions of 3 800 kg in the baking industry, 1 800 kg in the pulp industry, 1 400 kg in the oil industry, 500 kg in the bio-ethanol industry, 176 kg in the detergent industry and 120 kg in the textile industry. As such, deployment of enzymes will contribute positively to tackling climate change by making processes more efficient.

Overall, the project is expected to result in significant positive environmental effects: improving food quality and safety, minimising losses in logistics chains, increasing material and energy efficiency, and minimising the environmental impact of industrial processes. It thus seems reasonable to assume that the net economic returns to society will lead to a project ERR at least the same level as, or even higher than, the FRR. In particular, it is important to consider that at least 50% of the company’s investment contributes to climate action mitigation.

26. Research infrastructure

Martin Humburg

26.1 Introduction

Research Infrastructures provide space and resources for conducting research and fostering innovation. As their activities are usually non-commercial, research infrastructures most often form part of public universities or public research institutes. The EIB finances investments in research infrastructures because the R&D activities they enable are essential for Europe's economic competitiveness and well-being, and for delivering new solutions to green, digital, health and social challenges.[156]

Research infrastructures usually require public funding because the market fails to provide the necessary financial resources, deterred by uncertainty over the investment return,[157] relatively high initial investment costs, and long time-lags before financial returns are generated. The financial risk associated with R&D investments, particularly for basic research, is further elevated by the performer's inability to fully appropriate the economic benefits: knowledge diffuses rapidly, and property rights for many R&D activities cannot be clearly defined or effectively enforced. This makes it difficult to exclude other, competing economic actors from the benefits of investments, which reduces the associated private rate of return (Nelson, 1959; Arrow, 1962; Aghion et al., 2008). Moreover, basic research does not even aim at obtaining a direct economic return; rather, it focuses on delivering discoveries that have no direct economic value but are essential for future discoveries that could be commercialised.

Many, if not most, research infrastructures consequently struggle to demonstrate a financial return. However, there is ample empirical evidence that R&D is a key driver of productivity growth that yields positive economic returns. The most important channels through which public R&D activities contribute to economic growth are:[158]

- **Human capital formation**, mainly through training early-career researchers (postdocs and PhDs), many of whom will migrate into the private sector of the innovation system;
- **Generation of new knowledge** and its translation into new or improved technologies, products, services and processes that generate more value added;
- **Creation of new products and companies**, such as spin-outs and spin-offs;
- **Creation of networks, including between public and private researchers and users** through collaborative research, contract research, consulting and outreach activities.

In addition, public R&D is needed to address societal challenges that do not offer a direct economic return and, therefore, will never be (completely) financed by the private sector, such as mitigating the social impact of climate change.

[156] European Commission Communication (2021) 252 final. "On the Global Approach to Research and Innovation."
[157] As pointed out by the European Commission (2017). "The Economic Rationale for Public R&I Funding and Its Impact," p.26: "R&D systematically involves entering unexplored fields, which requires testing and verifying multiple options, and often implies failures. […] Moreover, even if the R&D activities can be concluded successfully, sometimes the newly developed product/process/technology turns out to be commercially unviable, which adds to the risks and uncertainties related to investments in R&D."
[158] Meyer-Krahmer and Schmooch (1998), Pavitt (1998), Salter and Martin (2001) or Georghiou (2015) cited in European Commission (2017).

26.2 Quantifying the economic returns from investments in research infrastructures

In estimating the ERR of investments in research infrastructures, the EIB builds on methodologies developed in DG REGIO's *Guide to cost-benefit analysis of investment projects,*[159] as well as work undertaken by economists and scientists at the University of Milan and the Centre for Industrial Studies during an EIB-supported research project.[160] These methodologies provide a conceptual framework and practical guidelines for quantifying the economic benefits accruing from investments in research infrastructures. They make it possible to assess whether the economic returns justify Bank investment, even in the absence of direct financial returns.

The key parameters for estimating the project ERR for research infrastructures are as follows.

26.2.1 Benefits from human capital formation

Working in an R&D infrastructure gives students, doctoral students and post-doc researchers access to the latest equipment and competitive, high-quality research environments. Consequently, they are expected to develop higher levels of knowledge and skills than their peers. The socioeconomic value of this benefit can be expressed as the expected incremental lifelong salary earned by such individuals over their entire careers, compared with the WOP scenario.[161]

26.2.2 Benefits from knowledge production, transfer and dissemination

New, extended or upgraded R&D infrastructures enable researchers to increase their scientific productivity, resulting in higher scientific output (i.e. more scientific publications) and, albeit less frequently, the registration of patents or the establishment of spin-offs and start-ups. A combination of methods is used to estimate the value of benefits from knowledge production, transfer and dissemination.

The socioeconomic benefit of scientific publications is valued using their marginal production cost, which mainly captures the time devoted to producing a publication, including research activity. This approach is common in CBA for types of products and services for which no appropriate market value or shadow price can be established.[162]

Spin-offs and start-ups make important contributions to knowledge and technology transfer by bringing new products or services to the market. Their value can be estimated as the expected profit gained by the spin-off or start-up during its lifetime, as compared to the WOP scenario. Investments in R&D infrastructure can positively affect this expected profit, for example by increasing the survival rate of spin-offs and start-ups, or increasing the total number of spin-offs and start-ups created.[163]

Benefits from granted patents vary greatly across sectors, technological fields and geographic areas. It is, therefore, recommended to base assumptions for CBA on relevant statistics, if available. Alternatively, the average value of a patent can be used, which tends to range between €100 000 and €300 000.[164]

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[159] European Commission, Directorate-General for Regional and Urban Policy (2014): Guide to Cost-Benefit-Analysis of Investment Projects, Economic appraisal tool for Cohesion Policy 2014-2020.
[160] Florio, M., Forte, S., Pancotti, C., Sirtori, E. and S. Vignetti (2016): Exploring Cost-Benefit Analysis of Research, Development and Innovation Infrastructures: An Evaluation Framework. European Investment Bank Institute.
[161] Florio et al. (2016).
[162] Most scientific publications are available to readers for free or at a very low price, and it is not possible to measure the socio-economic value of the knowledge embodied in these publications.
[163] For approaches for estimating the economic value of spin-offs and start-up see European Commission (2014, p. 283) or Florio et al (2016, p. 34).
[164] European Commission (2006). Study on Evaluating the Knowledge Economy. What are Patents Actually Worth? The value of patents for todays' economy and society, Final Report.

26.2.3 Benefits from the provision of academic consultancy and open access

Relative to the WOP scenario, a new, expanded or upgraded R&D infrastructure may provide more opportunities for consultancy services and open access for external users. The benefit estimate should account for the amount of time devoted by the infrastructure and its researchers to consultancy or open access activities, and the expected number of potential external users. The preferred ways to value this benefit are using the LRMC of services provided, estimating external users' WTP for the services, or taking market prices (if available).

26.2.4 Benefits from network creation

Investments in R&D infrastructure may lead to more conferences and workshops on specific scientific topics, helping to disseminate knowledge, strengthen researchers' networks, and enable the formation of new research consortia. New R&D infrastructures, particularly if unique, may also attract visitors or organise outreach activities to popularise science. These benefits should also be accounted for when estimating the economic return on investments in R&D infrastructure. A suitable way to estimate the benefits from new or strengthened networks is the travel cost method: it draws inferences on visitors' WTP from spending incurred to consume a good, including the cost of the trip, the opportunity cost of time spent travelling, entry fees, on-site spending, and accommodation costs.

26.2.5 Counterfactual scenario (without project)

As discussed in chapter 3, a main pillar of CBA is the definition of a counterfactual scenario, used to ensure that all costs and benefits are estimated in incremental terms. Incremental benefits must be weighed against a potential incremental increase in operating costs and other social costs. Where a project aims to renovate degraded facilities and attain superior performance to that for which the facility was originally designed, the WOP scenario must include the investment costs necessary to restore the performance level of the original infrastructure. For an ageing infrastructure, these recovery costs may be high, which reduces the relative costs of the WP scenario compared to the WOP scenario.

26.2.6 Reference period

The useful life of an R&D infrastructure is usually assumed to be around 25 years, depending on the particular circumstances. Given the fast pace of scientific development in the field of technology, such a long useful life will require substantial investments in the maintenance and upgrading of infrastructure and equipment. These investments need to be included in CBA.

26.3 Case study: Renovation, extension and upgrading of an existing research and development infrastructure

The case study project comprises the renovation, extension and upgrading of an existing research institute in a cohesion region. The institute proposes investments of €80 million to bring facilities and equipment up to the latest standards and create additional space for growth in staff and in research and educational activities. This proposal is supported by public authorities — the institute's primary source of financing — because they expect the project to generate multiple socioeconomic benefits, including improvement of the country's innovation capacity and economic competitiveness.

The expected tangible effects of the project on the research institute's performance are summarised in Table 26-1.

26.3.1 Quantitative economic analysis

After the collection of further data from the promoter by EIB (e.g. on salaries, average travel costs, expected shadow profits of spin-offs), and assuming a reference period of 25 years and an SDR of 5%, the economic analysis yields the following estimates:

- NPV of €77.6 million;
- ERR of 11.5%;
- B/C ratio of 2.5.

These should be considered lower-bound estimates as they do not include benefits more difficult to measure, such as impact on regional competitiveness, cultural effects for visitors, and benefits from the institute's research on environmental protection.

Table 26-1: Expected impact of the project on the research institute's performance

Indicator	Without project	With project
Scientific staff (incl. postdocs and PhDs)	807, no increase over time owing to lack of space	Annual increase of 2%
University students receiving part of their education at research institute	2 000	Annual increase of 2%
Number of publications	700, no increase over time	Increase in proportion to increase in staff (2% annually)
Patents granted	1 every five years	1 each year: competitive scientific equipment and attraction/retention of talent
Spin-offs	1 every five years	1 each year: increased collaboration with industry and attraction/retention of talent
Annual number of conferences organised	3	Gradually increasing to 14: increased competitiveness and availability of appropriate facilities
Annual revenue from contract research	€350 000	Gradually increasing to €1 500 000 over first five years: competitive scientific equipment and increased collaboration with industry
Annual value of open access	€300 000	Gradually increasing to €900 000 over first five years: competitive scientific equipment and increased collaboration with industry
Annual operating costs	€6 000 000	€8 000 000

26.3.2 Sensitivity analysis

illustrates that the project's NPV is mainly driven by benefits relating to current core activities, namely the formation of human capital (early-career researchers and university students) and the production of scientific output (publications). However, 18% of the expected NPV derives from generating more spin-offs — an area where the institute lacks a strong track record. To test the robustness of the estimates obtained, and the potential impact of changing assumptions, it is advisable to perform a sensitivity analysis on the main NPV drivers.[165]

[165] An alternative approach is the use of a stochastic model that approximates the probability distribution functions of the socio economic net present value or other indicators (see Florio et al. 2016). The advantage of a stochastic model over one that is based on punctual values is that it takes into account the risks of forecasting errors. However, this requires that the probabilities of the values of each critical variable entering the model be known or at least approximated, which is not always the case.

Figure 26-1: Types of benefits and their contributions to net present value (EURm)

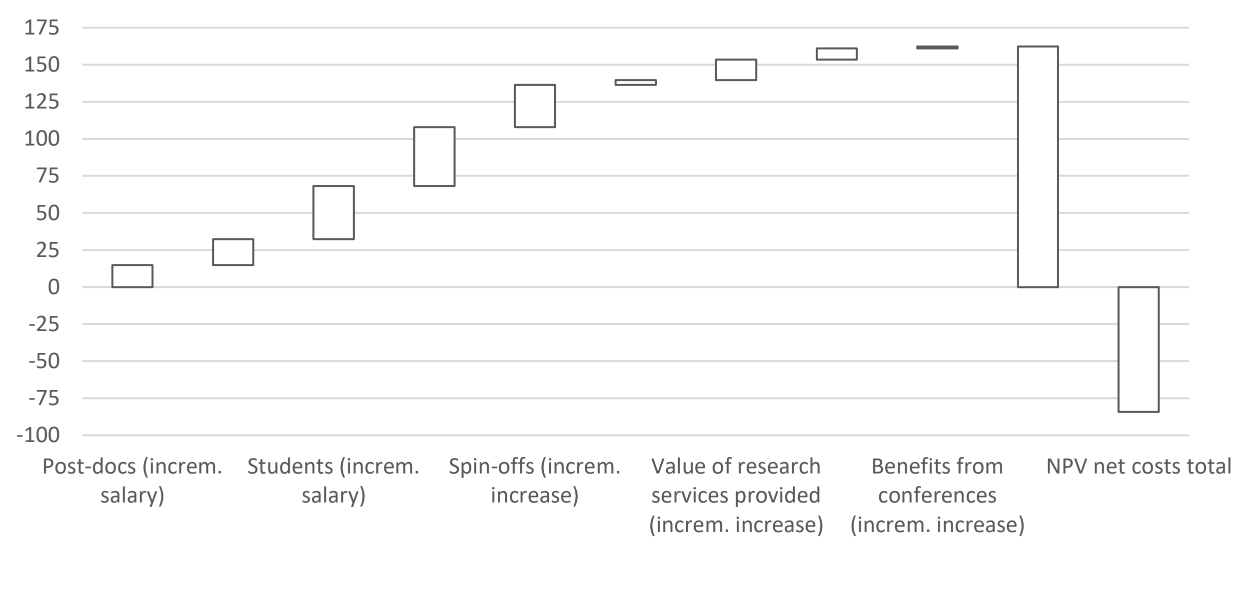


Table 26-2 shows how the ERR estimate changes if adjustments are made to assumptions underlying the base case, specifically to the number of publications (a function of the number of additional staff) and the number of spin-offs. The sensitivity analysis shows that in a pessimistic scenario, the ERR would fall to 7.5%, whereas in an optimistic scenario, the ERR would increase to 13.3%. The analysis thus indicates that project ERR would be positive even in the pessimistic scenario, providing assurance that the project will generate a positive economic return.

The sensitivity analysis also yields an important insight: the project's socioeconomic return depends strongly on the institute's ability to increase scientific production by hiring additional staff. It is, therefore, important for the investors to ensure that appropriate recruitment measures and incentives are in place for attracting the envisaged number of staff.

Table 26-2: Results of sensitivity analysis

	Numbers of publications and staff increase by 1% per year as from 2022	Numbers of publications and staff increase as proposed by promoter until 2026 and by 2% per year thereafter (base case)	Numbers of publications and staff increase as proposed by promoter until 2026 and by 3% per year thereafter
1 spin-off every two years as from 2027	**7.5%**	10.8%	11.4%
1 spin-off each year as from 2027 (base case)	8.4%	**11.5%**	12.1%
2 spin-offs each year as from 2027	10.1%	12.7%	**13.3%**

Note: Since the socioeconomic benefit of scientific publications is valued using their marginal production cost, this benefit mainly depends on additional staff costs.

26.3.3 Qualitative analysis

It is useful to compare the results from a quantitative ERR estimation with the findings of a qualitative assessment, allowing checks for consistency and the appropriateness of assumptions.
In situations with little available data to inform a quantitative ERR estimation (e.g. for new R&D infrastructures), qualitative assessment of the investment's socioeconomic benefits can also replace quantitative assessment.

Table 26-3 illustrates a qualitative assessment for the case study project. Its results are consistent with the assumptions and outcomes of the quantitative assessment.

Table 26-3: Qualitative assessment of the economic rate of return

ERR components and externalities	Project performance	Rating
Propensity to improve scientific production	The country is a moderate innovator with relatively low levels of public and private financing for R&D. The project provides financial resources for investments in public R&D infrastructures, which are strongly needed to improve the country's R&D capacity. As the country's leading research organisation, the promoter is the most obvious beneficiary of such investments, holding the largest potential for performance improvements. The upgraded and extended infrastructure provided by the project will, thus, be an important basis for improving the quality and quantity of the institute's research. However, among other more structural issues, the organisational structure and the ability to attract talent will need to be addressed to optimise performance.	Very good
Propensity to improve human capital formation and fill the innovation gap	The promoter plays an important role in training university students and early-stage researchers (PhDs) — an indicator on which the country scores poorly compared to other Member States. The number of early-stage researchers trained by the institute has significantly grown over recent years, and is expected to grow further once the new facilities are completed. Filling the innovation gap is a main project objective, and the topics on which the institute is conducting research have large potential for technology transfer.	Very good–Excellent
Propensity to boost job creation, productivity and economic growth	The project will enable the institute to increase its staff numbers. Construction activities will generate approximately 3 500 person-years of employment. The institute's track record on technology transfer, particularly spin-offs, is rather weak. Against this background, the project components (including new equipment purchases) have been designed and selected for their potential to generate opportunities to collaborate with industry.	Very good–Excellent
Propensity to protect and enhance environmental sustainability	Around 15% of the institute's staff work on topics of high relevance to enhancing environmental sustainability. The project's climate action and environmental sustainability component is substantial because energy-efficiency measures will be implemented in the new and upgraded buildings.	Very good
Overall rating		**Very good–Excellent**

27. Manufacturing capacity

Antonello Locci and Tom Andersen

27.1 Methodology

The economic analysis seeks to ascertain that a project aligns with the Bank´s financing rules, addresses relevant market failures, and is an efficient and rational allocation of resources. The Bank not only carries out a systematic appraisal of project proposals but also subsequently monitors and evaluates the projects chosen to receive financing.

The manufacturing project appraisal considers feasibility and analyses options. The project feasibility assessment considers the following: the rationale for Bank financing (value added and market failures), technical description, production capacity, investment costs, market and sector characteristics, implementation, operation, environmental impact, financial return from the investment, and economic benefits arising from the project. In this analysis, alternative options to the proposed project are duly considered.

As such, the economic appraisal of a project includes: (i) evaluation of value added by the project; (ii) calculation of the project ERR; (iii) estimation of external costs and benefits, such as environmental impact, regional development and employment creation; and (iv) a sensitivity analysis.

The usual outcomes of a manufacturing industry project include inter alia, the end-product produced; the impact on employment; social surplus (producer and consumer surplus); support for regional livelihoods; and generation of fiscal revenues for the local community, regional authorities and the state.

27.1.1 Market analysis

The market addressed by the project needs to be analysed to confirm that the investment is economically justified and financially viable. A project involving capacity expansion may have an import-substitution or export-oriented rationale. The project's impact on local, regional and global markets (as relevant) is taken into account when assessing potential market demand, market supply, growth forecasts, sector developments, prices, competitors, and potential new capacity on the horizon. All this information feeds into the financial and economic analyses.

27.1.2 Financial profitability

Financial variables resulting from the project appraisal are used to analyse the project's cash flow and thereby establish the FRR, which can be benchmarked against other projects financed by the Bank. This analysis generates most of the information on inputs, outputs, prices and timing that the Bank needs to undertake CBA.

CBA is usually performed as a differential cash flow analysis (with and without the project). The time horizon is determined by the project's economic life, and is usually 8–15 years for productive investments. This may be limited by the length of concession rights, need for large reinvestments, product substitution risks, and other factors. Real or constant prices are used. A priori, it is expected that the project's FRR will be positive and exceed the company-specific hurdle rate (i.e. the company's WACC), as an investment would not normally be undertaken unless providing a positive return to the promoter. However, for environmental investments without an inherent capacity expansion (e.g. developing an air filter to remove particulates and gas, or deploying other carbon-abatement technologies), the project FRR could be negative.

27.1.3 Economic profitability

The economic analysis appraises the project's contribution to the economic welfare of society at large. As the focus extends beyond the promoter's interests, all input and output variables in the financial analysis must be adjusted, while societal benefits and social costs (externalities) are added to the evaluation. The economic appraisal yields the project ERR.

If the project involves subsidies or other transfers, they have to be netted out. This means that input and output prices should be net of VAT and other indirect taxes. If there are significant market distortions, then prices are also adjusted to reflect opportunity costs. However, this is rarely the case in most productive industries within the European Union, as markets are liberalised and prices only slightly or not at all distorted. A plausible exception is the situation of a project promoter having acquired land below market price, or at too low a rent to properly reflect the opportunity cost of this project input. An essential production input that often needs adjusting to reflect its SOC is labour cost (wages), as labour markets are imperfect. A so-called shadow wage should be applied to reflect that under conditions of high unemployment, actual wages are higher than the opportunity cost of labour.

A project's environmental impact is also considered. For example, a capacity expansion will usually lead to increased CO_2 emissions, which should be considered in their own right but also relative to the alternative scenario, which may generate even higher emissions. The economic value of this negative externality needs to be factored in may, all else equal, lead to an ERR below the FRR. Conversely, a project may have an environmental purpose (e.g. a significant energy-saving or emission-lowering component) that leads to net environmental benefits not included in the FRR analysis.

When a project's implementation leads directly to reduced (or increased) CO_2 emissions, such emissions should be consistently accounted for following the EIB's carbon footprint methodology.[166]

In developing countries, market prices for products considered strategic are often regulated by the government. Such prices have to be adjusted to reflect the internationally prevailing price, if it exists in the focal sector. Where there is no international market price for the product in question, the import parity price (or border price) may be calculated and used instead.

Other potential benefits with a social impact include training, education, school construction, water wells, energy for households, medical checks, vaccinations and health facilities, any of which may be provided to the local community as part of the project.

All significant social and economic spillovers, even when unquantifiable, should generally be taken into account. The analysis should list the main unquantifiable externalities in addition to those included in the ERR calculation. Where relevant, potential project impact in terms of relocating economic activity and/or creating new activity should also be considered in the analysis.

[166] For greenfield projects, if no carbon price mechanism is applied in the country where the project is implemented (for example projects outside the EU), it could be possible—if data are available—to calculate an "adjusted" FRR to define how the facility/plant performs compared with the respective EU ETS benchmark. This will require an estimate of the equivalent carbon cost that the company would have to pay under EU ETS and this would be applied for the FRR calculation. The ERR would then be calculated as indicated above, by considering the shadow cost of carbon as defined in the EIB Climate Bank Roadmap netted by those carbon costs already accounted for in the financial profitability.

27.2 Case study: Constructing and operating a cement plant

This project involves the construction and operation of a greenfield integrated cement plant, dedicated to supplying cement to the local market. The plant will be centrally located e.g. close to essential raw materials, but still well placed to supply the main economic centre in and around the country's capital. Unmet cement demand prevails in the country, which is a lower-income economy in need of cement for reconstruction and further economic development. A local entrepreneur wants to build a greenfield cement plant to produce cement locally, instead of importing cement over long distances and at high prices from nearby countries to address future growing demand. The project rationale is, therefore, import-substitution, and the right timing (before other market entrants) should allow the promoter to build a strong market share in a growing cement market, generating local jobs in a region suffering high unemployment and general underemployment.

The project will use best available technology including transitional abatement technology: using biomass to meet some fuel demands will reduce CO_2 emissions by at least 25% compared to conventional production of Ordinary Portland Cement.[167] In addition, more environment-friendly cementitious composites are available locally (e.g. pozzolans), and will substitute at least 20% of clinker in the production of blended cement. In total, the direct CO_2 emission reduction should reach at least 30–40% from year 1, increasing to above 50% during the project lifetime.

27.2.1 Impact of the project

The plant will address an unmet, growing demand for cement while completely substituting cement imports. Thus, the project should help ensure lower cement prices, facilitate infrastructure development, and meet general housing demand by using abundantly available locally available raw materials. Moreover, the project will support the government's industry and urban infrastructure development goals (e.g. public and private housing, hospitals, bridges, dams, schools and enterprises), as outlined in national planning programmes. Onn the local and regional level the project will impact on economic activity in the area around the site, particularly employment. It will, thus, enhance the livelihoods of many inhabitants in the local community, which currently suffers unemployment and underemployment. Significant indirect employment will also be created.

27.2.2 Market context

Cement is being imported and transported over long distances, incurring high financial and environmental costs in the process. In some cases, additional surcharges make imports even more expensive. Even if the government were to alleviate import restrictions and fully liberalise the market, selling prices to direct customers would not fall lower than import parity prices. The project company would, nevertheless, retain its competitive advantage given its advantageous location vis-à-vis the country's capital.

Growth in cement demand usually tracks GDP growth in low-income countries, and is generally driven by housing, large scale public infratructure projects and general construction sector developments. Cement is heavy and bulky, and thus expensive to transport over long distances. Consequently, cement is largely a local/regional business. As cement is a uniform product, price is an important sales parameter. The cement industry has every characteristic of maturity: low profit margins, cyclical capacity build-up, limited innovation, a constant struggle with overcapacity, and regular consolidation waves. Still, there is no suitable substitute for cement.

In recent years, cement demand in the country has been growing faster than GDP, at an average of 15% per year; this rate is expected to continue for the next five years. There is still significant unmet demand, and current plans include infrastructure projects and large-scale housing construction.

[167] There are different types of cement. For example, CEM1 (Ordinary Portland Cement) contains 100% cement (but can contain a maximum of 5% of other materials), CEM2 contains 65% cement, with the remaining 35% being made up of fly ash, slag, limestone and other ingredients, and CEM3 contains around 45% cement etc. Lower cement content in concrete will, all else equal, reduce emissions. Blending with e.g. the silicate-based material pozzolan can improve the properties of concrete and may replace CEM I lowering the carbon footprint of concrete.

In sum, the company should be able to command an average sales price well above its average production cost and below the cost of the cheapest imported cement in the region. Given the timing of the project and its favourable location, the new plant will be well placed to address the growing cement demand, and should thus help the promoter secure a significant market share despite other important cement plants under construction and due to come on stream in the medium term. Even under moderately adverse market conditions, the present plant should remain viable.

As other projects are in contemplation and there is a substitution risk of smaller quantities of lower quality cement from higher-cost competitors in the future, price competition may later increase. Hence, a sales price significantly lower than the present import parity price has been assumed for the ERR calculation. Even with this adjustment, the estimated average sales price is still well above the average production cost.

For carbon costing, projects inside and beyond Europe are treated the same way. This analysis therefore includes an increasing price of carbon under the EU ETS throughout the project's economic life, which negatively affects the project FRR — the same applies to any project involving CO_2-emitting activities not fully covered by free allowances.

Table 27-1 summarises the results of the project's economic appraisal, which assumes that the plant has an economic life of at least 15 years. All monetary figures are expressed in constant prices.

The ERR is based on estimates (see line 11) of the SOC for labour, the economic price for cement, and the estimated shadow cost of carbon, as set out in the CBR and the European Union's commitment to fully decarbonise by 2050. Using these estimates, the project ERR is 11%, which is higher than the FRR. This indicates that the promoter will not appropriate the full economic benefits of the project.

The calculated ERR should be regarded as the lower boundary of the true ERR, since no quantitative adjustments have been made for the important spillovers to other economic sectors such as infrastructure and housing, which will substantially benefit when more cement becomes available and at lower prices. Also not reflected are the significant indirect employment effects around the plant site, although these effects will be somewhat counterbalanced by the negative externalities of increased traffic and associated emissions as local human activity increases.

The project has received technical assistance through a grant to explore using encroacher bush woodchips to meet the plant's energy demand. If this initiative is successful, the plant will have an additional renewable energy source, further lowering its carbon footprint while also rehabilitating land for farming. As such, this should have a marginally positive impact on the project ERR.

Table 27-1: Calculation of a greenfield industrial project's economic rate of return

		year	-2	-1	0	1	2	3	4	5	10	15
	<u>Production/sales</u>											
(1)	Cement production	000 ton				1400	1950	2150	2150	2200	2200	2200
(2)	Cement Net Sales	MEUR				105	146	161	161	165	165	165
	<u>Production cost</u>											
(3)	Variable costs including EU ETS	MEUR				61	73	80	82	86	100	119
(4)	Fixed costs	MEUR				7	10	10	10	10	10	10
(5)=(3)+(4)	Total production cash costs	MEUR				68	83	90	92	96	110	129
(6)=(2)-(5)	**Operational profits**	**MEUR**				**37**	**63**	**72**	**69**	**69**	**55**	**36**
(7)	Investment cost	MEUR	85	125	125	50						
(8)	Working capital	MEUR				20						
(9)	Replacement investments	MEUR								5	5	5
(10)=(6)-(5)	**Operating cash flow**	**MEUR**	**-85**	**-125**	**-125**	**-33**	**63**	**72**	**69**	**64**	**50**	**31**
	IRR	**10%**										
(11)	Net economic benefits					55	73	70	58	44	- 50	- 171
(12)	**Economic cash flow, incl SCC, net of ETS**		**- 91**	**- 137**	**- 131**	**22**	**136**	**141**	**127**	**109**	**- 0**	**- 140**
	ERR	**11%**										

28. Telecommunications

Anders Bohlin and Tobias Münstermann

28.1 Methodology

28.1.1 Broadband and very-high-capacity networks

In the last 20 years, the deployment of NGB and VHC networks has facilitated much faster data up- and download speeds, with fibre-based technologies starting to replace the slower, entirely copper- or coax-based first-generation wireline technologies. Relatedly, the economic benefits of broadband networks for consumers have been increasingly emphasised by economic research (Bertschek et al., 2016; Bresnahan and Trajtenberg, 1995).

Proponents of comprehensive broadband availability have underscored that this general-purpose technology brings positive externalities in major economic sectors. These advantages and promises of broadband technologies have also captured the attention of policymakers at national and European level in the last decade. The wide-scale roll-out of fibre-optic NGB is believed to indirectly spur job creation in ICT and other related industries; more generally, it is ascribed enormous potential for facilitating productivity increases and economic growth. The effects of VHC networks on socioeconomic variables concerning demand, median income, and the unemployment rate may vary across geographic localities. Therefore, these networks could be a strong tool for policymakers to support local economic growth and social development (Hasbi, 2020[168]).

Accordingly, the Bank has initiated a comprehensive review of available empirical evidence on the impact of NGB and VHC networks.[169] Whereas positive effects on GDP and productivity are expected, the overall impact of broadband on labour markets is ambiguous on a priori grounds. Though broadband adoption and digitalisation substantially facilitate new job creation, they also change the demand for labour skills.

The above review allows the underlying effects on GDP to be disentangled. First, there is a direct effect from pure investment activities in the course of deploying new network infrastructure: additional employment and economic production are generated. There are also related multiplier effects. Second, on the demand side there is an indirect effect through the adoption of fibre-based broadband services by firms and households.

The econometric results from the above-mentioned review are largely in line with previous NGB-related empirical results, suggesting strong direct effects on GDP and indirect effects on employment. Furthermore, the regression framework used identifies differential effects of VHC adoption and VHC coverage, as well as differential effects of different types of fibre-to-the-x networks.

To ascertain the impact of individual projects financed by the Bank, a simulation model has been developed based on available empirical literature and the estimation results.[170] The model assesses the economic return of VHC network investments for rural and urban areas. It further distinguishes the different types of network operators involved in VHC network deployment (incumbents vs. alternatives) as well as broadband-enabling factors, and then computes the project ERR. The model is described in chapter 13.

[168] Impact of Broadband Quality on Median Income and Unemployment: Evidence from Sweden, 21 December 2020
[169] With support from Eco Austria and more specifically Briglauer et al.
[170] In particular from EcoAustria.

28.1.2 Mobile broadband

Similar to NGB and VHC fixed infrastructures, mobile broadband is associated with positive effects on the economy, such as higher GDP and employment. Admittedly, mobile broadband and the impact of specific generations of its technologies have received less research attention than fixed broadband or broadband in general. Nonetheless, there is a consensus that mobile broadband technologies have brought significant benefits for consumers, businesses and the wider economy.

Many of the economic benefits of NGB and VHC infrastructures also apply to mobile broadband. Additionally, mobile broadband provides increasing opportunities for working on the move, as well as maximising the opportunities of business digitalisation through the internet of things and, especially, the move to Industry 4.0 — for instance, with industrial machinery using 5G technology for low latency wireless data transfers.[171] This can facilitate more flexible and efficient ways of working and enhance productivity (Bertschek and Niebel, 2016).

In addition to its macroeconomic impact and productivity enhancements, mobile broadband can also deliver consumer benefits. For example, the data packages included in mobile subscriptions usually increase over time; in combination with higher down- and upload speeds, this enables innovative apps and services, often available at low costs to end-users.

According to the latest Digital Economy and Society Index (DESI) report (2020) from the European Commission, 4G coverage in Europe reached 96% by the end of 2019. Most Bank-financed mobile broadband projects thus relate to increasing the service capacity and quality delivered by 4G and to rolling out 5G.

The 5G roll-out is still in its infancy. At the time of writing, 5G networks are more of an upgrade of the previous mobile technologies and yet to unleash the full potential of 5G, which is expected to provide a broader range of new or enhanced capabilities, going beyond the increased capacity and achievable bandwidths seen with 4G. The additional economic benefits could be far more extensive than those brought by previous generations of mobile technologies. Moreover, the further development of 5G use cases able to take advantage of the additional capabilities will be essential for assessing the additional economic benefits.

Mobile (wireless) broadband coverage with 3G or a higher network standard exerts a significantly positive impact on GDP per capita. The coefficient suggests that **a 1 percentage point increase in *3G+* coverage increases *GDP_pc* by about 0.0015%**.

For the telecoms industry, mobile broadband technology is very capital intensive because of the constant coverage and capacity investments required to meet market demand: for industry operators, the average CAPEX-to-revenue ratio is around 15% on an annual basis. This adds to the significant contribution to GDP from mobile telecommunications.

[171] Lundgren, Skoogh, Johansson, Stahre and Friis. 2017. "The Value of 5G Connectivity for Maintenance in Manufacturing Industry," commissioned by Chalmers University of Technology

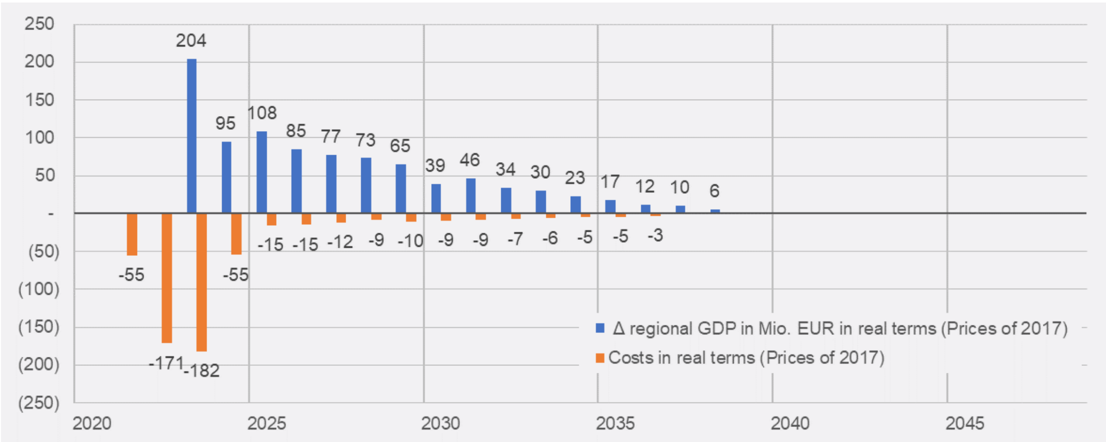
28.2 Case Study 1: High-capacity broadband

As an example, suppose that a high-capacity broadband project is undertaken that increases the NGB broadband adoption in a particular region from 12% to 79%. Total investment costs of €618 million will be incurred between 2021 and 2036, with operations starting in 2023. The assumed operational lifetime of the new infrastructure is 25 years.[172] The Excel tool, which has been developed to assess the economic rate of return, calculates the project's effects on GDP (depicted in Figure 28-1).

Overall investment costs amount to 0.59% of regional GDP, while the total economic benefits amount to 0.96% of regional GDP. The underlying long-term inflation rate is 1.3%. Based on available data, the spreadsheet model currently allows us to fix prices at 2017 levels. Using 2017 as the base year yields a total net benefit of €360 million. The costs and benefits of the project yield an economic rate of return (ERR_i) of 18.6%.

The case study project costs and the ERR calculation are presented in Table 28-1. The FRR reflects the financial profitability of the case study VHC network investment project from the perspective of a profit-maximising network operator. By contrast, the ERR estimates the overall economic benefit of this investment for the region as a whole, including any positive externalities in terms of increased productivity across the economy. The EIB separately considers the project's internal rate of return, to ensure that there will be funds from the project for the re-payment of a loan, but also the aggregate positive effect on society from the availability of better broadband infrastructure. When comparing the two, the ERR will generally be (at times substantially) larger than the FRR.

Figure 28-1: High-capacity broadband project investment costs and economic benefits



From the EIB's perspective, both return rates matter. The FRR is important as it may be too low for the operator to eventually deploy the new broadband infrastructure, given its profit-maximisation objective. When a proposed project generates a sufficiently high ERR (i.e. at least larger than the FRR), this justifies market intervention by the EIB. Where more than one project meets this criterion and available funding is constrained, the Bank can use the ERR to rank projects and prioritise those generating the highest economic return.

[172] Note that this represents a rather conservative estimate of the economic lifetime of NGB/VHC networks. Whereas tax depreciation schedules are typically 15 years or more, the service lifetime of fibre-optic cable is 30 years or more and, indeed in practice, fibre-optic cable in backbone networks has already been in use for over 30 years (information available at: https://www.corning.com/catalog/coc/documents/application-engineering-notes/AEN092.pdf).

The externalities in the ERR stem from two major sources. First, the improvement in high-speed NGB and VHC infrastructures raises the productivity of firms in the specific region. This will, on average, lead to increased growth of these firms and, thus, to rising regional income and GDP. Second, employment prospects are improved for people living in the region, which is another major driver of economic growth. Here, the two elements constituting benefits in the ERR calculation are any taxes related to additional employment and any difference between after-tax salaries and the shadow cost of labour. The employment benefit has been observed for people in rural areas, who can increase their working hours and/or start working (in some cases at home) by using digital infrastructures and relevant services like video conferencing, virtual private network access and cloud computing. Furthermore, in rural and urban areas, better broadband infrastructure will improve the productivity and employment prospects of high-skilled people.

Projects that generate a low FRR may also generate a low ERR. This may be found for projects in regions with a relatively high availability rate but low adoption, since economic benefits are driven by broadband adoption (usage), rather than coverage. In addition, regions with a high adoption rate could benefit less in economic terms since the marginal benefit of NGB tends to decrease as the adoption rate rises. Finally, improving broadband networks where the population density is very low (e.g. in extremely remote rural areas, such as alpine regions) may have a low FRR, since it is not profitable, and a low ERR, since positive economic externalities are low in sparsely populated regions. In such cases, fixed-line broadband might not be an appropriate technology and infrastructure deployment could be realised at comparatively lower costs with mobile broadband technologies.

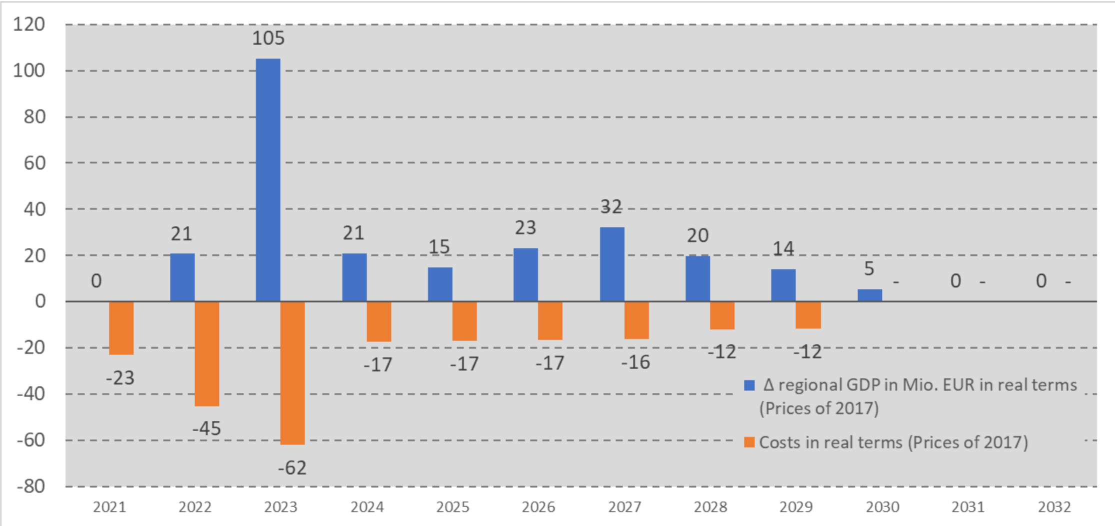
Table 28-1: Investment costs and economic rate of return calculation for a high-capacity broadband project

	Costs, Net Present Values & the ERR	SUM	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Project Costs											
(1)	in Mio. EUR		58	183	196	60	17	16	14	10	12	11
(2)	Costs in real terms (Prices of 2017)	567	55	171	182	55	15	15	12	9	10	9
(3)	Costs in % of regional GDP	0,59%										
(4)	Costs/ Home Connected	€ 528										
(5)	**Net Present Value (direct GDP Effect)**											
(6)	NPV in real terms (Prices of 2017)		- 55,03	- 171,28	5,47	32,55	83,85	63,75	58,88	58,39	49,28	27,27
	ERR (direct)	15%										
	Direct and indirect GDP-Effect	0,66	0,00%	0,00%	0,02%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%
(7)	Total GDP Effect (cumulative)		96 811	96 811	97 031	97 135	97 255	97 351	97 438	97 523	97 599	97 645
(8)	Δ regional GDP in Mio. EUR		0	0	220	104	120	96	88	84	76	47
(9)	Δ regional GDP in Mio. EUR in real terms (Prices of 2017)	discounted	0	0	204	95	108	85	77	73	65	39
(10)	Total GDP Effect	927	0	0	204	95	108	85	77	73	65	39
	in % of GDP (2017)	0,96%										
	Net Present Vallue (TOTAL GDP Effect)											
(9) - (2)	NPV (in Mio. EUR)	360	- 55	- 171	22	40	93	71	65	64	55	31
	ERR (%)	19%										

28.3 Case study 2: Upgrading from 4G to 5G

As an example, suppose that a project is undertaken to upgrade 4G and roll out 5G. The project is expected to be implemented from 2021 to 2023 and lead to a 5G coverage level of 60% by year-end 2023. The overall investment costs, including continuous follow up investments, total €255 million. 5G services are scheduled to become operational in 2022, and the economic life of the investment is estimated at eight years. It is also assumed that the number of users of innovative 5G services will increase from 5% at service launch to 100% at the end of economic life. Using the GDP coefficient of 0.0015%, a modified version of the spreadsheet model (adapted to mobile projects and to include the additional assumptions) produces the GDP effects depicted in Figure 28-2.

Figure 28-2: Mobile broadband project investment costs and economic benefits



Overall investment costs amount to 0.57% of regional GDP, while the total economic benefits amount to 0.65% of regional GDP. The increase in regional GDP is taken as a proxy for the overall productivity effect across the economy, with the provisos explained in chapter 13. The underlying long-term inflation rate is 2%. Using 2017 as the base year (as in case study 1) yields a total net benefit of €34 million. The costs and benefits of the project yield an economic rate of return (ERR_i) of 18.9%. The project costs, the direct and indirect GDP effects and the ERR are presented in Table 28-2.

Table 28-2: Investment costs and economic rate of return calculation for mobile broadband project

	Costs, Net Present Values & the ERR	SUM	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
	Project Costs											
(1)	in Mio. EUR		25	50	70	20	20	20	20	15	15	0
(2)	Costs in real terms (Prices of 2017)	222	23	45	62	17	17	17	16	12	12	0
(3)	Costs in % of regional GDP	0,57%										
(4)	Costs/ subscriber	€ 219										
(5)	**Net Present Value (direct GDP Effect)**											
(6)	NPV in real terms (Prices of 2017)		-23	-27	31	1	-4	4	12	5	1	5
	ERR (direct)	2%										
	Direct and indirect GDP-Effect	0,66	0,00%	0,01%	0,04%	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%
(7)	Total GDP Effect (cumulative)		39 183	39 206	39 325	39 349	39 366	39 394	39 433	39 458	39 475	39 482
(8)	Δ regional GDP in Mio. EUR		0	23	118	24	18	28	39	25	18	7
(9)	Δ regional GDP in Mio. EUR in real terms (Prices of 2017)	discounted	0	21	105	21	15	23	32	20	14	5
(10)	Total GDP Effect	256	0	21	105	21	15	23	32	20	14	5
	in % of GDP (2017)	0,65%										
	Net Present Vallue (TOTAL GDP Effect)											
(9) - (2)	NPV (in Mio. EUR)	34	-23	-25	43	4	-2	7	16	8	2	5
	ERR (%)	19%										

29. Forestry

Alexander Horst and Sylvain Caurla

29.1 Methodology

29.1.1 Introduction

Afforestation refers to the conversion of bare or cultivated land into forest. It is an effective measure to combat land desertification and presents numerous other benefits, such as carbon sequestration, improvement of soil health and quality, regulation and purification of groundwater, preservation of microclimates, and restoration of rich biodiversity. Afforestation projects to combat desertification are in line with the EU Forestry Strategy, *EU communication (2019) on stepping up EU action to protect and restore the world's forests*, the EU Biodiversity Strategy (2020) and the EU Strategy on Adaptation to Climate Change (2021). They are also aligned with the SDGs, particularly 13 and 15, and with the Bank's climate action policy objective.

29.1.2 Social benefits

In areas subject to desertification, afforestation programmes aim at creating windbreaks in the form of "green walls" and "green dams" to stabilise and reduce dust storms, avert wind erosion, and serve as carbon sinks, particularly when planting locally adapted native and other climate-resilient tree species.

Afforestation can also provide an additional source of wood products, thereby reducing the pressure on existing forests. New forests can stabilise the climate via evapotranspiration, which increases local rainfall volume and reduces surface temperature. In terms of climate change mitigation, afforestation plays an important role in sequestering carbon in aboveground and belowground forest biomass, and storing carbon in soils and harvested wood products. New forests also help regulate the flow of rainwater, while trees ensure that water is better held in the soil, thus improving the underground water table. Afforestation can help protect and/or restore habitats for biodiversity. Finally, it can positively impact on employment in the implementation phase (planting and maintaining seedlings) and once the forest is created (collecting, transforming and selling timber and non-timber forest products (NTFPs)).

The values assigned to social benefits can be estimated through the market prices of goods and services produced and rendered by afforestation measures (e.g. carbon sequestration, arable land). For valuing non-market goods and services, methods based on SP or RP models can be used. These methods allow, for example, estimation of the WTP for maintaining the existence of (or willingness to accept compensation for losing) an environmental feature such as biodiversity. As described in chapter 5, the EIB is currently strengthening the values it uses to estimate the benefits and costs of B&E services.

29.1.3 Social costs

In arid locations, the implementation of afforestation measures can be constrained by lack of water, leading to a trade-off between soil carbon sequestration and other water uses. Moreover, arid ecosystems such as grassy steppes shelter unique biodiversity and specific economic activities. Their transformation into forest lands risks losing this particular biodiversity as well as grazing land for domestic herds.

Similar to social benefits, these social costs can be evaluated based on market prices for goods and services (if available) or using the RP or SP models. Developing these models and analysing the results are often time-consuming, complex endeavours. These difficulties can be overcome by using value transfer, whereby quantitative estimates of ecosystem service values from existing studies are applied to another context.

29.1.4 Screening criteria

The EIB finances afforestation projects that align with the EU taxonomy. All relevant carbon pools must be assessed. Aboveground carbon stocks have to be maintained or increased relative to the carbon baseline over the rotation period of the forest. Projects proved to have technical, financial, economic and environmental sustainability, while also meeting the EIB's high standards and commitments, are approved and supported by the Bank.

Pursuant to the EU taxonomy, the afforestation plan must be accompanied by a sustainable forest management plan or an equivalent instrument under national law. In addition, the project activity must not involve degradation of land with a high carbon stock. Promoters must include SDGs in their overall strategy and fulfil all the social and environmental requirements set by the EIB.

29.2 Case study: Desertification control

29.2.1 The investment project

Bank financing is sought for a comprehensive desertification control programme involving afforestation and the implementation of sustainable forest management practices in Asia, over a five-year period. The newly established shelterbelt forests will increase carbon sequestration and storage, while also protecting soil and water, enhancing biodiversity, and actively controlling desertification through resilient forest ecosystems. The total area covered by the project is 138 000 ha. The project will establish (i) 125 kha of new protection (ecological) forests through afforestation with mixed native tree species, (ii) 10 kha of protection and production (economic) forests with native tree species, and (iii) 2.7 kha of new nurseries for the supply of seedlings in the project area and wider region.

The project implements five afforestation models, encompassing four ecological/protection forests and one economic forest. All five afforestation models use mixed native tree species to build green ecological barriers for wind-breaking and sand-fixation. The medium- to long-term outcomes will include diversified forest stands, healthier forest ecosystems, and increased resilience of those ecosystem to fires, pests and diseases.

29.2.2 Risk analysis

29.2.2.1 Site and species selection

There is a risk that some project sites and tree species are not properly selected, which could result in the project's objectives not being fully met (e.g. failure of plantations, less carbon sequestration).

Mitigation: During the appraisal, the promoter adjusted some initially proposed planting models by replacing species that require more frequent watering with drought-resilient species.

29.2.2.2 Sustainability of forest plantations during the operation phase (after planting)

There is a high risk that the afforestation of ecological (protection) forests is not sustainable. While specialised companies will be hired to carry out the initial afforestation work, responsibility will be handed over to individual farmers and communities four years after planting, thereby disrupting practices. In particular, the continuity of the exploitation phase — maintaining plantations — may be compromised by the relatively low yields of forests planted for conservation purposes: these yields are limited to the collection of NTFPs and sale of thinning wood. These disruptions must be anticipated and mitigated through training and monitoring.

Mitigation: The promoter has set up a new mechanism for protecting and maintaining the ecological forests. The mechanism is included in the project's implementation handbook, and specifies the responsibilities during the operation period (until year 25) of three parties: (i) community forest stations, (ii) township forest farms and forest rangers, and (iii) individual farmers and cooperatives.

29.2.2.3 Climate vulnerability and associated risks

The region's temperate, semi-arid monsoon climate may expose certain project areas to severe droughts and wildfires during hot and dry periods of the year. In addition, meteorological data suggest that the project region has experienced recurring major flood events in recent years. Other natural hazard risks include pests and disease, storms, fire and frost.

Mitigation: Fire hazards will be reduced by introducing close-to-nature forest management regimes with mixed tree-species stands, including fire-resilient broadleaved species, instead of monoculture plantations. The selection of locally adapted, drought-resilient species will also mitigate climate vulnerability.

29.2.2.4 Ensuring seedling capacity through establishing new nurseries

The project requires a considerable amount of seedlings. To prevent any shortage, the promoter proposes establishing 2.7 kha of new nurseries, operated by different implementing entities including private entrepreneurs and state forest farms.

29.2.3 Market supply and demand

The project will yield financial benefits through the sale of NTFPs and fresh fruits; environmental benefits through the provision of ecological services, such as sand-fixing, wind-breaking and carbon sequestration; and other economic benefits through controlling desertification, such as avoided losses of arable land and, thus, avoided decreases in crop productivity.

The project will produce a modest output of wood products, allowing a very small volume of selective logging (thinning) for some fast-growing trees (e.g. poplar, willow and white birch). These sustainable wood uses will somewhat alleviate local demand for timber, although the revenue generated from timber sales is expected to be minimal. The standing volume of forest plantation at the end of the project lifetime is expected to be about 7.2 million m^3. As a by-product of forestry activities, the promoter will also benefit from NTFPs (e.g. fruits, berries and pinecones), with combined sales revenues from these products expected to total €4.6 billion over the 25-year project lifetime.

29.2.4 Financial and economic analyses

29.2.4.1 Investment costs

The overall project investment costs were estimated at €658 million, with an EIB loan of up to €300 million. As detailed in, these costs cover two main components:

(i) Forestry activities (i.e. afforestation with native species, planting eco-friendly economic forests);
(ii) Project support system (project enabling activities such as establishing nurseries, and capacity-building activities such as training on project monitoring and evaluation or forest certification at provincial and county levels).

29.2.4.2 Financial and economic profitability

The financial and economic analyses assumed a conservative period of 25 years, in line with the loan tenor and comprising the initial construction period of 5 years and the operational period of 20 years. The rotation cycle of the forests exceeds 50 years, as the plantations are established for protection purposes, not timber production. Inflows and outflows are valued in constant terms. The financial analysis considers revenue streams from sales of berries and pinecones under the four ecological models and from sales of apples under the economic model. Table 29 2 presents the estimations of financial and economic returns.

Table 29-1: Summary breakdown of project investment costs

Project investment costs	Total investment (€ million)
Project forestry costs	**553**
Mixed forests of native tree species	509
Ecosystem-economics	44
Project support system	**72**
Nursery	72
Operational capacity building	1
Other costs	**5**
Administration of the implementation entity (0.17%)	1
Survey, design and acceptance (0.33%)	2
Works supervision and monitoring (0.245%)	2
Tendering (0.045%)	0
Total base costs	**630**
Contingencies	**9**
Technical contingencies	3
Budget reserve	6
Interest during construction	**18**
Total investment	**658**

Two major economic benefits were identified and valued for the economic analysis: CO_2 sequestration and protection of agricultural lands through shelter forests (combating desertification).

- By planting forests on degraded bare and abandoned lands, and by improving forest management practices, the project will lead to a net sequestration of about 637.5 kt CO_2 equivalent (CO_2e) per year. Applying the EIB shadow cost of carbon, the annual climate mitigation benefits will range from €54 million in 2020 to €427 million in 2044.
- The economic value of combating desertification was estimated by comparing a WOP scenario with the WP scenario. In the WOP scenario, arable land surrounding the project area shrinks at an annual rate of 1%; in the WP scenario, each afforested hectare is assumed to protect one hectare of agricultural land, thereby maintaining crop productivity. The total area protected from desertification was then multiplied by the average value of the main crop. The resulting economic benefit of protecting the agricultural land has an estimated NPV of nearly €220 million over the 25-year economic life cycle (using a 4% discount rate).

The project's consolidated FRR is positive, at 6.1%, accruing mainly from the net margins of NTFP production. The standing value of timber at the end of the reference period was included in cash flows and estimated at €216 million for an approximate volume of 7.2 million m^3.

Considering the economic benefits described above, the estimated ERR is 32%, mostly attributable to the high carbon sequestration benefits. The project is also expected to generate a wide range of additional ecosystem services, such as improved water retention capacity of soil, increased organic material content in soil, reduced soil erosion and landslides, higher biodiversity in habitats, and mitigated risks of forest fire and flooding. These are difficult to quantify in advance, but a qualitative estimation of the benefits ERRis expected to increase project ERR well beyond 32%. Following the upgrading of methods to quantify B&E benefits (described in chapter 5), these flows will also be incorporated into the ERR calculation in future appraisals.

Table 29-2: Financial and economic analyses for forestry project (detailed model)

	Financial Analysis (in EUR million)	2020	2021	2024	2025	2033	2040	2044
	Costs - Afforestation							
(1)	Model 1	50	56	11	-	-	-	-
(2)	Model 2	13	40	11	-	-	-	-
(3)	Model 3	46	17	1	-	-	-	-
(4)	Model 4	33	12	0.5	-	-	-	-
(5)	Model 5	6	8	5	-	-	-	-
	Costs - Project Support System							
	Nursery							
(6)	Materials and labour	26	3	-	-	-	-	-
(7)	Infrastructure	34	7	-	-	-	-	-
	Operational capacity building							
(8)	Project monitoring and evaluation fee	0.06	0.09	0.13	-	-	-	-
(9)	Forest certification fee	0.005	0.01	0.01	-	-	-	-
(10)	Municipal-level training	0.003	0.005	0.01	-	-	-	-
(11)	County-level training	0.002	0.003	0.005	-	-	-	-
	Costs - Others	-	-	-	-	-	-	-
(12)	Administrative fee of the implementation entity (0.17%)	0.11	0.17	0.25	-	-	-	-
(13)	Survey & design fee (0.33%)	0.21	0.33	0.49	-	-	-	-
(14)	Works supervision fee (0.245%)	0.16	0.25	0.36	-	-	-	-
(15)	Tendering fee (0.045%)	0.03	0.05	0.07	-	-	-	-
	Costs - contingencies	-	-	-	-	-	-	-
(16)	Contingencies	0.3	1	1	-	-	-	-
(17)	Budget reserve	1	1	1	-	-	-	-
(18)	Interests during the implementation period	4	4	4	-	-	-	-
(19)=(1)+(2)+…+(18)	**Total investment costs**	**213**	**148**	**36**	**-**	**-**	**-**	**-**
	Operational Costs *							
(20)	Model 1	-	-	-	1	63	63	63
(21)	Model 2	-	-	-	0.3	2	2	2
(22)	Model 3	-	-	-	1	1	1	1
(23)	Model 4	-	-	-	18	56	38	38
(24)	Model 5	-	-	-	18	70	69	64
(25)	Nursery	-	-	0.5	17	6	17	11
(26) = (20)+…+(25)	**Total operational costs**	**-**	**-**	**0**	**55**	**199**	**191**	**179**
	Revenue							
	Sales							
(27)	Model 1 - pine cones	-	-	-	-	106	106	106
(28)	Model 4 - sea buckthorn berries	-	-	-	20	66	45	45
(29)	Model 5 - fruits	-	-	-	20	84	81	74
(30)	Nursery - seedlings	-	-	66	1	28	28	28
(31)= (27)+(28)+(29)+(30)	**Total revenue**	**-**	**-**	**66**	**41**	**284**	**260**	**253**
(32)=(31)-(26)-(19)	***Cash flow (EBITDA)***	*(213)*	*(148)*	*30*	*(14)*	*86*	*69*	*74*
(33)= Σt (32)	*Cumulative cash flows*	*(213)*	*(362)*	*(524)*	*(538)*	*(200)*	*335*	*631*
(34)	*Residual Value*							*210*
(35)=(32)+(34)	***Cash flow + residual value***	*-213.10*	*-148.46*	*29.71*	*-13.91*	*85.81*	*69.48*	*284.57*
FRR=	**6%**	5.3%						
	**includes harvesting, sales, administration and tending costs*							

	Economic Analysis	2020	2021	2024	2025	2033	2040	2044
	Climate mitigation							
(36)	Carbon dioxide (annual relative carbon sequestration) (million tCO2eq)	0.6355	0.6355	0.6355	0.6355	0.6355	0.6355	0.6355
(37)	Carbon dioxide price (CBR approved values, EUR2020)	85	103	157	175	354	557	671
(38)=(36)x(37)	**Climate Change Mitigation value (EUR million)**	**54**	**65**	**100**	**111**	**225**	**354**	**427**
	Desertification mitigation							
(39)	Prevented desertification (WP-WoP) (ha)	0	0	4,655	5,587	13,035	19,553	23,277
(40)	Total crop revenue (EUR/ha)	1,411	1,411	1,411	1,411	1,411	1,411	1,411
(41)=(39)x(40)	**Combating desertification (EUR million)**	**0**	**0**	**7**	**8**	**18**	**28**	**33**
(44)= (35)+(38)+(41)	***Economic Cash Flow (EUR million)***	**-159**	**-83**	**136**	**105**	**329**	**451**	**744**
ERR=	**32%**							

30. Advanced biofuels

Laura Maria Catana

30.1 Methodology and policy context

30.1.1 Introduction

According to the Renewable Energy Directive II (RED II)[173] and its new 3.5% target on transport energy set for 2030, advanced biofuels[174] are fuels produced from the conversion of non-food biomass feedstock.[175] This feedstock comprises mostly by-products,[176] residues,[177] or crops unsuitable for food and feed production; their energy content is convertible to biofuels and their physical properties are comparable to those of fossil fuels. Bioindustrial activity, such as the production of food, feed, forestry products and other biomaterials, generates residues and by-products, some of which are considered waste. Through the production of advanced biofuels, these residues and by-products become valuable feedstock for energy generation.

Because different feedstocks are used, the technologies applicable to bioenergy conversion are not standardised; most are still under research, development or in an early stage of deployment. Through intense innovation activity around production technology, some capacity to deploy sustainable volumes of advanced biofuels (mainly from lignocellulosic biomass) has matured to commercialisation, with potential to become cost competitive.

The use of advanced biofuels contributes to the overall reduction of CO_2 emissions. It contributes to the 3.5%[178] blending target set by the European Commission through RED II for 2030. In addition, advanced biofuels help Member States to comply with the reporting obligations under the Directive on Indirect Land-Use Change[179] and the stricter targets on decarbonisation to which Member States have committed under National Renewable Energy Action Plans (NREAPs). Advanced biofuels currently represent about 1% of renewable energy sources for transport, along with other alternative fuels such as hydrogen and electricity. Advanced biofuel projects are also aligned with the EU Strategic Energy Technology Plan, the European Green Deal (2020) targets, the 2050 Decarbonisation Roadmap, SDGs 7 and 13, and the Bank's climate action policy objective.

30.1.2 Benefits of advanced biofuels

The European Union encourages the use of sustainably produced advanced biofuels from sustainably sourced feedstock, aiming to reducedependence on fossil fuel and crude oil imports for transport needs, and thereby mitigate potential geopolitical and economic effects of volatile energy supplies and fluctuating fuel prices.[180] In addition, advanced biofuels provide low-carbon power alternatives to fossil fuels, without requiring significant adjustments to energy transport, storage and distribution systems or to existing engines when blended with conventional fuels.

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[173] Ratifying the 2009/28/EC Renewable Energy Directive (RED)
[174] Also referred to as "second generation (2G) biofuels"
[175] As per the Annex IX, part A of the Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the promotion of the use of energy from renewable sources, issued in 2018, the feedstock might be: cultivated algae, municipal waste, bio-waste, biomass of industrial waste and forest and forest-based industries, straw, animal waste and sewage sludge, tall oil pitch and palm oil residue, crude glycerin, bagasse, grape marcs and wine lees, nut shells, husks, cobs or other non-food cellulosic material or non-ligno cellulosic material.
It is important to note that the feedstock and not the process used to produce the advanced biofuels determine whether the biofuels are considered to be "advanced."
[176] A production residue that is not a waste.
[177] A material that is not deliberately produced in a production process but may or may not be a waste.
[178] There is a soft limit on used cooking oil (UCO) and animal fats at 1.7%.
[179] Directive (EU) 2015/1513
[180] European Energy Security Strategy COM(2014) 330 final: link

By focusing on sustainable production of advanced biofuels — sourcing mainly regional feedstock considered sustainable under the CBR — carbon emissions targets for transport would be supported and various other benefits achieved, including job and wealth creation, rural development, enhanced technological expertise and innovation, and climate improvements. The shift towards advanced biofuel production and use is supported by the implementation of certification schemes. In addition, many advanced biofuel options share common pathways with the building blocks of biomaterials, and therefore enable further technology development beyond transport energy.

30.1.3 Social costs

Implementing advanced biofuel projects can be constrained by uncertainty over potential environmental impact. Concerns may also arise over whether feedstock availability, sustainability, quality and logistics will meet the requirements to achieve economies of scale in production. Some advanced biofuel conversion processes are sensitive to feedstock quality deviations, which can negatively affect conversion efficiency, processing stability and operational costs. Also, collecting feedstock from households or small suppliers embeds a significant transaction cost that does not exist in the large-scale exploitation of fossil fuels.

30.1.4 Screening criteria

The Bank applies strict, detailed screening criteria for the appraisal of advanced biofuel projects, aligned with the Directive on Indirect Land-Use Change and the RED II guidelines. Projects must demonstrate their technical, financial, economic, social and environmental sustainability, as detailed below.

A. Technical:

- The promoter has industrial experience and knowledge in the energy, process technology, or agricultural sector;
- The project has sufficient technological readiness for commercial deployment;
- A comprehensive feasibility study has been carried out by a qualified consultant or agency, taking into account all business risks.

B. Economic and financial:

- The promoter has sufficient equity financing;
- A comprehensive market analysis has been carried on the relevant feedstock and biofuel markets, identifying credible offtake contracts for the feedstock needed and biofuels produced;
- The applicable advanced biofuel policy and potential preferential treatments have been analysed for the relevant offtake markets;
- The project shows sufficient financial profitability under realistic assumptions;
- The project's total economic returns exceed its private financial returns and the SDR.

C. Environmental:

- The project is environmentally sustainable and complies with applicable EU regulations, including GHG saving targets and calculation methods, as well as the EU taxonomy criteria on biogas and biofuels for use in transport;
- The promoter pledges to include SDGs in its overall strategy;
- The environmental impact assessment and the integrated pollution prevention and control permit are in place, when relevant for the operation;
- A verifiable climate impact and risk analysis has been carried out.

D. Social:

- The promoter has applied the Bank's standards on gender, age, marital status, sexual orientation, ethnic origin, nationality, religion and disability, and has implemented a grievance mechanism;
- The project demonstrates an acceptable social, health and safety system, with implemented policies.

Although the Bank has only financed a few advanced biofuel projects to date, this sector is gaining ground, as exemplified by the increasing number of project proposals received. However, the vast majority of these proposals fail to meet the strict screening criteria.

30.2 Case study: Advanced biofuels industrial facility

30.2.1 Investment

Based in a cohesion area of Europe, the promoter seeks financing for a first-of-its-kind industrial facility to produce sustainable 2G bioethanol from locally supplied lingocellulosic residual biomass. The approved EIB loan represents 75% of the project's eligible investment cost. This share exceeds 50% (the general limit) because the advanced bioethanol plant is conducive to meeting long-term energy and climate targets under the Modernisation Fund. The project is, therefore, partially eligible under the Energy Transition Package. Moreover, financing the construction of an advanced bioethanol plant is aligned with the Bank's energy lending policy. The project investment cost is summarised in Table 30-1.

Table 30-1: Summary breakdown of project investment cost

DESCRIPTION / YEAR	TOTAL PIC (M EUR)	%	TOTAL Loan (M EUR)	%
ADVANCED BIOETHANOL	**51.9**	**1.0**	**38.9**	**1.0**
Engineering and project management site cost	**37.5**	**0.7**	**28.1**	**0.7**
Engineering design and supervision Environmental Impact Assessment	*0.4*	*0.0*	*0.3*	*0.0*
Project management and administration	*1.3*	*0.0*	*0.9*	*0.0*
Other: auditor/fees/ capitalised travel expenses	*0.2*	*0.0*	*0.1*	*0.0*
Licence, base project, licensor support	*2.3*	*0.0*	*1.8*	*0.0*
Civil works, buildings, tanks, site development	*19.1*	*0.4*	*14.4*	*0.4*
Equipment & machinery	*14.2*	*0.3*	*10.6*	*0.3*
CHP unit	**10.6**	**0.2**	**7.9**	**0.2**
Biogas Plant unit	**3.8**	**0.1**	**2.8**	**0.1**
Civil works, buildings, tanks, site development	*3.8*	*0.1*	*2.8*	*0.1*

30.2.2 Risk analysis

30.2.2.1 Environmental risk

As the project makes use of straw, a by-product of wheat production, it may increase pressure on the environment by extracting organic matter that would otherwise be returned to the soil, either directly or via livestock bedding. The reduction of drought resilience through harvesting straw and depleting soil organic matter may be exacerbated by climate change. Hence, sufficient crop residues must be left in place during multiannual crop rotation.

The production unit will employ an innovative process for extracting sugar from the cellulose and hemicellulose fraction of lignocellulose. In addition, the technology supplier to the promoter has performed numerous tests on alternative lingocellulosic raw materials, such as residues from forestry and agriculture (e.g. corn stover and sugar cane bagasse), as well as energy crops such as miscanthus and even residual wood — all are aligned with Annex IX, RED II Directive.

30.2.2.2 Supply-chain risk

The main supply-chain risk is the occurrence of adverse weather shocks during the wheat growing and harvesting seasons, which would reduce the supply and quality of straw and other lignocellulosic feedstock. Another risk concerns the prevailing market practice of loose contractual arrangements, which poses potential problems if the logistics chain is disrupted. In this particular operation, the feedstock supply risk is mitigated by an excess supply of straw in the sourcing area, as well as the possibility to carry some harvested straw over to the following harvest year, so as to smooth the annual availability of feed stock.

30.2.2.3 Implementation risk

Several factors contribute to the risk of schedule delays and cost overruns: the scale of the investment; the need to coordinate multiple vendors and contractors for the plant's commissioning; the upscaling of technology during construction and initial operation; and the time needed to achieve the promoter's target efficiency levels. This risk is mitigated by the promoter's sound in-house experience of deploying industrial projects involving proprietary process technology, equipment and machinery suppliers (with engineering, procurement and construction (EPC) contracts). The promoter also has proven performance on the pilot unit and its scale-up.

30.2.2.4 Operational risk

To mitigate the risk associated with technical failures in the plant and the provision of raw materials, the promoter has onboarded experienced technical and procurement teams, devised operation and emergency guidelines, and implemented risk management systems.

30.2.2.5 Market risk

The operation is exposed to a significant risk concerning demand for bioethanol. There is also risk surrounding the governance of biofuel and resulting by-product markets, as regulatory changes could impact the blending requirements and final product prices. These risks have been mitigated by the promoter's approach to use the produced bioethanol blended with fossil fuels for internal consumption — aligned with RED II, the European Union's GHG emissions targets, and the NREAP.

30.2.3 Financial analysis

The project FRR is estimated at 13.1% (see Table 30-2), based on conditional constant (fixed) prices and a 15-year economic life. The key parameter driving financial returns is the sales price for bioethanol, estimated according to market conditions at the time of project appraisal.[181]

In the sensitivity analysis, project FRR would decrease to 11.2% if the investment cost increased by 10%, and to 9.2% if the gross operating margin also decreased by 10%.

[181] 1,515EUR/ton

Table 30-2: Financial profitability estimation for the advanced biofuels project

				2020	2021	2022	2023	2024	2025…	2037	2038
	Incremental benefits										
	Bioethanol										
(1)	Sales	000 EUR		0	0	0	0	12,000	13,200	13,800	13,800
(2)	Subsidy	000 EUR				4,879	5,269	1,988			
(3) = (1) + (2)	Total	000 EUR		0	0	4,879	5,269	13,988	13,200	13,800	13,800
	Incremental operating costs										
	Bioethanol										
(4)	Direct Costs	000 EUR		0	0	0	0	5,294	5,349	5,859	5,859
(5)	Indirect Costs	000 EUR		0	0	0	0	1,453	1,456	1,459	1,459
(6) = (4) + (5)	Total	000 EUR		0	0	0	0	6,748	6,805	7,318	7,318
(7) = (3) - (6)	**Gross Operating P**	000 EUR		0	0	4,879	5,269	7,241	6,395	6,482	6,482
	Investment Schedule										
	Bioethanol										
(8)	CAPEX	000 EUR		1,708	118	19,546	21,969	8,528			
(9)	Residual Value	000 EUR								0	7653
(10) = (8) + (9)	Total			1,708	118	19,546	21,969	8,528	0	0	-7,653
(11) = (7) - (10)	**Project Cash Flow**	000 EUR		-1,708	-118	-14,666	-16,700	-1,287	6,395	6,482	14,136
(12) = IRR (11)	**FIRR =**		**13.1%**								
	SENSITIVITY ANALYSIS										
	Sensitivity : +10% EIB Project Cost										
(13) =(7) - [1.1*(11)]	Project Cash Flows	000 EUR		-1,879	-130	-16,621	-18,897	-2,140	6,395	6,482	14,901
(14) = IRR (13)	**FIRR =**		**11.2%**								
	Sensitivity: +10% EIB Project Cost & -10% in GOP										
(15) =[0.9*(7)] - [1.1*(11)]	Project Cash Flows	000 EUR		-1,879	-130	-17,109	-19,423	-2,864	5,756	5,834	14,253
(16) = IRR (15)	**FIRR =**		**9.2%**								

30.2.4 Economic analysis

The project generates positive externalities in the form of environmental and public health benefits through reduced GHG emissions, achieved by substituting renewable energy for fossil fuels. The ERR is estimated at 17.1% (see Table 30-3), based on quantified and monetised carbon savings. These were calculated on a life-cycle assessment basis for biofuels, and compared to a baseline price scenario for the combustion of fossil fuel equivalents, as per the calculation method in RED II.

On top of the quantified impact, the operation generates externalities that can be estimated only qualitatively. Hence, project ERR is expected to exceed 17.1%.

The economic price of bioethanol was aligned with its counterfactual, which is the price of Euro-super 95 gasoline, as available on the market and excluding taxes. No other prices were adjusted as the markets for inputs and remaining outputs were considered to be near-perfectly competitive.

Table 30-3: Economic profitability estimation for the advanced biofuels project

			2020	2021	2022	2023	2024	2025…	2037	2038
	Incremental benefits									
	Bioethanol									
(1)	Sales	000 EUR	0	0	0	0	12,000	13,200	13,800	13,800
(2)	GHG savings	000 EUR					2,000	2,500	8,000	8,500
(3) = (1) + (2)	Total	000 EUR	0	0	0	0	14,000	15,700	21,800	22,300
	Incremental operating costs									
	Bioethanol									
(4)	Direct Costs	000 EUR	0	0	0	0	5,294	5,349	5,859	5,859
(5)	Indirect Costs	000 EUR	0	0	0	0	1,453	1,456	1,459	1,459
(6) = (4) + (5)	Total	000 EUR	0	0	0	0	6,748	6,805	7,318	7,318
(7) = (3) - (6)	**Gross Operating Profit**	000 EUR	0	0	0	0	7,252	8,895	14,482	14,982
	Investment Schedule									
	Bioethanol									
(8)	CAPEX	000 EUR	1,708	118	19,546	21,969	8,528			
(9)	Residual Value	000 EUR							0	7,653
(10) = (8) + (9)	Total		1,708	118	19,546	21,969	8,528	0	0	-7,653
(11) = (7) - (10)	**Project Cash Flows**	000 EUR	-1,708	-118	-19,546	-21,969	-1,276	8,895	14,482	22,636
(12) = IRR (11)	**EIRR =**	**17.1%**								
	SENSITIVITY ANALYSIS									
	Sensitivity : +10% EIB Project Cost									
(13) =(7) - [1.1*(11)]	Project Cash Flows	000 EUR	-1,879	-130	-21,500	-24,165	-2,128	8,895	14,482	23,401
(14) = IRR (13)	**EIRR =**	**15.5%**								
	Sensitivity: +10% EIB Project Cost & -10% in GOP									
(15) =[0.9*(7)] - [1.1*(11)]	Project Cash Flows	000 EUR	-1,879	-130	-21,500	-24,165	-2,854	8,006	13,034	21,903
(16) = IRR (15)	**EIRR =**	**13.8%**								

31. Interurban railways

Marcial Bustinduy (revising an earlier edition by Alfredo Diaz)

31.1 Methodology

31.1.1 Overview

The Bank finances a very diverse portfolio of projects in the rail sector, involving infrastructure and rolling stock. Infrastructure projects usually include civil infrastructure and superstructure (electrification system, signalling and communications, track, etc.), although some brownfield projects focus only on rehabilitating, renewing or upgrading certain superstructure components (e.g. to deploy the European Rail Traffic Management System). In the case of rolling stock projects, the Bank's analysis considers whether the new trains are intended for fleet replacement or expansion.

Project analysis combines financial and economic perspectives. The economic appraisal features a standard CBA, usually based on information provided by the promoter such as a complete feasibility (or pre-feasibility) study, demand analysis, cost estimates, and other relevant details. Such information is often updated during the due diligence process, for example when studies were performed several years ago and include outdated inputs, or when the Bank adjusts for optimism bias.

The appraisal compares the proposed project with "do-minimum" or "do-nothing" alternatives, but does not include an options analysis of possible alternative solutions. This is because the operation is normally fully defined at the appraisal stage and therefore the objective of the appraisal is to ensure the chosen option ("do something") offers sufficient returns, rather than choosing among alternatives. In exceptional cases where the Bank becomes involved at an early stage, an analysis of various "do-something" options may be conducted during pre-appraisal. This options analysis may also include a "do-minimum" scenario, limiting spending to that necessary to keep the system operational at the current technical level.

31.1.2 Process for appraising rail projects

In the appraisal of rail projects, several issues must be adequately addressed:

- Context and background: The project must be adequately identified within the context of a regional, national or European investment programme, depending on the type of project. A rail project must be consistent with national and EU objectives, including Trans-European Transport Network (TEN-T) objectives and compliance with low-carbon and resilient pathways;
- Scope: The project's scope is not always defined clearly (or at all). In such cases, the EIB works with the promoter to clearly define the project. As self-sufficiency is required; i.e. all components needed to make a project operable must be included within its scope[182] This is not always straightforward and sometimes requires a wider view: for example, a railway line from A to B also requires stations at both ends, while upgrading infrastructure to increase the design speed must be accompanied by rolling stock capable of operating at that higher speed. Conversely, the project scope should not include unrelated components or components that are not needed to make the project operable (e.g. buildings unrelated to the operation of trains, or road infrastructure with no interference with the rail project, should not be included in the scope);
- Market analysis and demand forecasting: A high-quality demand analysis is essential for adequate planning and accurate project evaluation. Generally, implementing a rail project will result in increased demand. Existing traffic, diverted traffic from other modes, and generated traffic must each be clearly identified, as well as the evolution of traffic during the economic life of the project. Some projects may not attract additional traffic but will instead tackle capacity bottlenecks, thus maintaining modal share and avoiding traffic diversion to other modes;
- Financial analysis;
- Economic analysis.

[182] The definition of the scope of the project can be an iterative process in which several alternatives are assessed and modified in order to find the most efficient solution. In such a pathfinder process, inefficient components that can be separated from the project can be withdrawn.

31.1.3 Financial analysis

The financial analysis basically considers two main stakeholders: the infrastructure manager (IM) and the railway undertaking (RU). It analyses the implications of project implementation for their cash flows, considering investments, operating costs and revenues. The main cash flow streams considered (with all values expressed in financial terms) are as follows:

- For the IM, responsible for railway infrastructure (tracks, stations, special services):
  - Investment costs for infrastructure (e.g. land acquisition, construction of depots);
  - Maintenance costs of infrastructure;
  - Operating costs of infrastructure;
  - Operating revenues from track access charges, stations and services;
  - Grants received for the project.
- For the RU, responsible for providing freight and passenger transport services:
  - Investment costs for rolling stock (and, in some cases, maintenance workshops);
  - Maintenance costs of rolling stock (and workshops, if applicable);
  - Operating costs of rolling stock, including track access charges, personnel, services, etc.;
  - Operating revenues from freight and passenger transport.

Some railways still operate as (quasi) monopolies in certain regions or countries, with no separation between infrastructure and operation of trains. A consolidated financial analysis is conducted in such cases considering the following cash flow streams:

- Investment costs (including rolling stock);
- Infrastructure maintenance and operating costs;
- Rolling stock maintenance and operating costs;
- Revenues from freight and passenger transport.

31.1.4 Economic analysis

The economic analysis examines the impacts of the project on the economic welfare of society. CBA assesses each of the following variables for freight and passenger traffic in the project and alternative scenarios:

- Investment costs: These cover planning, design, supervision, management, land, construction and rolling stock. All costs must be expressed in economic terms, so market prices need to be adjusted to reflect opportunity costs.[183] The residual value of assets is considered in the analysis.
- O&M costs of infrastructure: This variable usually differs in value between the “do-minimum” and “do-something” scenarios and can be higher or lower in the project scenario (e.g. some installations could result in the rationalisation of workplaces). Where new assets are installed, maintenance costs could increase.
- VOCs: This variable captures passenger and freight diverted to rail from other modes (such as road and air).
- Rolling stock O&M costs, which could include two types: (i) additional train services required to serve additional demand created by the project; and/or (ii) technological changes (e.g. introducing electric trains instead of diesel trains in electrification projects).
- Distance and journey times: These are calculated for the new railway, existing railway, and modes from which demand is shifted; where appropriate, access and egress times are included.
- Safety: Benefit derived from traffic that is diverted into rail from other modes with a higher accident incidence (mainly road). This is calculated by applying the external cost related to traffic injuries per vehicle-kilometre to the increase or decrease in traffic activity for each affected mode. The external cost related to traffic injuries takes into account the accident rate for each mode and the VOSL.

[183] Economic transfers (e.g., taxes representing a pure transfer, subsidies, etc.) are discounted and corrections are made (i.e., shadow prices) whenever applicable.

- CO_2 emissions: These are calculated based on the emissions factor per vehicle-kilometre or passenger-kilometre and considering the increase or decrease in traffic for each mode, as well as the shadow cost of carbon. For electric modes, the emissions factor takes into account the power grid factor of the project country.
- Other user benefits, such as reliability or comfort, as well as externalities, such as noise and local pollutants, may be considered when appropriate.

The appraisal follows the willingness to pay and opportunity cost aggregation method. Therefore tax changes and interest payments represent transfers from one group of society to another and therefore are not taken into account for the economic appraisal.

The economic indicators obtained are the ERR, NPV and B/C ratio. These are used to estimate whether the proposed project is economically sound or, in some cases at pre-appraisal, to compare various alternatives, ranking them in order of efficiency in economic terms.

31.2 Case study: Increasing railway line capacity

A single-track railway line is operating close to capacity. The line is an important transit freight link for distributing goods from a port to hinterland destinations. It is also located at an important corridor for passenger traffic, and thus carries many long-distance travellers. The passenger RU is contracted by the government to provide services under a public service obligation framework. The track is in good condition and uses a state-of-the-art signalling system. The entire length of the line is electrified.

Around 75 trains per day are using the line, of which 50 are freight trains and the rest carry passengers. Demand is increasing for freight and passenger transport, and this positive trend is likely to continue. However, the infrastructure does not allow additional trains to be operated without disruptions: in effect, this section of the railway network has become a bottleneck. Moreover, the single-track section connects to double-track sections at both ends. Therefore, the planning authority decided to investigate the possibility of increasing capacity by installing an additional track. This would allow rail to cater for traffic growth and avoid a modal shift to road, in line with policy objectives for sustainable transport and climate change mitigation.

The single-track line can be seen as part of a longer railway corridor, since much of the demand is for long-distance travel. Therefore, the project boundaries are extended to include the origin-destination pairs generating traffic in this section.

The “do-minimum” scenario is defined as investing enough resources in the existing single-track section to maintain good operating conditions: existing traffic would be expected to continue and the IM would not be able to provide additional slots (capacity constraints), thus capping rail traffic growth and diverting passengers to other modes (bus, lorry, plane, ship and car).

The “do-something” scenario entails the installation of a second track in this section to increase capacity. With double-track, the line’s capacity would increase to above 300 trains per day — enough to cope with future demand. No increase in design speed is foreseen.

The time horizon for the cash flow analysis is 30 years, whereas the weighted average economic life of the project is 35 years. This implies that some residual value should be considered. In the economic analysis, a correction factor of 0.9 is applied to financial transfers.

The results are summarised in the tables below.

Table 31-1: Cash flow and financial profitability estimation for infrastructure manager

		PV	2021	2022	2023	2030	2040	2050
1	Investment + Maintenance	503.3	155.3	155.3	155.3	4.0	4.0	4.0
2	Net Operating cash flow pass	9.5	0.0	0.0	0.0	0.3	0.3	1.7
3	Net Operating cash flow freight	63.4	0.0	0.0	0.0	4.6	4.9	5.3
4=2+3-1	Total net operating cash flow	72.9	0.0	0.0	0.0	4.8	5.2	7.0
5=4-1	**Net Cash Flow**	**-430.5**	**-155.3**	**-155.3**	**-155.3**	**0.8**	**1.2**	**3.0**
	Operator FIRR	**-6.8%**						
	Operator FNPV (EUR M)	**-430.5**						

The IM is able to recover its marginal costs before the investment takes place. However, the maintenance costs increase substantially after installing the second track. Existing demand is not enough to cover the resulting additional costs in the first years after opening. Assuming that the track access charges are not adjusted after the second track opens, the IM will need governmental support in the medium term. However, in the long term (from 2030 onwards), demand will be high enough to cover the marginal costs and the IM will be able to operate self-sustainably. It is clear, though, that the investment will need governmental aid.

Table 31-2 shows that the operator (RU) accrues a positive operating cash flow from freight transport services. However, passenger transport services are unprofitable, raising the need for governmental support.[184] Although the RU will achieve positive operative results in the long term thanks to the good performance of freight transport services, the financial results (operator FRR) are still negative. Through a clear and transparent fiscal separation of freight and passenger transport services, the RU could obtain governmental support to cover the financial gap under a public service obligation framework, while continuing to profit from freight transport services.

The overall project, entailing infrastructure and train operation, is not financially profitable, as shown in Table 31-3. By contrast, the economic analysis shows that the project generates enough benefits to society to justify the costs (see Table 31-4). Specifically, project ERR is 11% and the B/C ratio is above one.

Table 31-2: Cash flow and financial profitability estimation for railway undertaking

		PV	2021	2022	2023	2030	2040	2050
1	Investment	41.0	0.0	0.0	30.0	0.0	0.0	0.0
2	Net Operating cash flow pass	-67.7	0.0	0.0	0.0	-3.5	-4.2	-6.5
3	Net Operating cash flow freight	59.4	0.0	0.0	0.0	0.3	4.4	10.3
4=2+3	Total net operating cash flow	-8.3	0.0	0.0	0.0	-3.2	0.2	3.7
5=4-1	**Net Cash Flow**	**-49.3**	**0.0**	**0.0**	**-30.0**	**-3.2**	**0.2**	**3.7**
	Operator FIRR	**-1.5%**						
	Operator FNPV (EUR M)	**-49.3**						

184 The governmental support is not shown in this example.

Table 31-3: Cash flow and financial profitability estimation for infrastructure manager and railway undertaking

		PV	2021	2022	2023	2030	2040	2050
1	**Capex and Opex**	544.3	155.3	155.3	185.3	4.0	4.0	4.0
2	**Operating cash flow pass**	-58.2	0.0	0.0	0.0	-3.3	-4.0	4.8
3	**Operating cash flow freight**	122.8	0.0	0.0	0.0	4.9	9.3	15.6
4=2+3	**Total Operating Cash Flow**	64.6	0.0	0.0	0.0	1.6	5.4	10.7
5=4-1	**Net Cash Flow**	-479.7	-155.3	-155.3	-185.3	-2.4	1.4	6.7
	Operator FIRR	**-5.1%**						
	Operator FNPV (EUR M)	**-479.7**						

Table 31-4: Economic returns of railway project

	Economic costs	**PV**	**2021**	**2022**	**2023**	**2030**	**2040**	**2050**
1	Infrastructure	399.5	139.7	133.1	126.7	0.0	0.0	0.0
2	Rolling stock	36.9	0.0	0.0	24.5	0.0	0.0	0.0
3	Renewals	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	Maintenance	133.7	0.0	0.0	0.0	5.8	3.6	2.2
5	Residuals	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	Ancillary projects	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7=1+2+3+4+5+6	Total	570.1	139.7	133.1	151.2	5.8	3.6	2.2
	Economic benefits	**PV**	**2021**	**2022**	**2023**	**2030**	**2040**	**2050**
8	VOT	64.6	0.0	0.0	0.0	2.3	0.0	1.5
9	OPEX	430.8	0.0	0.0	0.0	16.6	9.8	8.8
10	Comfort	20.9	0.0	0.0	0.0	0.8	0.0	0.4
11	Noise	33.3	0.0	0.0	0.0	1.3	0.7	0.7
12	Safety	65.8	0.0	0.0	0.0	2.5	0.0	1.3
13	Env CO2	551.7	0.0	0.0	0.0	12.0	13.9	20.2
14	Env other	24.1	0.0	0.0	0.0	0.9	0.0	0.5
15=8+9+10+11+12+13+14	Total	1191.2	0.0	0.0	0.0	36.4	24.6	33.3
16=15-7	**TOTAL FLOWS**	**621.2**	**-139.7**	**-133.1**	**-151.2**	**30.6**	**21.0**	**31.1**
	EIRR	**11.0%**						
	NPV	**621.2**						
	B/C	**2.1**						

32. Roads

Pierre-Etienne Bouchaud (reviewed by Diego Ferrer)

32.1 Methodology

The Bank applies a standard CBA to all road projects above a certain investment cost (€25 million). Projects submitted for financing typically concern urban and interurban greenfield roads and motorways, bypasses, widenings, and the rehabilitation of national, regional and rural roads. However, the Bank does not consider pure maintenance projects. The economic appraisal usually includes: (i) identification of the project scope and area of influence; (ii) quantification of the economic costs of building and maintaining the infrastructure; (iii) determination of the associated economic benefits over time, in terms of travel-time savings, VOC savings, reduction in accident levels, and climate and environmental impact; and (iv) calculation of the project ERR and assessment of the economic justification.

32.1.1 Project definition

The economic appraisal of road projects starts with evaluating the relevant mobility strategies at international, national and regional levels. The Bank checks that climate strategies are integrated in the mobility plans, and that all modes are considered in the analysis of transport solutions within the project's corridor.

The first step in the appraisal is analysing alternatives prepared by the promoter. The Bank checks that a range of project alternatives are considered, encompassing least-cost options, and whether the "do-minimum" alternative is credible.

The second step is to precisely define the project scope as an independent, standalone functional unit of the road network. In other words, road projects are understood as the improvement or addition of a road section (or link) connected to an existing road network through interchanges and junctions (or nodes).

The third step is determining the project's area of influence. This is defined as the smallest area capturing network and other effects generated by the project.

Finally, the economic evaluation generally considers the costs and benefits in the WP scenario relative to those in the WOP scenario. In some cases, the comparison is made relative to a "do-minimum" scenario entailing a specific investment and maintenance cost profile, e.g. simply to prevent that the road collapses.

32.1.2 Economic costs

The economic costs of a road project is based on bills of quantities and encompasses a unit price analysis for reference. It includes costs actually paid by the promoter, such as for preparation, construction and maintenance, and any other costs corresponding to use of resources. Economic costs include land acquisition even if it does not lead to a payment (e.g. if the land is already owned by the Promoter or the Government). This is because there is an opportunity cost to use the land for building the road rather than for another purpose. As there is no creation of an asset, however, land acquisition is not eligible for Bank financing.

Some cost items such as taxes and interest payments, even when borne by the promoter, are not considered economic costs as they represent internal transfers (from one group of society to another). In most cases, the promoter's project costs net of VAT are a suitable proxy for the project's economic costs. In several countries, however, more adjustments are required to consider these internal transfers in full, especially with regard to hidden taxes and subsidies. Infrequently, shadow pricing and conversion factors are applied to address distortion between actual costs and economic costs, notably for foreign exchange rates (in regulated markets) and wage rates (in case of significant underemployment of unskilled labour or severe shortages of skilled labour) (See Section 2.2.3 on shadow prices).

32.1.3 Economic benefits

The benefits of road projects financed by the Bank may include: (i) travel-time savings; (ii) VOC savings; (iii) reduction in accidents; (iv) reduction in GHG emissions; and (v) reduction in noise, local pollutants and visual impact. Other direct benefits can arise from a fall in maintenance spending if existing road assets have become expensive to maintain. Wider economic benefits are generally not included in the analysis as they may introduce double-counting, particularly relative to travel-time savings.

Notably, a project may have disbenefits in any of these five categories, representing additional economic costs. For example, a project may lead to an increase in VOCs if the route becomes longer (e.g. via a bypass) or speeds become higher (e.g. a motorway replacing a two-lane road). In the same vein, accidents can be more frequent or deadlier on a new road allowing higher speeds.

Economic benefits stem mainly from improvements in traffic flow and speed within the project's area of influence. The EIB requires promoters to perform a thorough state-of-the-art traffic analysis, with the main objective of projecting the amount of traffic that will shift from existing routes to the new infrastructure. The traffic analysis also involves forecasting traffic growth in the area of influence as a function of relevant variables, such as GDP per capita, car ownership, fuel costs, demographics and land use. For a toll motorway, the traffic analysis should also consider the impact of toll levels.

32.1.4 Traffic

The Bank does not typically perform its own traffic forecasting for road projects submitted for financing. Instead, it analyses the promoter's traffic studies and assesses their quality and credibility. In particular, the EIB expert concentrates on key elements such as (i) current traffic in the existing corridor; (ii) initial traffic on the new road at opening; (iii) traffic shifting to the new road from existing alternatives; (iv) traffic induced by the comfort of the new road; and (v) traffic growth in the project's area of influence.

The Bank considers average annual daily traffic as the main indicator for traffic in the project road and its area of influence. Traffic is divided into light vehicles (LVs), heavy vehicles (HVs) and buses. The WP and WOP capacities are also respectively assessed, as well as speed flow curves and other parameters, such as minimum and maximum speeds, vehicle occupancy and trip purpose.

32.1.5 Economic analysis

The Bank relies on traffic and economic studies carried out by promoters, often through external consultants. Whenever applicable, the Bank requires promoters to improve or complement their studies with additional assessments, including sensitivity analyses. The results are compared to those of similar projects and available benchmarks whenever possible. EIB experts have accumulated substantial experience in the economic appraisal of road projects across many countries. Internal independent expertise is, thus, a key element when analysing traffic and economic studies presented by promoters.

The Bank uses its own CBA model — the Economic Road Investment Appraisal Model (ERIAM) — to check the economic assessment of interurban road projects above a certain cost.[185] This simple yet reliable and transparent model provides a good indication of the project's economic profitability. The ERIAM is maintained by external consultants and regularly audited and tested by independent external parties.

The usual approach is to first run the ERIAM using the promoter's assumptions, inputs and parameters. The idea is to replicate the promoter's modelling exercise using the Bank's internal tool, and thereby compare headline results and methodology. The EIB expert then runs sensitivity tests by adjusting a number of key variables to assess the credibility of main inputs and parameters. Particular attention is given to traffic and investment cost estimates. Comparisons are made with previous projects in the same region or country.

Scenario analysis is core to the Bank's exercise. The EIB expert may identify a risk of optimism bias in traffic assumptions, or spot unusually high values for some parameters. The end result of the review is the Bank's "baseline scenario," which considers (i) the project's investment and maintenance cost profile, as estimated by the Bank's engineer; (ii) the project's traffic forecast, as estimated by the Bank's transport economist based on the promoter's study; and (iii) other relevant metrics. The estimated

[185] ERIAM is less suited for urban roads and small road schemes.

values may be in line with or diverge from the promoter's forecasts. The economic analysis includes a sensitivity analysis and a Monte Carlo risk analysis to test key assumptions.

Following the approval of the CBR in 2020, the economic analysis has been supplemented with the "adapted economic test" (AET) for projects increasing road capacity. This test calculates the project ERR under a set of more restrictive assumptions relative to the Bank's baseline scenario, including (i) traffic growth in line with recognised long-term decarbonisation plans and (ii) electric vehicle penetration rates in line with policy targets up to 2050. The CBR has also increased carbon costs, thereby penalising road operations leading to increased emissions.

The Bank's main economic indicator to assess a road project's economic performance is the ERR, typically calculated over a 25 to 30-year reference period. Road rehabilitation projects must demonstrate that their baseline scenario ERR exceeds the Bank's hurdle rate for road operations; for road-capacity-expansion projects, that hurdle rate must be exceeded by the ERR from the AET. The ERR is also a useful indicator for comparing a road operation against other alternatives and projects in the region or country.

The case study described in the next section illustrates the approach outlined above.

32.2 Case study: Road project

This section presents an example of the Bank's economic appraisal of a road project. The case study entails a new 20-kilometre 2x2 lane motorway between two cities, built parallel to an existing two-lane carriageway on which the traffic level is reaching saturation. The safety situation is also a concern for local authorities.

The Bank's first step is to analyse the country's mobility strategy, climate considerations and other applicable overarching policies. In most cases, there is a national multimodal mobility plan including an investment programme, which normally includes the project as a priority scheme.

The project is submitted to the Bank with an accompanying feasibility study, which includes a detailed traffic and economic study covering alternative options and road alignments. If need be, the Bank organises working sessions with the promoter and its consultants to discuss the assumptions and methodology. Next, the Bank performs its own CBA using the ERIAM. In the case study, the new network situation created by the project (WP) is compared to a "do-minimum" scenario (WOP).

This section (i) defines the project and its area of influence; (ii) assesses construction costs; (iii) analyses traffic; (iv) enumerates the assumptions determining project benefits; (v) provides the main results of the economic analysis; and (vi) performs sensitivity and risk analyses.

32.2.1 Project definition

The new 20-kilometre 2x2 motorway will run between two cities currently serviced by a two-lane interurban road. The road will add capacity and have a design speed of 120 km/h to accommodate the significant volumes of traffic observed — including a substantial percentage of HVs. The project's area of influence covers the existing road section between the two cities. There is no alternative route between the two cities.

32.2.2 Costs

The project's total financial cost is estimated at €62 million. Besides civil works, this cost covers preliminary studies, management, supervision, land acquisition, environmental mitigation measures and technical contingencies; however, it excludes financial contingencies and interest during construction. The investment cost equates to around €3 million per kilometre, which is considered reasonable given the flat terrain on which the motorway is built. No major structure is envisaged.

Costs used in the economic analysis exclude taxes, interest payments and other transfer costs. They are expressed in constant terms. The project's total economic cost is derived from the financial cost, if warranted by using a coefficient to convert domestic market prices to international economic prices, and to adjust for unskilled labour and the levying of some taxes other than VAT. In the present case study, a coefficient of 92% is used and the economic cost is therefore estimated at €57 million.

The project will be implemented over a three-year period, with preparatory works and procurement finalised by the end of 2022, construction works starting early 2023, and works scheduled for completion at the end of 2025.

The project will increase the maintenance costs borne by the promoter, as it adds new road sections to the network. Annual maintenance costs, including life-cycle costs, will rise by €17 500 per kilometre or €350 000 per year.

32.2.3 Traffic analysis

Large traffic volumes are observed in the corridor, which is expected to accommodate average annual daily traffic of almost 9 300 vehicles in 2025. As a two-lane road, the existing infrastructure is reaching capacity, especially with HVs representing 19% of total vehicles.

By adding a new road to the corridor, the project will give road users two main options: use the existing route as a local road through major cities or travel via the new project motorway as a transit route. HVs above a certain size will be prevented from using the local road through urban areas.

Traffic growth on the existing road has been uneven but high on average over recent years (5% increase per year over the past three years). These growth rates are deemed unsustainable in the long term, so more conservative traffic growth assumptions are made, based on forecasted national GDP growth rates and using elasticity factors. Within the project's area of influence, traffic growth rates are assumed to be mainly driven by macroeconomic variables such as GDP, population, car ownership, fuel costs and land-use.

32.2.4 Project assumptions

The following other main assumptions are made to determine the project's benefits:

- Base-year average annual daily traffic is around 8 000 vehicles, including 19% HVs. Forecasted annual traffic growth is 5% until 2025, 4% from 2026 to 2031, and 2% from 2032 onwards. Some induced traffic is assumed, since increased capacity will positively affect travel speed and comfort. Induced traffic is estimated at 5% of existing traffic.
- Capture rates are assumed to average 60% for LVs (20% for regional vehicles, 100% for long-distance vehicles) and 70% for HVs (40% for regional, 100% for long-distance). They apply from 2026 (motorway opening) and stay the same for the entire analysis period.
- Maximum speeds for LVs and HVs are defined as follows: (i) 90 km/h for LVs on the existing road against 120 km/h on the new motorway; and (ii) 80 km/h for HVs on the existing road against 90 km/h on the new motorway.
- Minimum speed is estimated to be 10 km/h on the existing road for LVs and HVs, and forecast to become 20 km/h for LVs and HVs on the new motorway.
- Road condition is fair for the existing road and will be very good on the new motorway.
- VOT is applied to calculate time-related costs since this variable is based on the loss of productive time. Work time is valued at the full economic travel rate, while commuting time and leisure time are valued at a fraction of this value. The economic value of travel time is based on the following metrics for the project country in 2022: (i) €34.70 per person-hour for work time, representing 20% of traffic; (ii) €10.70 per person-hour for commuting time, representing 40% of traffic; and (iii) €9.20 per person-hour for leisure time, representing 40% of traffic.
- The cost of an HV driver is assumed to be €53 191 per year (salary + operator non-salary cost).
- Trip purposes for HVs are 100% business, with an average occupancy rate of one person per vehicle. Assuming 1 540 productive hours per year, the weighted average VOT per HV is €34.50 per hour. With an assumed vehicle occupancy rate of 1.45 persons per LV, the weighted average VOT is €21.60 per hour.
- Electrified vehicles represented 0.2% of the vehicle fleet in 2020. The Government adopted a transport policy with the following targets 12.5% in 2030, 35% in 2040, 75% in 2050, and 100% in 2060. The Bank expert kept these assumptions for the analysis.
- Accident rates for fatalities and injuries per million vehicle-kilometres are assumed to be 0.3 on the existing two-lane interurban road and 0.07 for the new motorway. Accident rates for damage-only accidents per million vehicle-kilometres are assumed to be 1.31 on the existing road and 0.84 for the new motorway. The same levels of severity are assumed in the WP and WOP scenarios.

Table 32-1: Economic appraisal results for a road project — baseline scenario (upper half) and adapted economic test (AET) (lower half)

ECONOMIC COSTS	PV (5%)		2026	2031	2036	2041	2046	2051	2055
Construction costs	(57)		0.000	0.000	0.000	0.000	0.000	0.000	0.000
Operation & maintenance	(5)		(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	(0.322)
Residual value	0		0.000	0.000	0.000	0.000	0.000	0.000	2.092
Total costs	(61)		(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	1.770

BENEFITS	PV (5%)	% of total	2026	2031	2036	2041	2046	2051	2055
VOT savings	56.5	43.9%	2.241	2.974	3.580	4.312	5.199	6.277	7.311
VOC savings	2.7	2.1%	0.127	0.197	0.254	0.263	0.197	0.016	(0.007)
Safety benefits	74.7	58.1%	2.868	3.853	4.697	5.725	6.979	8.508	9.968
Climate impacts	(4.5)	-3.5%	(0.174)	(0.270)	(0.375)	(0.418)	(0.390)	(0.264)	(0.274)
Environmental benefits	(0.8)	-0.6%	(0.040)	(0.048)	(0.053)	(0.057)	(0.062)	(0.068)	(0.073)
Total benefits	128.6	100%	5.022	6.707	8.104	9.826	11.923	14.469	16.925
Economic cash flow			5	6	8	10	12	14	19

EIRR 11.0% **NPV (€M 2022) 67.27** **B/C 2.10 : 1**

ECONOMIC COSTS	PV (5%)		2026	2031	2036	2041	2046	2051	2055
Construction costs	(57)		0.000	0.000	0.000	0.000	0.000	0.000	0.000
Operation & maintenance	(5)		(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	(0.322)
Residual value	0		0.000	0.000	0.000	0.000	0.000	0.000	1.814
Total costs	(61)		(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	(0.322)	1.492

BENEFITS	PV (5%)	% of total	2026	2031	2036	2041	2046	2051	2055
VOT savings	50.1	44.1%	2.215	2.771	3.235	3.778	4.414	5.159	5.846
VOC savings	0.7	0.7%	0.085	0.110	0.118	0.080	(0.014)	(0.186)	(0.241)
Safety benefits	66.4	58.5%	2.835	3.594	4.254	5.034	5.958	7.052	8.070
Climate impacts	(3.1)	-2.7%	(0.163)	(0.228)	(0.288)	(0.275)	(0.196)	(0.043)	(0.044)
Environmental benefits	(0.7)	-0.6%	(0.039)	(0.044)	(0.047)	(0.050)	(0.052)	(0.055)	(0.058)
Total benefits	113.5	100%	4.933	6.202	7.272	8.568	10.110	11.926	13.574
Economic cash flow			5	6	7	8	10	12	15

EIRR 10.0% **NPV (€M 2022) 52.09** **B/C 1.85 : 1**

- Considering the country's average income, the values used to assess the benefits of lower accident rates are set at €2.15 million per fatality, €280 000 per case of serious injuries, €21 500 per case of light injuries, and €4 300 for each incident of material damage only.
- A residual value is considered at the end of the analysis period (2055), as this precedes by two years the end of the project assets' estimated physical life (32 years). Based on this two-year discrepancy, the residual value in 2055 is estimated at slightly above €2 million.

32.2.5 Main results of the economic analysis

The Bank conducted its own economic CBA using the audited version of the ERIAM. The analysis period runs from 2023 to 2055. As shown in Table 32-1, the project ERR is estimated to be 11% in the Bank's baseline scenario. This corresponds to an NPV of €67 million (5% discount rate) and a B/C ratio of 2.1.[186]

Because the project increases road capacity, it is subject to the CBR's adapted economic test, which applies more restrictive inputs to reflect EU policy targets set for the road sector. In this case, the adapted test includes a 30% reduction in traffic growth relative to the baseline scenario[187], a 95% electric vehicle penetration rate in the corridor's fleet, and an €800 per tonne cost of carbon by 2050. The ERR yielded by the adapted economic test ERRis 10%, which is still high and exceeds the applicable hurdle rate for EIB-financed road operations.

In conclusion, the project is economically sound, even under restrictive scenarios in line with EU policy targets for decarbonisation.

[186] For the given set of assumptions, the economic performance indicators for the road project are shown in Table 32-1

[187] The main metrics of the adapted economic test stem from the 2020 EC Sustainable and Smart Mobility Strategy, which provides decarbonisation scenarios for the mobility sector in the EU, including the expected evolution of road demand and vehicle electrification at aggregate level.

33. Urban public transport

Mauro Ravasio

33.1 Methodology

33.1.1 Introduction

The EIB supports urban public transport projects aligned with its transport lending policy. To be eligible for Bank financing, projects should target market failures in urban mobility, such as negative externalities in terms of GHG emissions, air and noise pollution, road accidents and congestion, as well as limited access to employment, education, health and wider services caused by lack of physical connectivity or affordable mobility options.

Such market failures are typically addressed by encouraging a modal shift from inefficient and energy-intensive transport, such as private motorised vehicles, to more sustainable and active transport. Moreover, technological improvements lead to higher transport efficiency, including the transition to alternative fuels.

Although diverse, most urban public transport projects appraised by the Bank have significant anticipated impact on service supply and demand, and involve constructing new (or extending existing) suburban railways, metros, tramway lines and bus or other mass transit schemes.

The scope of such projects usually encompasses: (i) civil works to construct the new line(s), stations, depot, and maintenance and traffic control centre; (ii) equipment for power supply, signalling, and communication and maintenance; and (iii) the acquisition of rolling stock, including on-board equipment. These three components generally form part of an integrated project and are assessed as a single operation.

In some cases, however, only one component is financed, for instance to renew or marginally increase the capacity of an existing line. A full CBA would not be meaningful (given the lack of credible alternatives) or sufficiently accurate (given the lack of modelling). For such projects, therefore, the EIB relies on relevant performance indicators for its economic assessment, which would ultimately be qualitative in nature.

33.1.2 Project benefits

Project benefits that are quantifiable in a CBA typically fall into two broad categories: GC of travel and externalities.

Regarding the GC of travel, the economic appraisal considers users and non-users of the project under assessment. Among users, diverted passengers are further distinguished by their previous transport mode, while generated demand (i.e. journeys that would not occur without the project) is treated separately.

Non-users are passengers that continue travelling by the same transport mode — typically private car or existing public transport services — but benefit, for instance, from reduced road congestion or lower saturation of a public transport line.

To estimate the project's impact on the GC of travel, an average time saving is first attached to each category of users and non-users. The promoter is responsible for forecasting demand and estimating time savings using a robust transport model. The methodology and assumptions of the model is reviewed by the EIB during the appraisal.

Total time savings are then monetised using VOT,[188] which is country-specific and differentiated by trip purpose and transport mode. The rule of a half applies as explained in chapter 17. In addition, average time savings might be weighted to reflect the additional disutility perceived by transport users in relation to access/egress and waiting time, or other service quality aspects such as reliability and comfort.

[188] Based on a study by RAND commissioned by the EIB.

For users diverting from private transport modes, CBA also considers the VOC savings associated with reduced vehicle-kilometres. These savings are either derived directly from the traffic model or estimated based on average load factors, trip lengths, and operating costs per kilometre.

Economic benefits associated with the GC of travel grow across time with real GDP per capita and demand. Real GDP per capita affects the average VOT and monetised time savings to different extents depending on the assumed elasticity, which is normally between 0.5 and 1.

Demand affects time savings and car-kilometre savings. In this respect, note that average time savings are often kept constant across time in the Bank's economic analysis of urban public transport projects. In practice, these savings will evolve with demand for the project and all competing modes of transport.[189]

Regarding the second broad category of benefits, externalities usually include reduced emissions of air pollutants and CO_2e, as well as increased road safety. When adequate and reliable information is available, the assessment can be extended to other externalities, such as reduced noise emissions and vibrations.

Emissions of air pollutants and CO_2e are evaluated using similar methods. For each transport mode, the difference in vehicle-kilometres with and without the project is determined. This difference is then associated with specific emission factors then monetised using a specific value for each tonne of emissions. For CO_2e emissions, a further step is required to estimate the change in energy consumption, which is then multiplied by the CO_2e of the specific fuel for internal combustion vehicles or the average CO_2e factor of the country's electricity generation mix.[190]

Somewhat similarly, road safety benefits are assessed by applying road accident coefficients to the difference in vehicle-kilometres generated by the project: this estimates the reductions in fatalities and injuries, to which specific monetary values are then applied.[191]

Economic benefits associated with reductions in these externalities will change over time with demand and real GDP per capita. Real GDP per capita affects the monetary value attached to each pollutant and to fatalities and injuries. For CO_2e emissions, the EIB adopts specific CO_2e shadow prices at fixed key dates, as described in the CBR.

Demand affects only changes in externalities that were generated by modal shift and, hence, the anticipated decrease in car usage. In this respect, note that the externalities determined by changes in the supply of other public transport modes are estimated based on change in mileage, and not driven by demand.[192]

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[189] For instance, if demand is assumed to grow during the time span of the analysis for both the project (say a new tram line) and competing modes of transport (say private cars) the impact on time savings will be uncertain due to the rise in saturation and congestion levels respectively. As a consequence, commercial speeds for the tram are likely to decrease beyond optimal capacity and the same will occur on the road network. As demand is often modelled for one single key date, any assumption in this respect may turn out to be inaccurate. However, when the traffic model provides clear evidence for additional key dates, an evolution of average time savings will be considered in the economic appraisal.

[190] EIB Carbon Footprint Methodology.

[191] Based on a study by RAND commissioned by the EIB.

[192] This is due to the assumption that the reorganisation of the public transport network occurs only once, in the year the new line enters into service, and that the associated saving remains constant over the timespan of the economic analysis.

33.1.3 Project costs

Project costs usually fall into two broad categories: investment costs and operating costs. Investment costs are estimated through a standard methodology applied to all EIB projects.[193] The economic appraisal considers the total project investment cost, excluding price escalation and interest during construction.

In CBA, the investment costs for the construction period are expressed in constant prices and are conservatively estimated by including technical contingencies. A residual value is considered in the last year of the analysis, representing the depreciated asset values of the project's components and any additional investment costs related to asset renewals throughout the appraisal period.

Operating costs are estimated based on the vehicle kilometres planned for the new service and a unit cost per kilometre, which usually includes direct costs without overheads. For instance, depending on whether the project entails an entirely new line or the extension of an existing network, unit costs may either be average or marginal. Operating costs for new services are often compensated by the reduced supply of other public transport services and, potentially, other competing modes. This benefit is calculated in the same way as the operating costs for the new service.

33.2 Case study: New tramway line

A European urban area with around 350 000 inhabitants is suffering from increasing road congestion. Public transport is provided by bus only, and its quality is decreasing due to a reduction in commercial speed. The public transport share of urban mobility is low and expected to further deteriorate in the future, with an associated negative impact in terms of transport efficiency and environmental externalities.

To change this negative trend and increase use of public transport, the transport authority plans to introduce the area's first tramway line, with the construction of necessary infrastructure and associated facilities and purchase of rolling stock.

The new tramway line is expected to carry around 28 million boarding passengers in its first year of operation (2026). Demand is expected to grow at 1.50% per year until 2030, then 0.75% per year from 2031. Of the expected boarding passengers, 85% will be diverted from existing bus services, 10% will be diverted from private cars, and 5% will make newly generated journeys.

For each boarding passenger that shifts from bus or car, the average time saving is 6 minutes or 1 minute, respectively. The traffic model also provides the total volume of time savings for non-users (i.e. benefits to private car users from reduced road congestion), which equals around 594 000 hours per year. Time savings are computed in the analysis through appropriate VOT and divided by two where the rule of a half applies.

Regarding externalities, those resulting from reduced car-kilometres are calculated by taking the number of passengers expected to divert from car to tram and assuming an average trip length of 5 kilometres and a car load factor of 1.1 — consistent with the assumptions and results of the traffic model. For the externalities deriving from changes in vehicle-kilometres for public transport modes, the calculation assumes an addition of 1.5 million tram-kilometres and a reduction of 1 million bus-kilometres.

Public transport supply by mode is also used to assess the operating costs of the new tramway (based on a unit cost of €7.50 per tram-kilometre) and the operating cost savings for existing bus services (based on a unit cost of €5.00 per bus-kilometre).

[193] EIB Project Investment Cost methodology

Table 33-1: Calculation of economic profitability for the urban public transport project

			NPV	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050	2055
	Project demand																	
(1)	Total demand (M passengers/year)			-	-	-	-	-	28.0	28.4	28.8	29.3	29.7	30.8	32.0	33.2	34.5	35.8
	Existing users																	
(2)=% (1)	Tramway (M passengers/year)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(3)=(2)*(Min/pax)/60*(€/h)	Time savings compared to tramway	M EUR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Diverted users																	
(4)=% (1)	Bus (M passengers/year)			-	-	-	-	-	23.8	24.2	24.5	24.9	25.3	26.2	27.2	28.3	29.3	30.4
(5)=% (1)	Car (M passengers/year)			-	-	-	-	-	2.8	2.8	2.9	2.9	3.0	3.1	3.2	3.3	3.5	3.6
(6)=(4)+(5)	Total (M passengers/year)			-	-	-	-	-	26.6	27.0	27.4	27.8	28.2	29.3	30.4	31.6	32.8	34.0
(7)=(4)*(Min/pax)/60*(€/h)	Time savings compared to bus	M EUR	311.5	-	-	-	-	-	23.0	23.5	24.0	24.6	25.1	25.1	26.4	27.8	29.2	30.7
(8)=(5)*(Min/pax)/60*(€/h)	Time savings compared to car	M EUR	6.7	-	-	-	-	-	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7
	Generated users																	
(9)=% (1)	Generated demand (M passengers/year)			-	-	-	-	-	1.4	1.4	1.4	1.5	1.5	1.5	1.6	1.7	1.7	1.8
(10)=(9)*(Min/pax)/60*(€/h)/2	Time savings for additional journeys	M EUR	9.2	-	-	-	-	-	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.9	0.9
	Environmental benefits																	
(11)=[(g/bus*km)*(Mbus/km)+(g/car*km)*(Mcar*km)]*(€/t)/1M	Reduction in NOx emissions	M EUR	3.2	-	-	-	-	-	0.252	0.256	0.260	0.264	0.268	0.263	0.272	0.281	0.290	0.300
(12)=[(g/bus*km)*(Mbus/km)+(g/car*km)*(Mcar*km)]*(€/t)/1M	Reduction in PM emissions	M EUR	1.3	-	-	-	-	-	0.094	0.096	0.098	0.100	0.102	0.101	0.106	0.111	0.116	0.121
(13)=[(g/bus*km)*(Mbus/km)+(g/car*km)*(Mcar*km)]*(€/t)/1M	Reduction in VOC emissions	M EUR	0.1	-	-	-	-	-	0.008	0.008	0.008	0.008	0.009	0.009	0.009	0.009	0.010	0.010
(14)=[(g/bus*km)*(Mbus/km)+(g/car*km)*(Mcar*km)]*(€/t)/1M	Reduction in SO2 emissions	M EUR	0.1	-	-	-	-	-	0.008	0.009	0.009	0.009	0.009	0.009	0.009	0.010	0.010	0.010
(15)=[(g/bus*km)*(Mbus/km)+(g/car*km)*(Mcar*km)]*(€/t)/1M	Reduction in CO2 emissions	M EUR	10.8	-	-	-	-	-	0.826	0.836	0.845	0.855	0.864	0.889	0.915	0.942	0.970	0.999
(16)=(11)+(12)+(13)+(14)+(15)	Total environmental benefits	M EUR	15.5	-	-	-	-	-	1.189	1.205	1.220	1.236	1.252	1.271	1.311	1.352	1.395	1.440

Calculation of economic profitability for the urban public transport project *(continued)*

	Other benefits																	
(17)=(#/Mcar*km)*(Mcar*km)*(M€/#)	Reduction in road fatalities	M EUR	4.9	-	-	-	-	-	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5
(18)=(#/Mcar*km)*(Mcar*km)*(M€/#)	Reduction in road severe injuries	M EUR	3.7	-	-	-	-	-	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
(19)=(17)+(18)	Total benefits of road safety	M EUR	8.6	-	-	-	-	-	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8
(20)=(€/bus*km)*(Mbus*km)	Bus savings	M EUR	60.2	-	-	-	-	-	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
(21)=(€/car*km)*(Mcar*km)	Car savings	M EUR	42.8	-	-	-	-	-	3.2	3.2	3.3	3.3	3.4	3.5	3.6	3.8	3.9	4.1
(22)=(20)+(21)	Total OPEX savings	M EUR	103.0	-	-	-	-	-	8.2	8.2	8.3	8.3	8.4	8.5	8.6	8.8	8.9	9.1
(23)=(Mpax)*(Min/pax)/60*(€/h)	Time savings for users remaining on roads	M EUR	72.9	-	-	-	-	-	6.0	6.1	6.1	6.1	6.1	6.0	6.0	6.0	6.0	6.0
	Costs																	
(24)	Project investment costs	M EUR	279.5	18.0	72.0	108.0	126.0	36.0	-	-	-	-	-	-	-	-	-	- 154.8
(25)	Projet upgrades	M EUR	51.7	-	-	-	-	-	-	-	-	-	-	54.0	-	54.0	-	54.0
(26)=(€/tram*km)*(Mtram*km)	Project operating costs	M EUR	135.5	-	-	-	-	-	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3
(27)=(kWh/tram*km)*(Mtram*km)*(g/kWh)*(€/t)/1M	Project CO2 emissions	M EUR	11.3	-	-	-	-	-	0.4	0.4	0.5	0.5	0.5	0.8	1.1	1.4	1.7	2.0
(28)=(3)+(7)+(8)+(10)+(16)+(19)+(22)+(23)	**Total benefits**	**M EUR**	**527.3**	**-**	**-**	**-**	**-**	**-**	**40.2**	**40.9**	**41.5**	**42.2**	**42.8**	**42.9**	**44.5**	**46.1**	**47.8**	**49.6**
(29)=(24)+(25)+(26)+(27)	**Total costs**	**M EUR**	**478.1**	**18.0**	**72.0**	**108.0**	**126.0**	**36.0**	**11.6**	**11.7**	**11.7**	**11.7**	**11.8**	**66.1**	**12.4**	**66.6**	**12.9**	**- 87.6**
(30)	**EIRR**		**6.1%**															
(31)=(28)-(29)	**NPV**	**M EUR**	**49.2**															
(32)=(28)/(29)	**B/C**		**1.10**															

Finally, investment costs total around €360 million, spread over the five-year construction period. A residual value of around €155 million is calculated as the result of linear depreciation of the initial investment. The subsequent upgrades and renewals are also included in the analysisat a total non-discounted amount equal to €162 million.

Table 33-1 summarises the results of the economic appraisal, including the PV for each benefit and cost item described above, discounted at a rate of 5%. All monetary values are expressed in constant prices and increase annually with GDP real growth per capita, assuming rates of 0.75% until 2030 and 0.25% from 2031.

The project's economic performance is summarised by three indicators: the ERR of 6.1%, NPV of €49 million, and B/C ratio of 1.10.

34. Airports

J. Doramas Jorge-Calderón

34.1 Methodology

34.1.1 Introduction

Airport infrastructure can be divided into landside and airside. Landside infrastructure serves to process passengers or cargo. Related projects may involve rehabilitating existing capacity; expanding the capacity of cargo or passenger terminals; improving access to terminals through parking facilities or rail stations; and enhancing product quality through increased use of jetways to access aircraft. Airside infrastructure serves to process aircraft. Related projects may involve rehabilitating existing capacity; constructing new runways or widening/lengthening existing ones; adding taxiways to increase the capacity of existing runways; expanding apron space to increase aircraft parking capacity; or enhancing air traffic control capacity at or near an airport. These objectives may be combined in a project; alternatively, EIB financing may be sought for the construction of completely new airports.

For the appraisal of airport projects, the Bank applies the same methodology used under the JASPERS initiative (Joint Assistance to Support Projects in European Regions).

34.1.2 Landside benefits

Project benefits are measured using the standard framework for the GC of transport. There are three main sources of benefits from investing in landside capacity. The first is avoiding the diversion of traffic to alternative travel times and modes. Time diversion occurs when passengers are forced to take trips at non-preferred, less convenient times. The cost to the user is measured by applying the traveller's VOT to the difference between the preferred and actual travelling times. Mode diversion occurs when travellers are forced to use second-best transport modes or alternative airports. For the traveller, this increases the GC as access and egress times are greater and the alternative transport mode may be less efficient.

Both diversion types are valued as two hours' travel time by default, which reflects the conditions in most projects the Bank appraises. The two-hour norm can be modified to fit project circumstances. Diversion is assumed to occur once an airport's annual traffic is at least 33% higher than the terminal design capacity. This percentage corresponds to design standards in the *Airport development reference manual* (ADRM) of the International Air Travel Association (IATA) and (from the tenth edition onwards) Airports Council International.[194] Up to the ninth edition of the ADRM, the percentage, or relative, difference corresponds to the relative difference between service level C, generally the reference level of design, and service level E, just before system breakdown. From the tenth edition, it mirrors the relative difference between the "optimum" service level and the threshold between the "sub-optimum" and "under-provided" service levels.

The second source of benefit is reduced congestion in terminals, which shortens user throughput time. This starts to compute once traffic reaches service level C, until it reaches service level E — at which point all new traffic is diverted — and is valued at 10 minutes of user travel time.

The third source of benefit is the generation of traffic, comprising passengers who would not have travelled at all without the project. This is valued as the difference in GC between using the airport and the alternative to the airport, applying the rule of a half.

In addition, when a project involves upgrading service quality for passengers by replacing remote stands with contact stands, this improvement is valued at about €15 per applicable passenger, adjustable to any valuations available for the airport under consideration. However, to the extent the airport increases charges to reflect the improvement, the benefit is proportionately reduced when calculating project returns to avoid double-counting benefits already captured in producer surplus.

[194] IATA and Airports Council International are the trade representative associations for airlines and airports, respectively.

34.1.3 Airside benefits

Airside investment should produce two main sets of benefits. First, enhanced airside capacity will bring increases in departure frequency and the range of routes served by the airport, relative to the WOP scenario. Consequently, frequency delay[195] and potentially also trip duration will be reduced, contributing to a lower GC of transport. Frequency delay is valued using the standard VOT, assuming a flat distribution of passengers throughout the day or otherwise adjusted to reflect traffic conditions at the airport under appraisal. Second, airside investments may shorten aircraft processing times, thus reducing airlines' operating costs.

When the airside investment involves increasing peak aircraft movements, the WOP scenario assumes that airlines will instead increase aircraft size to the extent allowed by the airport facilities. This decreases the benefit of investing in capacity to increase aircraft movements, as larger aircraft are cheaper to operate per passenger.[196] The analysis uses an elasticity of −0.5 for the aircraft operating unit cost relative to aircraft size.

34.1.4 Producer surplus and costs

Any producer surplus would be measured (before deducting CAPEX) consists of the difference between airport revenues —including aeronautical and non-aeronautical— and operating costs. Regarding non-aeronatucial activities, only those revenues and costs accruing to the airprot operator are considered. Concessionaires using airport real estate for retail and other activities are assumed to make a competitive return, involving no additional considerations in the economic appraisal.

Diverted traffic would mostly travel through alternative airports, so the project will have an adverse effect on the producer surplus of those airports. Therefore, the net producer surplus of the project consists of the portion of surplus attributable to generated traffic.

The project costs include capital investment in constructing infrastructure and additional airport operating costs once the new infrastructure is operational. Unless the promoter supplies specific project data, the Bank assumes that the facility experiences increasing returns to scale until reaching a design capacity of 4 million passengers per year; thereafter, returns are constant. There may still be density economies while the terminal facility is utilised below design capacity.

Should the airport's new operative requirements result in significant increases to aircraft operating costs, these are included as additional costs attributable to the project.

34.1.5 Externalities

Air transport is associated with four main external costs: GHG emissions, air pollution through particulate emissions, noise emissions, and forced relocations to make room for infrastructure. Only the last can be attributed directly to airports, and is included in airport appraisals using the Bank's standard methodology (see chapter 7). The first three external costs are caused primarily by airlines operating from an airport, and can only be attributed to the airport or air traffic control to the extent that these cause an increase in traffic. Thus, in an airport or air traffic control project appraisal, only aircraft emissions attributable to generated traffic are considered as incremental costs.

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[195] The frequency delay is the difference between the average passenger's preferred departure time and the closest flight departure feasible for the passenger. Other things being equal, the greater the departure frequency, the lower the frequency delay, and hence the time cost of travel to the passenger.

[196] This is to be understood on an "all else being equal" basis. For example, some airlines may operate cabins with narrower seat pitch or an alternative class configuration, achieving lower unit costs with smaller aircraft than other airlines using larger aircraft but higher quality cabin arrangements. Similarly, an aircraft may display lower unit costs than a larger aircraft of an older generation.

The external costs of generated traffic are measured using standard aircraft emissions data, valued at standard EIB emissions values for the external and internalised cost of carbon (see chapter 4).[197] Any internalised emissions, such as the proportion of GHG emissions paid for through the EU ETS or the Carbon Offsetting and Reduction Scheme for International Aviation, are subtracted from external costs.

34.2 Case study: Airport capacity-rehabilitation project

Let us assume it is 2026 and an airport with a terminal capacity of 5 million passengers per year (at IATA service level C) already has annual traffic of 5.5 million passengers. On this basis, the airport is already experiencing congestion. Airline tickets currently incorporate a carbon price of €56 per tonne of CO_2, which is set to gradually grow to €350 per tonne by 2050. This results in traffic being set to grow at an average annual rate of 1.5% over the long term, rather than the faster average annual rate of 4% over the last 20 years.

While the airport would need to expand capacity to accommodate such traffic growth, the current case study focuses on a parallel project to rehabilitate terminal capacity for 1 million passengers and avoid decommissioning. Table 34-1 displays the calculation process, including values for project performance in selected years in the WP and WOP scenarios. The table also presents the PV for each benefit and cost item, discounted at 3.5% (values are discounted to 1 January 2026). All monetary values are expressed in constant prices, so the discount rate constitutes the real discount rate.

If the project were not implemented, capacity would drop from 5 million to 4 million passengers in 2030 as the facility requiring rehabilitation would be shut down for failing to meet minimum regulatory requirements (row 1). With the project, airport capacity would be maintained at 5 million passengers until 2050 (row 10).

The project involves CAPEX of €30 million, slightly over half the CAPEX required to build a new facility of similar size. As the construction period will extend over five years, the project's CAPEX has a PV of €28 million.

Whereas capacity-expansion projects primarily serve to avoid congestion, the main benefit from capacity-rehabilitation projects is avoiding traffic diversion. In the WOP scenario, traffic would start diverting very early into the project life, so the gain from the project in terms of avoided diversion totals €611 million (778 minus 166, with rounding error, rows 7 and 17, respectively). Congestion is a net source of disbenefit, at a loss of €57 million (346 minus 404, with rounding error, rows 9 and 19, respectively). Traffic will continue growing at 1.5% per year, for which the existing capacity of 5 million passengers is insufficient. The number of passengers processed at the airport will be higher with the project than without it, but because all passengers will be experiencing congestion, total congestion costs will be higher with than without the project.

Carbon emissions related to generated traffic have a PV of €221 million, of which €68 million is internalised (see rows 22 and 23). The €68 million is the carbon-abatement cost paid for by passengers — through EU ETS, the Carbon Offsetting and Reduction Scheme for International Aviation, or environmental taxes — while the €153 million balance is the (external) cost imposed by the project on other economic agents to abate emissions. Including emissions of noise and air pollution, the project's net environmental external cost is €160 million (row 26).

[197] For an example of a study estimating aircraft emissions, see CE Delft (2002) "External Costs of Aviation" CE Delft: the Netherlands, available online:
http://www.cedelft.eu/publicatie/external_costs_of_aviation_(background_report)/279?PHPSESSID = ad8353cb75ccfdf097561c2fc46a6f6a

Table 34-1: Calculation of economic returns for the capacity-rehabilitation project

		Units	**PV ***	**2026**	**2030**	**2040**	**2050**
	WITHOUT PROJECT						
(1)	Design passenger capacity	(thousand)		5,000	4,000	4,000	4,000
(2)	Passengers	(thousand)		5,500	5,320	5,320	5,320
(3)	Diverted passengers	(thousand)		0	466	1,309	2,288
(4)	Deterred passengers	(thousand)		0	52	145	254
(5)	Operating revenues	(EUR m)	1,776	110.0	106.4	106.4	106.4
(6)	Operating costs	(EUR m)	888	55.0	53.2	53.2	53.2
(7)=(3) x time cost	Cost of diversion	(EUR m)	778	0.0	19.5	63.6	128.9
(8) = 0.5 x (4) x time cost	Cost of deterrence	(EUR m)	43	0.0	1.1	3.5	7.2
(9) = (2) x time cost, if(2)>(1)	Cost of congestion	(EUR m)	346	18.3	18.8	21.8	25.3
	WITH PROJECT						
(10)	Design passenger capacity	(thousand)		5,000	5,000	5,000	5,000
(11)	Passengers	(thousand)		5,500	5,837	6,650	6,650
(12)	Diverted passengers	(thousand)		0	0	112	1,091
(13)	Deterred passengers	(thousand)		0	0	12	121
(14) = (4) - (13)	Net traffic generation	(thousand)		0	52	133	133
(15)	Operating revenues	(EUR m)	2,054	110.0	116.7	133.0	133.0
(16)	Operating costs	(EUR m)	974	55.0	58.4	61.7	57.2
(17) = (12) x time cost	Cost of diversion	(EUR m)	166	0.0	0.0	5.4	61.5
(18) = 0.5 x (13) x time cost	Cost of deterrence	(EUR m)	9	0.0	0.0	0.3	3.4
(19) = (11) x time cost, …if (11)>(10)	Cost of congestion	(EUR m)	404	18.3	20.7	27.3	31.7
(20) = (8)-(18) = 0.5x(14) x … … x time cost	Value of traffic generation	(EUR m)	34	0.0	1.1	3.2	3.7
(21)	Investment cost	(EUR m)	28	5.0	0.0	0.0	0.0
	NET EXTERNALITIES						
(22)	Cost of carbon emissions	(EURm)	221	0.0	3.9	20.9	31.9
(23)	Internalised GHG costs	(EURm)	68	0.0	0.9	5.6	14.0
(24)	Cost of noise emissions	(EURm)	4	0.0	0.1	0.4	0.4
(25)	Cost of air pollution	(EURm)	3	0.0	0.1	0.3	0.3
(26)=(22)-(23)+(24)+(25)	Total external cost	(EURm)	160	0.0	3.2	16.0	18.6
	PROJECT RETURNS						
(27)=-(5)+(6)+(15)-(16)	Gain in producer surplus		278	0.0	5.2	18.1	22.6
(28)	PS diverted traffic		169	0.0	4.7	14.0	26.1
(29)=(7)+(8)+(9)+(27)	Benefits	(EUR m)	1,359	18	45	107	184
(30)=(17)+(18)+(19)+… …+(21)+(26)+(28)	Costs	(EUR m)	935	23	29	63	141
(31)=(29)-(30)	Net benefit	(EUR m)	**424**	-5	16	44	43
	ERR		**43%**				

Note: * PV is the present value at year 0 discounted at 3.5%

The project brings about a substantial increase in carbon emission costs (row 22) because, in its absence, part of the existing facility will be closed, which would deter substantial traffic early in the appraisal period. The project, compared to the WOP, generates a lot of traffic, thus generating a substantial increase in emissions (relative to the WOP scenario). In contrast, capacity-expansion projects produce much lower relative emissions (WP versus WOP) because deterred traffic plays a much lesser relative role than in capacity-rehabilitation projects.

Total benefits far outweigh costs, and the project ERR is extraordinarily high at 43%. By contrast, capacity-expansion projects tend to produce lower ERRs, in the region of 15–20%.

35. Seaports

Tom Scheltjens

35.1 Methodology

35.1.1 Introduction

Port projects usually involve expanding the capacity of cargo and passenger terminals and scaling up the seaside infrastructure to accommodate larger vessels. The investments in infrastructure and superstructure are borne by public entities managing the port and private entities operating the cargo terminals. Infrastructure investments include maritime works (breakwaters, quays and dredging works) to provide the necessary berthing conditions, and landside works (reclamation and other civil works) to provide the required handling space. This is complemented by superstructure, which includes pavement, buildings and the equipment required to handle cargo and passengers. Economic appraisal should consider the investment costs for additional infrastructure and superstructure, even if the investments implemented by the Bank's borrower belong exclusively to only one of the two categories. If additional investments by a third party are required for the operations of the project, (e.g. expanding access roads), these investments should also be accounted for in the analysis.

35.1.2 Project benefits

Project benefits are measured on basis of changes in the GC of transport. The benefits of investing in port capacity mainly result from the following physical effects. The additional capacity avoids traffic diversion which would occur when future demand exceeds capacity: without the project, passengers and cargo would use less convenient alternative ports once the existing facility reached capacity and congestion costs started to increase. By providing adequate infrastructure to accommodate demand, the project allows users to travel or ship goods via their preferred port and realise a reduction in the GC of transport by avoiding the traffic diversion. A second positive impact would be relieved congestion at the port, which reduces waiting times at anchorage and berth. However, this benefit is limited in a situation with traffic management, as once the port or terminal reaches capacity and congestion occurs, traffic is generally routed through alternative facilities in the region. Additional benefits can be expected if the investments allow a scale increase or enable other efficiency improvements. For example, when larger and/or deeper vessels with lower per-unit transport costs and emissions can use the port, transport and external cost reductions can be expected for existing and diverted traffic. Generally, this scale increase will only benefit a fraction of cargo flows in the port. This needs to be assessed by the analyst executing CBA.

When assessing project benefits, gateway cargo and transhipment cargo should be distinguished. Project benefits for gateway cargo are usually assessed by quantifying the traffic diversion benefits and scale benefits based on expected changes in the GC. Traffic diversion benefits are quantified based on unit land transport costs — including environmental external costs — and the distances from the main origin/destination centres to the alternative port with available capacity and adequate infrastructure. The benefits are estimated by multiplying this distance by the unit land transport costs and related external costs. Scale benefits are estimated by quantifying the reduction in unit transport and external costs from increased vessel size and applying this to the fraction of traffic that would benefit from the scale increase.

For transhipment cargo, quantifying the economic benefits of capacity expansion or scale increase requires detailed insight into the operating and capital costs of the shipping lines in different hub-and-spoke network configurations. These effects are generally more difficult to quantify based on GC data. Therefore, it is normally assumed that a) in the absence of the project, similar facilities would be built elsewhere in the region at a similar GC; and b) inputs and outputs are traded in reasonably competitive markets. Under these circumstances, it is assumed that project FRR is a good proxy for the ERR; hence, the producer surplus before investments is used to indicate the project benefits. FRR is measured by the port's operating profit before depreciation, including the revenues and costs of the port authority and the port operator. As this approach does not include external cost savings (mainly GHG and other emissions) related to the change in transhipment flows resulting from the project, these should be accounted for in the CBA, qualitatively or, if data are available, quantitatively.

35.1.3 Project costs

As a minimum, the following project costs should be included in the economic analysis: a) the capital investment in constructing infrastructure; b) capital investment in additional superstructure needed to operate the project; and c) additional port maintenance and operating costs once the new infrastructure is operational. The analysis should include only those investments incremental to what would take place in the WOP scenario. If underused infrastructure and superstructure capacity is not available at an alternative port, the WOP scenario should include those costs (or they should be excluded from the WP scenario). The cost of environmental mitigation and compensation measures should also be included if these are required to implement or operate the project in line with applicable regulatory frameworks.

35.2 Case study: Expanding capacity of container terminal

A gateway container port has a container terminal capacity of 300 000 TEU[198] and a permissible draft of 12.5 metres. Annual traffic is nearing 230 000 TEU, and throughput is forecast to grow at 4% per year over the long term. The project under evaluation involves increasing the capacity of the container terminal by expanding the container yard, enlarging the terminal quay by 300 metres and by increasing the permissible draft to 14 metres; these developments would increase annual capacity to 600 000 TEU and enable the handling of container vessels up to 8 000 TEU capacity. Without the project, the existing container terminal would be operating at full capacity by year 7 and shipping lines would be forced to call at additional ports to load and/or unload cargo with an origin or destination in the natural hinterland of the port.

In order not to overcomplicate the example calculations in this hypothetical case study we calculate ERR and FRR for only one set of input assumptions. In line with the recommendations of this guide, a full CBA should calculate and present different scenarios based on different input assumptions for traffic developmenst and costs, and include sensitivity analysis to assess the potential range of outcomes.

35.2.1 Economic analysis

There are currently two alternative ports with potential spare capacity for container handling, respectively located 200 kilometres and 300 kilometres from the project port. These ports have suitable infrastructure but lack the equipment needed to handle additional traffic flows (e.g. quay cranes and container yard equipment). In view of the main origin and destination centres for container flows in the region, those additional traffic flows (if the project container terminal is not expanded) would need to be transported by land via one of the two alternative ports, meaning an estimated extra road distance of 150 kilometres (the ports have no rail connections). Average unit road transport costs are around €0.8 per TEU-kilometre. Following its opening in year 5, the new terminal has an estimated economic life of 26 years (until year 30). By that time, traffic demand will exceed the project design capacity.

Both avoided traffic diversion and the scale increase impact on the external costs of the supply chain. With fewer tonne-kilometres produced on the hinterland network, GHG emissions, pollutant emissions, noise and accidents related to road transport are all reduced. GHG and pollutant emissions from maritime transport are also reduced through the scale increase allowed by the project. All these external cost changes can be valued based on figures available in the economic literature and public guidance documents. If significant technological developments are expected that will alter future external costs (e.g. developments leading to decarbonisation and depollution of road and maritime fleets), it is advisable to take those into account by using variable unit figures for external costs. However, for the illustrative purpose of this example, those values are kept constant.

By reducing the GC, the project may lead to additional traffic compared to the WOP scenario, so called “generated traffic”. Transport demand has negative price elasticity, so demand for transport increases when the cost decreases. Although this effect is expected to be small for marginal projects, it should be considered for larger projects by comparing changes in average total logistics costs in the WP vs the WOP situation. The generated traffic will have transport benefits (generally half of the benefits for existing traffic, on average) but will also generate additional external costs at sea and on land.

[198] TEU means twenty-foot equivalent (container) unit.

Table 35-1 summarises the economic appraisal results for the hypothetical port investment project in our case study. It presents the results of calculations for selected years in the WP and WOP scenarios. An overview of all the input parameters is presented in Table 35-2.

The capacity of the container terminal increases in year 5 in the project scenario (row 4, Table 35-1). General traffic demand (row 1) and traffic demand capped by capacity in the WOP scenario (row 3) and WP scenario (row 5) is calculated for each future year based on current volumes and expected growth rates. The existing container terminal would reach full capacity by year 7. Additional cargo flows will then have to be loaded and unloaded at alternative ports. The volume of TEU affected by diversion is presented for each future year (row 6). Avoiding such traffic diversion constitutes the project's main benefit (row 9).

The scale increase made possible by the project allows weighted average per-unit transport cost savings of €10 per TEU (row 7). This benefit accrues to both diverted and existing traffic (row 10). Generated traffic volumes are estimated based on the cost savings of avoided diversion and the efficiency benefits from increased scale (row 8). The generated traffic benefits are calculated using the rule of a half (row 11).

The traffic diversion, scale increase and generated traffic lead to changes in produced road and maritime transport (tonne-kilometres). The scale increase in maritime transport leads to reduced per-unit external costs. The net impact is accounted for as GHG savings (row 12) and other external cost savings (row 13). External costs of GHG emissions are valued as proposed in the CBR. The other external cost changes are valued based on data from the European Commission's *Handbook on the external costs of transport,* using project-specific assumptions related to the structure of hinterland traffic (location, road types and congestion level) and fleet composition.

Total benefits are calculated by aggregating all the project benefits described above for each future year.

The investment cost is budgeted at €200 million, spread over four years (row 15). Investments in the equipment required to handle extra traffic are not considered, as we assume the alternative ports would have to invest in these asset types to adapt to new demand levels in the WOP scenario— the equivalent investments in the project port and two alternative ports are assumed to cancel each other out in the economic return calculation. However, the new infrastructure will result in additional annual maintenance costs of approximately €2 million per year (row 16).

The net value of benefits and costs is presented in row 18. For the NPV (shown as "net value") calculation, we use a discount rate of 3.5%. All monetary figures are expressed in constant prices, so the discount rate constitutes the real discount rate.

Table 35-1: Economic analysis calculations and results

		Units	PV*	1	2	3	4	5	10	15	20	25	30
(1)	Traffic demand	TEU m		0.24	0.25	0.26	0.27	0.28	0.34	0.41	0.50	0.61	0.75
	WITHOUT PROJECT (WOP)												
(2)	Capacity WOP	TEU m		0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
(3)=MIN (1,2)	Traffic WOP	TEU m		0.24	0.25	0.26	0.27	0.28	0.30	0.30	0.30	0.30	0.30
	WITH PROJECT (WP)												
(4)	Capacity WP	TEU m		0.30	0.30	0.30	0.30	0.60	0.60	0.60	0.60	0.60	0.60
(5)=MIN (1,4)	Traffic WP	TEU m		0.24	0.25	0.26	0.27	0.28	0.34	0.41	0.50	0.60	0.60
(6)=(5)-(3)	Diverted traffic	TEU m		-	-	-	-	-	0.04	0.11	0.20	0.30	0.30
(7)	Per unit efficiency benefits	EUR/TEU		-	-	-	-	10.00	10.00	10.00	10.00	10.00	10.00
(8)=f((6),(7),diversion costs,ε_d)	Generated traffic	TEU m		-	-	-	-	0.00	0.00	0.00	0.01	0.01	0.01
	PROJECT BENEFITS												
(9)=(6)*diversion costs	Capacity benefits (diverted traffic)	EUR m	233	-	-	-	-	-	4.85	13.71	24.47	36.00	36.00
(10)=(7)*(5)	Efficiency benefits (existing + diverted traffic)	EUR m	63	-	-	-	-	2.80	3.40	4.14	5.04	6.00	6.00
(11)=0.5*diversion costs*((7)+(8))	Benefits generated traffic	EUR m	5	-	-	-	-	0.05	0.14	0.31	0.51	0.73	0.73
(12)=f((8),(6),GHG emissions,GHG costs)	GHG savings	EUR m	67	-	-	-	-	0.29	0.99	2.93	6.36	11.25	13.72
(13)=f((8),(6),impacts,costs of impacts)	Other external impacts	EUR m	124	-	-	-	-	(0.26)	2.39	7.25	13.16	19.49	19.49
(14)=(9)+(10)+(11)+(12)+(13)	Total benefits	EUR m	493	-	-	-	-	2.88	11.78	28.33	49.54	73.47	75.94
	PROJECT COSTS												
(15)	Capex	EUR m	184	50.00	50.00	50.00	50.00						
(16)	Maintenance	EUR m	29	-	-	-	-	2.00	2.00	2.00	2.00	2.00	2.00
(17)=(15)+(16)	Total costs	EUR m	213	50.00	50.00	50.00	50.00	2.00	2.00	2.00	2.00	2.00	2.00
(18)=(14)-(17)	**NET VALUE**	EUR m	**280**	-50.0	-50.0	-50.0	-50.0	0.9	9.8	26.3	47.5	71.5	73.9
	ERR		***8.6%***										

Table 35-2: Input assumptions for economic analysis

Project and market data		
CAPEX	mio €	200
Maintenance	% of CAPEX	1%
Capacity WOP	mio TEU	0.3
Capacity WP	mio TEU	0.6
Current volumes	mio TEU	0.23
Container cargo weight average	tonne/TEU	10
Forecast annual volume growth	%	4%
Average hinterland distance saved	km	150
Average hinterland cost	€/TEUkm	0.8
Additional sailing distance to alternative port	km	120
Weighted average efficiency benefits (eg draft ir	€/TEU	10
Project start of operations	year	5
Greenhouse Gas emissions		
GHG emissions road	gram/TEUKM	350
annual reduction in per unit GHG emissions roa	%	0%
GHG emissions sea WOP	gram/TEUKM	50
GHG emisison sea WP	gram/TEUKM	49
Other external costs (noise, pollution, accidents, congestion, infra)		
Road	€/tonnekm	0.05
Maritime	€/tonnekm	0.0025
Generated traffic inputs		
Average handling costs	€/TEU	200
Average sea transport costs	€/TEUkm	0.15
Average road distance	km	300
Average sea distance	km	8000
Total logistic costs	€/TEU	1880
Transport demand price elasticity		-0.5
Average cost saving diverted traffic	€/TEU	120
Generated traffic by avoided diversion	%	3.2%
Generated traffic by efficiency benefits	%	0.3%

35.2.2 Financial rate of return

For a public entity managing a port, the financial return of an investment depends on (i) the concession fees or land lease fees charged to operators (fixed, variable or a combination) and (ii) the port fees charged to shipping lines (berthing charges, cargo dues, port dues, etc.). The pricing policy of port authorities differs significantly across the globe and within the European Union, and often has broader policy objectives. Ports are often considered strategic assets with relevance for regional development, sustainable transport and employment policy objectives. Accordingly, port pricing policy is not necessarily driven by profit-maximisation. For the same reasons, port investments are often supported by governments or the European Union with public funding.

The FRR of a port investment can be calculated based on applicable tariffs or taking into account planned tariff increases, but the result does not necessarily reflect the investment's true financial value. If a port infrastructure asset that receives investment is then made available to commercial operators in a competitive bidding process, the FRR will more likely reflect the financial value of the investment for the port authority.

Table 35-3: Financial analysis calculations and results

		1	2	3	4	5	10	15	20	25	30
Diverted traffic	TEU m	-	-	-	-	-	0.04	0.11	0.20	0.30	0.30
Generated traffic	TEU m	-	-	-	-	0.00	0.00	0.00	0.01	0.01	0.01
PROJECT REVENUES											
Concession revenues	EUR m	-	-	-	-	12.00	12.00	12.00	12.00	12.00	12.00
Port dues	EUR m	-	-	-	-	0.01	0.34	0.95	1.69	2.49	2.49
Public Grant (EU,national government)	EUR m	10.00	10.00	10.00	10.00	-	-	-	-	-	-
Total revenues	EUR m	10.00	10.00	10.00	10.00	12.01	12.34	12.95	13.69	14.49	14.49
PROJECT COSTS											
Capex	EUR m	50.00	50.00	50.00	50.00	-	-	-	-	-	-
Maintenance	EUR m	-	-	-	-	2.00	2.00	2.00	2.00	2.00	2.00
Total costs	EUR m	50.00	50.00	50.00	50.00	2.00	2.00	2.00	2.00	2.00	2.00
NET CASH FLOW	EUR m	**(40.0)**	**(40.0)**	**(40.0)**	**(40.0)**	**10.0**	**10.3**	**11.0**	**11.7**	**12.5**	**12.5**
FIRR	**4.3%**										
NPV @5% discount rate	**(14.6)**										

Table 35-4: Additional input assumptions for financial analysis

Financial analysis input		
Public Grant (EU,national government)	%	20.0%
Concession revenue increase	mio €/year	12.00
Average port dues Port Authority	€/TEU	€ 8.00

The required FRR financial return for the private operator depends on the general market risk and the specific project risk allocation between that operator and the public entity.

An example FRR calculation from the port authority's perspective is presented in Table 35-3, with additional input assumptions in Table 35-4. We assume that the port authority raises revenues through an additional annual concession fee of €12 million, and assume average traffic-related charges of €8 per TEU. The port authority will receive public grant funding amounting to 20% of the infrastructure CAPEX. Constant monetary values are used for comparison purposes. An investor would compare the project's nominal financial return, which accounts for the different inflation rates of costs and revenues, against the weighted cost of capital in the applicable micro- and macroeconomic environment.

36. Regional development

Paul Hickey

36.1 Methodology

36.1.1 Introduction

For the Bank, regional development investments should promote balanced economic growth and cohesion across a wide geographic area in accordance with a strategic planning framework. Generally, regional development is pursued by national or regional authorities through multiannual investment programmes that are multisector in nature and comprise many, typically small-scale, investments in infrastructure, public services and human capital. Such programmes are seldom fully defined in terms of constituent investments when presented to the Bank for appraisal; at that stage, the proposal usually sets out the strategic goals, thematic objectives and sector scope (e.g. transport, health, energy efficiency), accompanied by a sample of potential investments. The investments tend to be non-revenue-generating public goods that produce widely distributed economic and social benefits: examples include public roads, schools and flood protection measures. Given the variety of sectors, limited investment definition and the preponderance of non-revenue-generating public goods, the Bank's economic appraisal of regional development programmes necessarily relies heavily on a qualitative approach. Generally, the Bank concentrates on the quality of, and consistency between, the programme and its strategic framework; the promoter's institutional capacity to manage and monitor the programme; and the eligibility and expected economic impact of any identified investments.

36.1.2 General characteristics

Before proceeding further, it is helpful to present some typical features of regional development projects financed by the EIB. Only during project implementation does the full set of individual investments become known, as the promoter progressively selects them in accordance with the programme's objectives and parameters. To assess the expected economic impact of such projects and assure the validity of their assessment, the Bank conducts a two-stage appraisal following its framework loan[199] procedures. The first stage, which occurs prior to loan approval by the Bank's governing bodies, entails appraisal of the investment programme, the promoter's capacity and any investments already mature. The second stage, which occurs during implementation, involves the Bank approving the allocation of loan funds to individual investments based on their eligibility, compliance with Bank standards and policies and consistency with the technical description of the investment programme. The approach to the second-stage appraisal depends on the size of investments, with the degree of analysis greater for larger investments. Three distinct thresholds are applied: < €25 million, €25–50 million and > €50 million. For allocations to investments above €50 million, full due diligence appraisals are undertaken in which the economic impact is assessed following a sector-based approach (please see the relevant chapter of this guide). This chapter explains the approach to economic appraisal during the first stage.

Within the European Union, regional development projects are frequently conceived as a means of financing a Member State's share of investment (operational) programmes supported by EU structural and investment funds and agreed with the European Commission. The operational programmes and related partnership agreement form part of the strategic planning framework on which the Bank relies to assess expected economic impact. The Bank provides a type of framework loan dedicated to the purpose of financing these operational programmes: called a structural programme loan, it is tailored to reflect the approvals, monitoring arrangements and implementation timetable adopted by the European Commission for these operational programmes.

36.1.3 Appraisal methodology

Regional development projects can vary quite considerably in terms of content, geographic scope and the existence or otherwise of EU programmatic co-financing. Nonetheless, the common starting point for carrying out an economic appraisal is to review the strategic planning framework within which the project

[199] A framework loan is a multi-scheme operation for which the information available about the Investment Programme is not sufficient to perform a comprehensive appraisal of that Investment Programme before Board approval, which requires a deferred appraisal process.

sits. This is followed by evaluating the extent to which the investment programme is likely to deliver more balanced territorial development. Next, the Bank assesses the promoter's institutional capacity to implement the project and analyses any presented schemes of sufficient maturity. These steps are formalised in an MCA adapted for regional development projects (using, inter alia, the criteria set out in Table 36-1 and Table 36-2) that yields an estimate of the project's expected economic impact. Qualitative assessment of a structural programme loan is further informed by the economic assessment underpinning the operational programmes and partnership agreement. Based on this appraisal, the project is rated on the following scale: 1 - marginal; 2 - acceptable; 3 - good; or 4 - excellent.

When reviewing the relevant development strategy, the Bank checks its consistency with the relevant national policy framework and the degree to which its objectives are likely to advance the desired national and EU policy outcomes. For instance, for an investment programme designed to further the policy goal of reducing economic disparities between urban centres and peripheral areas, the Bank considers (i) how well connected the investment programme is to national policy via the regional strategy and (ii) the degree to which national policy has been adapted to local particularities by the regional strategy. An important factor is how well the regional strategy complements national-level policies and channels central government support to areas of the local economy identified at regional level as needing investment. Regarding regional strategy, the Bank evaluates the degree to which the investment programme is based on assessed needs and whether the investments form part of a coherent, integrated approach to development.

The Bank expects strategic development objectives to be pursued by a range of mutually reinforcing and complementary measures. For instance, the objective of helping a less-developed region to catch up requires measures to improve the business environment, which could include investments in training and upskilling, better transport connections to centres of employment, and support to small and medium-sized enterprises. The Bank would expect to find these measures translated into the investment programme, which amplifies their impact through combination with investments addressing other aspects of spatial inequality, such as relative deficiencies in public services or environmental quality. In order to ensure the validity of its assessment during the first-stage appraisal, the Bank allocates its loan funds to individual investments against a set of eligibilities and criteria defined under the framework loan.

The factors considered in evaluating the contribution towards balanced territorial development are presented in Table 36-1. The contribution towards environmental sustainability and climate action is estimated based on relevant objectives and targets of the investment programme.

Table 36-1: Territorial development factors

Coherent territorial development
• Strategic coherence • Complete in scope, logical in sequence
Impactful territorial development
• Wide-reaching • Providing transformative infrastructure • Promoting polycentricity and strengthening settlements • Unblocking development of settlement network and addressing missing links • Stimulating network/synergy effect • Resulting in supra-regional spillovers

A regional development project based on a sound strategic planning framework may be expected to generate widely shared economic benefits, assuming the necessary capacity exists for implementation. Given the nature of such projects, the ability to originate adequate volumes of eligible investments and monitor their implementation is critical to realising these benefits. Therefore, assessing the promoter's institutional capacity to manage and monitor the project is a key element in the Bank's appraisal of likely economic impact. The promoter's capacity is assessed using criteria including, but not limited to, those listed in Table 36-2.

To the extent that constituent investments are identified at the time of initial appraisal, these are evaluated for eligibility and coherence with the stated strategic objectives governing the investment programme. Relevant indicators (e.g. energy savings or the number of social facilities renovated) are taken into account, as well as the appropriateness of the procurement procedure. Where feasible, the contribution of each investment to the EIB's climate-action targets is calculated and used to inform the estimated contribution of the overall programme.

The economic impact may be estimated using an MCA similar to that used for urban development projects (chapter 37). As described comprehensively in chapter 11, MCA is a qualitative decision-making tool applied widely in project appraisal where quantitative CBA estimates are challenging or wider qualitative variables need systematic consideration to evaluate a project's desirability for society.

The MCA tool was designed to enable practitioners to undertake complex appraisals in a consistent manner using quantitative and qualitative data. The tool can accommodate and incorporate the outputs of CBA and other appraisal exercises, such as those evaluating environmental and climate impact, sustainability, technical quality and promoter capability.

Table 36-2: Determinants of promoter capacity

Organisation
• Internal decision and approval processes • Role of internal control and auditing • Availability of support from external consultants • Capacity to provide information on whole scope of the operation • Existence of a system to send required information to the Bank for second-stage appraisal and monitoring • Incorporation of past lessons learnt to improve investment programme management
People
• Permanent staff involved in the project and availability of other resources (expertise, capacity, and systems) to implement the promoter's procedures • Proof of involved staff undertaking relevant training • Promoter's experience in implementing schemes of a similar scale and complexity • Promoter's capacity to estimate project cost
Programme preparation and implementation procedures
• Adequate and clear internal procedures for preparation and implementation of the investment programme • Transparent and consistently applied selection criteria for schemes • Application of international standard contracts for works and supplies • Sufficient monitoring and supervision of scheme implementation • Adequate systems for assessing performance • Appropriate means of verifying spending • How state aid issues are addressed (if applicable)
Track record
• The Bank's previous experience, if any, with this promoter in multisector complex operations • Any relevant compliance issues concerning the promoter (past or present) • The promoter's past performance in delivering required information
Operating environment
• The legal context of sectors in which the promoter operates • Sector weaknesses identified in other Bank-financed projects • The track record of the country in applying and enforcing laws and transposing relevant EU directives (if applicable) • Effectiveness of public administration (particularly in the construction permitting process) • Any other country-specific risk (particularly beyond Europe)
Implementing bodies and final beneficiaries
• The capacity of the sector's implementing bodies and final beneficiaries • The means by which implementing bodies monitor scheme implementation

36.2 Case study 1: Regional framework loan

This project comprises a programme of investments in local infrastructure and public services, encompassing the sectors of healthcare, transport, social care, education and energy efficiency (of public buildings). The defining feature of the project region is its proximity to the capital city, which informs its land-use patterns, generates most of its employment, and exerts significant pressure on regional infrastructure. With increasing distance from the metropolitan area, there is a gradual transition from relatively intense, peri-urban land-use to more rural characteristics, with several significant towns interspersed throughout the region. Accessibility to the country's largest job market means the region ranks highly in terms of GDP, while the gravitational pull of the capital dictates the volume and pattern of traffic flows. The region's relationship to the capital city, though clearly underpinning its economic well-being, also creates challenges — a steadily increasing population exerts pressure on public services, and the prevalence of commuting to the metropolis places great strain on the local road network. Separately, the region is somewhat affected by the national trend towards an older population, bringing added demand for healthcare and other social services. Moreover, the physical obsolescence of public buildings has diminished the quality and efficiency of public services and reduced the standard of local amenities.

The EIB-financed investment programme is intended to address some of these challenges, enhancing amenities and general living standards in the region, while also improving environmental sustainability. Given the region's needs, the investment programme particularly emphasises healthcare and improving accessibility: plans include constructing, modernising and optimising the capacities of medical facilities, and making upgrades and repairs to local roads. Accordingly, a preliminary list of 52 projects was presented at the time of appraisal, primarily in the sectors of health, transport and energy efficiency.

The Bank found the investment programme to be plan-led and well grounded in the strategic planning framework for the region, which mainly comprises a regional development programme updated by a territorial district plan. The strategic framework was found to contain a blend of policies and objectives consistent with the goal of achieving balance between economic and social development and environmental protection. It is also well aligned with EU-funded national programmes.

The capacity of the promoter was assessed as good. In particular, the Bank concluded that the promoter's organisation is sound, with clearly established lines of responsibility and accountability and well-defined decision-making and approval processes. The promoter applies an internal control system to all investments it undertakes, involving quality assessment, selection, preparation, implementation and monitoring. For example, in the transport sector, investments are selected having regard to the significance of the road, its structural condition, environmental impact and the need to diversify investments within the region. Regarding investment monitoring, the promoter systematically collects data on implementation as part of a results-based approach.

The region is classified by the European Commission as "less developed" and by the EIB as a cohesion priority region — the investments are, thus, considered to support the European Union's economic, social and territorial cohesion. In this regard, the upgrading of social infrastructure and public facilities should match demographic needs and is expected to meet or exceed national standards. Meanwhile, upgrading the local transport network is anticipated to maintain and improve the accessibility of local public services and job opportunities for the general population. Without making these investments, the quality of public infrastructure and services would further degrade. It is, therefore, expected that the project will improve living conditions and enhance socioeconomic prosperity in the region. On these bases, the project was rated "good."

36.3 Case study 2: Structural programme loan

The Structural Programme Loan co-finances investment programmes funded by the European Structural and Investment Funds during 2014–2020. Specifically, it finances a combination of national and regional programmes agreed between individual Member States and the European Commission. In general, the investments focus on the following sectors: RDI, energy, tourism, education, training, access to employment, and innovation for enterprises. The regional programmes also involve urban sustainable development and regional economic development.

The national economy has been experiencing relatively strong growth thanks partly to increasing activity in the manufacturing sector and rising domestic consumption. However, much of the country is categorised as “less developed” by the European Union, and longstanding economic disparities between the capital city metropolitan area and the rest of the country remain problematic. Against the background of declining population, rising average life expectancy and low fertility, the country has an ageing population and rising dependency ratio, with long-term implications for public spending and the sustainability of social services. Only the capital city bucks the national trend of population decline, which has served to reinforce the concentration of population and prosperity in the capital. Furthermore, labour market mismatches have affected the national economy, leading to shortfalls in healthcare, manufacturing, transport and construction.

The national economy has significant potential for growth in areas such as electronics, biotechnology, advanced materials, chemicals, logistics and agribusiness. The capital city and its surrounding region remain an engine for national wealth creation with ample scope for further growth.

Broadly, the operational programmes co-financed by the EIB aims to address weaknesses hindering the development of competitiveness, while building upon the positive attributes of the Member State’s economy. The prominent areas of focus were:

- Improving the capacity and efficiency of the education system;
- Reducing regional economic disparities;
- Reinforcing the national R&D network and its linkages with industry and small and medium-sized enterprises, prioritising the sectors with best comparative advantage;
- Enhancing vocational training and overcoming the mismatches between labour supply and demand;
- Improving environmental management, particularly in the fields of drinking water quality, waste management, nature protection, renewable energy sources and energy efficiency;
- Promoting integration of the most socially disadvantaged groups;
- Promoting and increasing the economic capacity and attraction of the capital region.

The Bank’s programme appraisal concluded that the constituent investments would originate from a plan-led response to the needs of the national economy, based on rigorous analysis and extensive consultation with the European Commission. Starting with the partnership agreement between the Member State and the European Commission, the framework sets out how the government plans to use investment grants from the European Structural and Investment Funds, taking into account the country-specific recommendations adopted by the European Council. The framework is aligned with the national reform programmes and the EU strategy for smart, sustainable, inclusive growth, and also targeted at delivering the operational programme objectives.

Among the intervention areas included under the programmes, the greatest potential for economic impact was identified in the measures for (i) improving and adapting workforce skills and qualifications to prepare for the future jobs market and (ii) boosting the share of national GDP devoted to research and innovation. Of particular importance to the Bank’s public policy goals is the presence of investments combining upskilling measures and youth development, which would foster greater cohesion across age cohorts. Regarding spatial cohesion, the national policy provides the framework for achieving a more polycentric and balanced distribution of opportunities. For R&D, the operational programmes contribute to increasing the private-sector share in RDI and enhancing linkages between research results and market products and processes. For example, a national smart specialisation strategy aims to apply a bottom-up approach enabling innovative enterprises and business communities to propose the best options for funding RDI.

The promoter’s overall capacity to manage the investment programmes was considered to be sufficient. In particular, the prospects of cost-effective investments were enhanced by linking performance incentives to outcome and output indicators and the proposed adoption of additional management controls.

Overall, the economic effects were expected to be significant and will translate into more and better jobs, fewer people at risk of poverty and more balanced territorial development. Hence, the project was rated “good.”

37. Urban development

Mesut Akbas

37.1 Methodology

37.1.1 Introduction

Within the framework of the EIB's public policy goals, the Bank mainly supports urban development under integrated urban renewal, development and regeneration. This generally covers multisector investment programmes to implement sustainable urban development strategies for cities, as well as specific area-based action plans for urban development and regeneration. Bank-financed projects are usually generated by investment programmes of the cities, reflecting their development strategies as embedded in spatial development plans. These authorities use such investment programmes to stimulate local economic development and promote social inclusion to improve inhabitants' quality of life, primarily through public works and the provision of public services.

Urban development projects need to fulfil certain key criteria. They must be consistent with a coherent urban development strategy and city-wide or area-based land-use plan, which the Bank reviews to ensure the investment address long-term strategic goals. These projects should also follow an integrated approach to the spatial development of urban areas, considering relations between areas to achieve synergies. The EIB favours projects involving mixed-use development, rehabilitation and renewal, and the concentration of development to efficiently use urban services and avoid urban sprawl. Projects should also fit into regional plans and strategies to ensure their wider regional impacts are positive and that they contribute to balanced polycentric development. They should help cities act and invest in ways enabling all citizens to play their part in urban society, regardless of income, age, gender, or ethnicity.

The project appraisal process determines the actual demand for the investment programme, the justification for the intervention (any market failure or suboptimal investment situation), and the efficacy of the promoter's chosen policy response. Economic assessment is carried out through MCA, a tool developed by the EIB with support from external consultants.

37.1.2 Economic assessment

A typical urban development project comprises multiple sub-projects/schemes across several sectors. The various benefits and externalities they generate include, for example, improved living quality of the built environment; improved urban infrastructure, contributing to better functioning of the urban economy and enhanced health and social well-being of citizens; open public space and green areas, contributing to recreation, health and tourism; conservation and preservation of cultural heritage, contributing to culture, education and tourism; provision of social and affordable housing, contributing to social well-being and inclusion; and climate mitigation/adaptation together with wider urban resilience. Given the challenges of generating quantitative economic estimates for these type of projects, MCA is applied in project appraisal.

As described comprehensively in chapter 11, MCA is widely employed where (i) quantitative CBA estimates are challenging or (ii) wider qualitative variables need systematic consideration to evaluate a project's benefits for society. Both grounds apply particularly to urban development projects: they are often multisector and multischeme; they yield benefits in the form of externalities that are difficult to quantify; and detailed project information is sometimes not available until schemes are allocated during framework implementation. Furthermore, the integrated nature of these projects makes them more than the sum of their components, and it is difficult to quantify agglomeration benefits arising from the cumulative impact of schemes across a planning-led investment programme. Therefore, since 2016 a tailor-made MCA tool has been used to capture the benefits of planning-led, integrated urban-development investments.

MCA enables consistency in undertaking complex appraisals with a combination of quantitative and qualitative data. The tool can accommodate and incorporate the outputs of CBA and other appraisal exercises, such as those evaluating environmental and climate impact, sustainability, technical quality and promoter capability. These outputs can be embedded within the framework to inform the overall appraisal analysis.

As adapted for urban development projects, the MCA tool helps assess the extent to which a given project meets investment objectives, rather than ranking different projects/options (see the methodology presented in chapter 11). MCA translates performance against appraisal dimensions, sub-dimensions and criteria into numerical values, which are combined to give an overall assessment score. To assign these values, the appraiser makes informed judgments.

Table 37-1: Multicriteria analysis dimensions and sub-dimensions

Appraisal dimension	Appraisal sub-dimensions
Institutional	Policy-making & strategic planning, project context, organisational & agency functions, governance
Territorial	Regional integration, urban agglomeration, polycentric development, integrated spatial planning
Social	Provision of accessible facilities, employment generation, affordability, social cohesion, safety and security
Environmental	Natural and built environment, greenhouse gas emissions and pollution, climate mitigation, climate resilience
Economic	Economic performance, ERR, business performance, quality and reliability
Financial	FRR, budget constraints, need & demand, financial performance
Technical	Technical feasibility, regulation, procurement, innovation, implementation & monitoring, operational sustainability

As Table 37-1 shows, MCA is used to assess seven dimensions: institutional, territorial, social, environmental, economic, financial and technical. Each appraisal dimension has several sub-dimensions. A project's wider economic benefits to society are particularly reflected in the territorial, social and environmental dimensions but also in the economic and financial dimensions; meanwhile, the technical and institutional dimensions affect the likelihood of these benefits accruing during implementation. The sub-dimensions represent key supplementary components of the main appraisal dimensions that need to be considered and addressed. Under each sub-dimension are objectives that a project ought to fulfil. The objectives match prevailing EU and EIB policy guidance and practice, and are thus especially important from the Bank's perspective. Table 37-2 illustrates how objectives and criteria are set for one sub-dimension (urban agglomeration) under the territorial dimension.

Table 37-2: Illustrative objective and criteria for an appraisal sub-dimension

Dimension	Sub-dimension	Objective	Criteria
Territorial development	Urban agglomeration	Compact city	Qualitative criteria Extent to which the proposal: ✓ Promotes/supports the appropriate concentration and/or densification of economic and other activities in existing urban centres ✓ Limits urban sprawl ✓ Advances transport-oriented development ✓ Facilitates enhanced accessibility to goods and services ✓ Contributes to promoting sustainable mobility ✓ Fosters the introduction of mixed-use developments Quantitative criteria ✓ Density of the metropolitan area

Each objective is weighted, enabling appraisers to identify the relative importance of each objective (and its related appraisal criteria) to the overall appraisal. Appraisers allocate weights by indicating why a particular objective is considered of high or low importance. They then score performance against each independent objective from 1 (very poor) to 5 (very good). The MCA tool automatically generates an overall assessment result and identifies the maximum score that the project could achieve (see Table 37-3).

Table 37-3: Appraisal scoring and outcomes

Scores	
1 = Very poor (the proposal/project does not meet the objective/criteria)	
2 = Poor (significant mitigation measures necessary)	
3 = Acceptable (no significant measures required)	
4 = Good (the proposal/project meets the majority of criteria relevant to the objective)	
5 = Very good (the proposal/project meets every aspect of the objective)	
Appraisal outcome — Overall rating as sum of seven dimensions	
0–39%	Proposal/project is very poor, and therefore unacceptable
40–59%	Proposal/project is acceptable, but significant mitigation measures required
60–79%	Proposal/project is good though some mitigation measures may be required
80–100%	Proposal/project is very good and meets all/nearly all objectives

37.2 Case study 1: Resilient and sustainable city

The project mainly involves urban regeneration schemes aiming to reconvert streets through so-called superblocks. The city's ambitious plan is to take the streets back from cars and create mixed-use public spaces, including pedestrian zones, low-speed zones, and leisure and green areas. The plan also aims to reorganise traffic, with the promotion of public transport modes and strong coordination between providers of collection, delivery and distribution services (garbage and goods for residents and business). The project also includes schemes for social and cultural infrastructure, including schools, kindergartens, care homes, libraries and open spaces (parks and squares). Further project schemes target improving the energy efficiency of public lighting, traffic lights and public buildings. The project co-finances around 40 multisector schemes under the city's current multiannual investment strategy, and supports the implementation of the city's resilience model and climate plan.

Overall, investment schemes are supporting the city's aim to become carbon neutral by 2050. The city has issued a climate emergency declaration to accelerate the impact of climate action and promote the achievement of more ambitious emission-reduction goals by 2030. Relatedly, it has developed an in-depth assessment of the current state of climate action and potential future climate scenarios. In addition, the city has strong climate governance, which guarantees that climate principles are well rooted and integrated across the city administration, and reflected in the investment plans.

The city is at the forefront of resilient cities, as an active member of C40 (Climate Leadership Group) and the Global Resilience Network, and it collaborates closely with many other international organisations, such as the United Nations Human Settlements Programme, which established its resilience headquarters in the city.

The project is expected to have significant positive externalities, and multiple spillover effects are expected from the implementation of investment priorities, which are well integrated into the planning process and socioeconomic objectives of the city's strategy. The key strategic axes are:

- Spatial development plan, which supports polycentric, compact development with integrated land uses, focused on revitalisation and better (social) integration;
- Resilience model, which helps the city take a holistic, co-responsible approach to prioritising resilient projects and focusing actions on the most vulnerable groups. It is based on three pillars: climate resilience and adaptation, social resilience, and infrastructure and urban services resilience;
- Climate plan 2030, developing the climate resilience and adaptation pillar of the resilience model;
- District plans, which address the most vulnerable neighbourhoods with the aim of tackling social inequalities.

All the economic benefits, including the reduced flood risk and other project aspects, were evaluated by the Bank using MCA. The quality of the project was assessed in a structured manner across seven dimensions (institutional, territorial development, social, environmental, economic, financial and technical). The project was scored as "very good," with no need to apply mitigation measures.

More specifically, MCA produced an overall score of 90%, which places this operation in the category of "very good." The analysis shows that the project is acceptable across all seven dimensions analysed, the weakest two being financial (78%) and economic (73%). As the operation mainly comprises non-revenue generating investments and primarily targets sustainability and climate action, it scores most strongly on the environmental dimension (100%).

37.3 Case study 2: Affordable housing

This project involves an intermediated framework programme to support several social and affordable housing schemes (sub-projects). The financial intermediary channels EIB funds into the project promoters — primarily limited-profit housing associations and local authorities.

The aim is to construct about 2 100 new social and affordable housing units and to refurbish 1 500 units. The proposed new housing units are eligible under regional or national legislation as affordable or social housing to promote social mix and inclusion as well as sustainable urban development.

The project helps address the very strong demand for social and affordable homes in the country, caused by increases in prices and rents for land and housing, mostly in the capital city but also in other regions. Compounded by continuous in-migration, pressure has been rising on the availability of affordable housing across the country. National housing legislation sets a minimum and a maximum allowable rent for housing units.

The operation partially contributes to the objectives of the national strategy for adapting to climate change and the country's energy and climate plan.

The project is also expected to meet local housing needs and foster urban regeneration, thus boosting competitiveness and encouraging sustainable development patterns. In addition, it should help achieve a more balanced local residential market with sufficient housing supply meeting existing need from low- and middle-income households.

The social and affordable housing units are offered to households and applicants who meet certain criteria. Eligible tenants can apply for a public rent allowance driven by a well-proven, transparent system based on net income limits per household. Housing unit allocation is organised at local level using waiting lists. Municipal administrations typically reserve the right to allocate a minor part of the housing stock to priority and vulnerable groups (e.g. single parents, persons with disabilities).

The government-supported housing programmes are well tailored to meeting local housing needs in a region undergoing demographic changes, and to addressing the resulting urban renewal and transformation requirements. The housing investments form part of specific local integrated urban-development plans or target designated urban-renewal areas.

Table 37-4: Case study appraisal results

Dimension	Sub-dimension	Dimension performance
1.Institutional	1.1. Policy-making and strategic planning 1.2. Project context 1.3. Organisational and agency functions 1.4. Governance	**100%**
2.Territorial	2.1. Regional integration 2.2. Urban agglomeration 2.3. Polycentric development 2.4. Integrated spatial planning	**95%**
3.Social	3.1. Provision of accessible facilities 3.2. Employment generation 3.3. Affordability 3.4. Social cohesion 3.5. Safety and security	**70%**
4.Environmental	4.1. Natural environment 4.2. Built environment 4.3. Greenhouse gas emissions and pollution 4.4. Resource efficiency 4.5. Climate resilience	**77%**
5.Economic	5.1. Economic performance 5.2. Business performance 5.3. Quality and reliability	**78%**
6.Financial	6.1. Financial burden and budget constraints 6.2. Need and demand 6.3. Financial performance	**73%**
7.Technical	7.1. Technical feasibility 7.2. Regulation 7.3. Procurement compliance 7.4. Innovation 7.5. Implementation and monitoring 7.6. Operational sustainability	**76%**
Overall appraisal score		**81%**

The proposed schemes' economic rates of return are expected to be good but were not calculated because of the large number and small size of these schemes. Instead, the MCA confirms sound economic performance based on (i) a comprehensive housing and urban planning framework, fostering urban renewal and sustainable development; (ii) a highly regulated social and affordable housing sector; (iii) high housing quality standards, particularly regarding energy efficiency; (iv) robust demand; and (v) social inclusion. The MCA findings yield an overall score of 81%, which rates this operation as "very good." As shown in Table 37-4, the project scored acceptably in all seven dimensions analysed.

38. Solid waste management

Patrick Dorvil

38.1 Methodology

38.1.1 Introduction

Solid waste management (SWM) projects financed by the Bank may include one or several of the following components: collection equipment, sorting stations, composting/recycling facilities, mechanical biological treatment plant, anaerobic treatment facility, thermal treatment, and engineered waste disposal. The benefits of these projects, such as public health, economic productivity and positive environmental externalities, extend well beyond the individuals who enjoy them. Therefore, the EIB carries out an economic appraisal that goes beyond the financial appraisal.

This chapter details each step in the Bank's financial and economic appraisals of waste management projects:

- Eligibility check;
- Financial analysis, including cost-efficiency, cost-effectiveness and affordability;
- Economic analysis.

38.1.2 Eligibility of solid waste management projects

To be eligible for EIB financing, SWM projects must comply with the waste hierarchy principle, the EU Circular Economy Package, national waste legislation, and the "polluter pays" and proximity principles. They must also be Paris-aligned.

38.1.2.1 Waste hierarchy principle and legislation

The waste hierarchy principle is intrinsic to any waste policy. It sets priorities and rankings for the environmental soundness of SWM technologies and options. The preferred options are prevention or reduction of waste generation, and whatever waste is generated should, as far as possible, be separately collected in preparation for reuse or recycling (which includes composting). Energy recovery is a further intermediate step for dealing with residual waste that cannot be recycled. Landfilling is identified as the last resort, given its land-use environmental impact and the perpetual loss of resources.

Investments in the waste sector are strongly driven by the need to comply with national legal requirements, which in the European Union are guided by EU directives. These directives include the Circular Economy Package[200] adopted by the European Parliament on 18 April 2018 and by the Council of the EU on 22 May 2018. The legislative package amends the Waste Framework Directive (2008/98/EC), the Landfill Directive (1999/31/EC), the Packaging Waste Directive (94/62/EC) and the End-of-Life Vehicles Directive (2000/53/EC).

38.1.2.2 The "polluter pays" and proximity principles

The "polluter pays" principle is an economic policy that attempts to allocate the costs of pollution and environmental damage to polluters. As a core principle of environmental policy, it should ideally be applied throughout the European territory. The EU Waste Framework Directive establishes that "the costs of waste management are borne by the original waste producer or by current or previous waste holders." Nevertheless, given the characteristics of waste management as a public good, together with affordability and equity-related issues, the full application of "polluter pays" is almost impossible. Regarding the notion of equity, the affordability of SWM for service users must also be considered — especially beyond Europe and, where justified, in EU cohesion regions. Affordability is determined as a certain percentage of average disposable income per household or per citizen that could be spent on these services.

The proximity principle requires waste to be treated as close to the source as possible, with the objective of self-sufficiency.

[200] https://www.europarl.europa.eu/RegData/etudes/BRIE/2017/599288/EPRS_BRI%282017%29599288_EN.pdf

38.1.2.3 Paris alignment

In line with the political ambition behind the European Green Deal, all waste projects funded by the Bank must be aligned with the goals and principles of the Paris Agreement. The CBR[201] contains detailed information on the eligibility criteria for solid waste projects (annex 2, Table F).

38.1.3 Financial analysis

38.1.3.1 Profitability and sustainability analysis

Before deciding whether to finance a project, the Bank carries out a complete financial appraisal of the proposal, calculating the FRR based on expected incremental future cash flows, including CAPEX, OPEX and revenues. The financial analysis aims to verify that the promoter has the necessary financial resources and mechanisms to cover O&M costs, service the debt on project loans, and make future reinvestments.

The project's financial cash flows include investment and O&M costs for waste collection, treatment and disposal infrastructure; its revenues are generated through tariffs, taxes or gate-fees charged to users; sales of recyclates, energy, and compost material produced from relevant waste streams; and other sources such as financial contributions from producer responsibility schemes.

The economic lifetime of each project must be properly assessed by considering potential changes in legislation and technology. Basically, it defines the time horizon (reference period) for the financial analysis. The economic lifetime is usually set in line with the life span of the most important project assets.

38.1.3.2 Cost-efficiency and cost-effectiveness analysis

If there are no affordability constraints, the tariffs charged to users should cover the full costs of SWM services according to the "polluter pays" principle. A cost-efficiency analysis can determine whether it is worth financing a proposed waste management project. In principle, cost-efficiency in the solid waste context means providing services of the specified quantity and quality at minimum cost, thereby maximising the benefits and optimising resource use. The average incremental cost (AIC) methodology[202] has been adopted as most suitable for this task. The AIC is a discounting-based indicator, and the choice of the financial discount factor *r* is key to the analysis result. The following formula is used to calculate the AIC:

$$AIC = \frac{\sum_{t=0}^{t=n} \frac{(IC_t + NOM_t)}{(1+r)^t}}{\sum_{t=0}^{t=n} \frac{(OP_t)}{(1+r)^t}}$$

where IC_t denotes the investment costs in year *t*; NOM_t represents net O&M costs; OP_t is the project output in year *t* (i.e. tonnes of solid waste treated); *r* is the discount rate; and *n* is the number of years.

The AIC calculated for the appraised project is compared with the cost benchmarks of similar projects. This frequently causes difficulties as most waste management projects have significantly different costs. Besides the influence of a project's geographic and site-specific context, costs also largely depend on the precise nature and composition of the waste streams and technical processes a project employs. Another shortcoming is that the AIC includes only the project component to be financed, not the comprehensive SWM system costs.

The dynamic generation cost is an appropriate and simple cost-effectiveness indicator, usually expressed in euros per tonne of waste treated. It is obtained by dividing the NPV of the monetised total project lifetime cost — comprising CAPEX, OPEX and replacement costs over the reference period — by the NPV of the weight of treated waste. The dynamic generation cost of the appraised project is compared with existing benchmarks from similar projects in the Bank's portfolio.

[201] https://www.eib.org/attachments/thematic/eib_group_climate_bank_roadmap_en.pdf
[202] Dynamic Prime Cost (DPC) of Levelized Unit Cost (LUC)

In the solid waste context, effectiveness means providing legally compliant SWM services of sufficient quality for a targeted jurisdiction (city, region or country). Effectiveness is measured by the extent to which services of the required quality are being provided. Examples of performance indicators for effectiveness include:

- Households provided with collection services divided by total households;
- Population provided with collection services divided by total population;
- Quantity of waste recovered and recycled (material and energy) versus total quantity of waste disposed;
- Length of paved streets regularly cleaned divided by total length of paved streets.

Cost-effectiveness can be considered a subset of efficiency, focused on maximising the environmental improvement from a given amount of resources, or on achieving a given amount of improvement at the least possible cost. In concrete terms, for a waste project to be cost-effective, it must at least meet applicable legal requirements. Therefore, the waste management model applied should lead, in the long term, to the cost-effective shifting of generated waste towards material and energy recovery, to the extent possible.

Different effectiveness indicators are needed since the ultimate objective is the recovery of resources (tonnes per year) and/or energy recovery (MW per year). In many cases, both objectives are met. In addition, avoided resource use could be used in a quantitative CEA as an indicator, though it would remain theoretical.

38.1.3.3 Affordability analysis

The affordability of SWM services can be assessed from at least three perspectives: users (service recipients), municipalities (service providers) and society as a whole.

Affordability for users[203]

Charging for SWM services should ideally be based on the "polluter pays" principle.[204] Pricing may attempt to encompass the costs to human health, the environment and natural resources, as well as social and cultural harm.[205] Nonetheless, SWM services must be affordable to all individuals.[206] A household income distribution is frequently requested to the promoter to ensure that households in the lowest (or sometimes two lowest) deciles do not pay an excessive percentage of their income for the services. Therefore, affordability analysis must also consider the distribution of household incomes below average income.

Affordability for municipalities/regions

Municipal affordability concerns the ability of local public authorities to raise the funds required to develop, operate and maintain SWM services. In terms of charging for services, the range of methods can vary widely between municipalities, even within a single country. Charges may be based on waste volume or weight, the number of household members, property size, or even a fixed price — completely overlooking the "polluter pays" principle. Moreover, charges may vary between urban and rural areas.[207]

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[203] Another related concept is willingness-to-pay. The extent to which an individual is willing to pay for a hypothetical service also depends on how much he or she can afford. Therefore, in the marketing of Solid Waste services, both willingness-to-pay and ability-to-pay must be considered simultaneously.
[204] Or 'user pays' principle or pay as you throw – PAYT.
[205] This principle presents some shortcomings in terms of identifying and billing the polluters since waste collection is not performed via a fixed network.
[206] Another shortcoming: those who cannot afford the services have to be served because of the presence of externalities.
[207] At the time of writing, in France the cost ranges between EUR 63 and EUR 74 per ton in rural areas and between EUR 54 and EUR 65 per ton in urban areas. In Germany, an average household of 3 people pays EUR 100.80 per ton, but this differs not only from urban to rural areas but also between Länder (regions).

Affordability for society as a whole

This relates to the costs of the proposed service relative to national income. It is particularly important, as solutions affordable for one country may be unaffordable for another. Once the unit cost of a proposed SWM system is known, it can be compared with the typical indicative cost for providing such services in countries with similar income levels. User fees[208] range from an average of $35 per year in low-income countries to $170 per year in high-income countries.

38.1.4 Economic analysis

Conducting a proper economic analysis is sometimes challenging given the type of financial products provided by the Bank, such as framework loans and multisector investment projects. In addition, SWM services are normally provided in a regulated monopoly environment, so tariffs do not necessarily reflect the real service costs and should be replaced by economic benefits. It can also be challenging to estimate embedded externalities and indirect benefits (costs), which usually include:[209]

- Resource savings:
  - avoided waste to landfill (LRMC of landfill disposal);
  - recovery of recyclable materials and production of compost (market values/border prices/LRMC);
  - energy recovery (LRMC of substituted energy);
- Visual disamenities, noise and odours (hedonic price SP);
- Variation in GHG emissions (shadow price of GHG emissions);
- Health and environmental hazards (variation in contamination of air, water and soil; shadow price of pollutants).

In summary, important economic benefits result from a decrease in GHG emissions, comprising (i) direct emissions from waste management activities, such as methane from landfills, and (ii) indirect CO_2 emissions from transport, incineration and recycling plants. To the extent possible, the analysis should also consider avoided emissions and the benefits from reduced life-cycle GHG emissions from resource recovery using waste as a secondary material or energy source and replacing the use of virgin materials or fuel. Against this background, waste management projects that qualify as Climate Action and Environmental Sustainability (CA&ES) produce high economic benefits, including climate and other environmental externalities. Therefore, an estimated project ERR higher than the FRR justifies the investment, provided the unit investment and operating costs compare favourably with the Bank's project-specific benchmarks.

[208] https://datatopics.worldbank.org/what-a-waste/trends_in_solid_waste_management.html
[209] See the chapter on municipal waste management in the DG Regio CBA Vademecum 2021-2021 for more details.

38.2 Case study 1: Solid waste inside the European Union

This project involves the rehabilitation of recycling facilities, the treatment of process water and protection against noise pollution. It also includes the financing of recycling equipment with high added value in terms of energy efficiency and reduced CO_2 emissions. Finally, there are elements to improve the treatment of air emissions from recycling centres. Table 38-1 presents the project magnitudes.

The project FRR is estimated at 9%, which will allow the project promoter to achieve the financial performance of its business plan. This yield is calculated over the 12-year economic life of the assets financed. The project is justified by non-quantifiable economic benefits and positive externalities, including resource development, pollution reduction, reduced risks to public health, and job creation. The project will contribute 85% of climate action, achieving climate change objectives by reducing GHG emissions and increasing the percentage of renewable energy in final energy consumption. Thus, project ERR is in the range of 10–12%.

Table 38-1: Components of financial and economic returns

Project components	€ million
Soil rehabilitation	22
Shredder filters	67
R&D	24
Trucks	23
Energy-efficient machinery	61
GNV Truck fleet	19
Equipment	31
Sub-total	**247**
Miscellaneous	11
Financial and technical contingencies	12
TOTAL	**270**
FRR	**9%**
ERR	**10–12%**

38.3 Case study 2: Solid waste beyond Europe

This project involves the following:

- A sorting station, the first cell of sanitary landfill, a transfer station and the rehabilitation of dumpsites;
- The acquisition of collection equipment (bins, trucks, etc.);
- The design and construction of a biogas plant with a nominal capacity of approximately 25 000 tonnes of waste per year;
- An integrated environmental centre, comprising an additional sanitary landfill and a sorting station;
- Several soft components (e.g. social integration of waste pickers, public awareness activities).

Table 38-2 summarises the project investment costs.

Table 38-2: Investment costs of project beyond Europe

	€ million
Engineering service costs and project preparation	4
Construction	34
Equipment (First batch)	54
Equipment (Second batch)	9
Technical assistance	3
Miscellaneous	2
Financial and technical contingencies	6
Interest during construction	8
TOTAL	120

The financial analysis uses the discounted cash flow approach, considering only cash inflows and outflows. Further, project cash flows are determined on an incremental basis, considering differences in costs and benefits between the WP and WOP scenarios (where WOP consists of a "business as usual" or "do minimum" scenario). Based on the project's financial cash flows, the main financial indicators were calculated; the results are presented in Table 38-3.

Table 38-3: Main results of the financial analysis

Indicator	**Without EU grant**		**With EU grant**	
Financial rate of return	6%	FRR/C	10%	FRR/K
Net present value (€)	−29 387 747	FNPV/C	−613 607	FNPV/K

The financial indicators reflect the project's non-commercial nature (FRR below discount rate (9%) and financial NPV, or FNPV, negative) and demonstrate the financial leverage effect of the EU grant.

The project is expected to improve the financial sustainability of the targeted region, as better SWM services will enable a gradual increase in tariffs. While tariffs will have to remain low initially to reflect affordability constraints (where the constraint is assumed as 1% of disposable household income), they are still expected to cover O&M costs and generate sufficient revenues for debt repayment and initial reinvestments.

Improper SWM in the targeted region has significant negative externalities, impacting on the environment and health. ERR is expected to be high as the project offers resource recovery, pollution abatement, reduced risks to public health, mitigation of climate change, diversion of biodegradable waste from landfill, generation of economic activities, and job creation.

39. Water and wastewater

André Oosterman and Thomas van Gilst

39.1 Methodology

39.1.1 Introduction

Investment in water and wastewater infrastructure contributes to improving human health through higher quality and more reliable water supply. It also enhances environmental protection by reducing untreated wastewater discharge into recipient water bodies and ecosystems. Larger EU grant programmes (e.g. DG REGIO), as well as all programmes beyond Europe that are financed by investment loans, require a quantitative CBA. However, given the difficulty of quantifying the environmental and health benefits resulting from safe water, sanitation and pollution abatement, the EIB sometimes appraises projects using CEA or other approaches. Where relevant, the economic costs (CBA and CEA) and economic benefits (CBA only) of mitigating and adapting to the adverse impact of climate change should be considered.

39.1.2 Cost–benefit analysis

To conduct CBA, project benefits need to be calculated. Water and wastewater services are (usually) provided in a regulated monopoly environment (with numerous price and cost distortions), so tariffs may not reflect the benefit attributed by consumers to services they receive. A better indicator of the value attributed to service benefits is WTP.

WTP is usually determined via contingent valuation (i.e. based on surveys). However, this technique is inherently susceptible to strategic or ill-informed responses because interviewees (often from low-income, unserved areas) find questions on hypothetical service levels highly abstract and beyond their personal experience and context. RP analysis, for instance using the rates paid by unserved customers to private vendors, can strengthen the analysis of WTP. However, perhaps because WTP studies are expensive to conduct, they are almost never available; other methods are more commonly used.

The more usual starting point for economic analysis is, thus, to assess financial profitability — a method addressed in Chapter 2. The first step is converting financial to economic prices (including the elimination of inter-societal transfers such as taxes and subsidies, which should be cost–benefit neutral from a societal perspective). The assumption for water and wastewater services is that the tariff represents the value of direct benefits from basic service provision: essentially, it is equivalent to the avoided private costs, such as private investment and operational costs for wells and septic tanks and the high expense of purchasing water from vendors. If this is not the case, however, the calculated sum of avoided costs should be used instead of the tariff.

In the second step, despite the difficulties of estimating water and sanitation externalities and indirect benefits, the quantifiable benefits and costs are added.[210] These typically include:

- Improved health and living conditions leading to savings in private and public health costs;
- Time savings, for example among people that fall ill or need to fetch water from afar, leaving more time available for (i) income-generating activities or (ii) leisure (which should not be underestimated); [211]
- Environmental benefits, some of which are valued relatively easily by assessing the drop in treatment cost, reduction in GHG emissions, or recreational value; those more difficult to quantify include benefits derived from preserving natural habitats and species that provide ecosystem services such as air quality, adequate climate, water purification, pollination, prevention of erosion, spiritual and aesthetic value, knowledge systems and educational value;[212]

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[210] Whittington D. (1994), The economic benefits of potable water supply projects to households in developing countries (www.adb.org/Documents/EDRC/Staff_Papers/es53.pdf).
[211] Esther Duflo et al; Happiness on Tap: Piped Water Adoption in Urban Morocco. Available at: (www.nber.org/papers/w16933.pdf)
[212] Shadow prices for reduced CO_2e emissions (expressed in EUR per tonne) are regularly updated and made available on the EIB website.

- Other indirect benefits, such as generated economic activities that would not otherwise take place (as some approaches are controversial, such benefits are rarely considered by the EIB). [213]

Given the inherent risk of the different items above overlapping, it is essential to avoid double-counting.

Many of the above externalities cannot be monetised because there are no markets for such goods. However, they can be estimated through (i) proxies using value ranges found in the literature (e.g. Hutton and Haller, 2004); and (ii) more specific studies, such as Ecotec's (2001) research on the benefits of compliance with the environmental acquis for Candidate Countries.[214,215,216]

Accurate estimates are hard to establish, and each CBA requires judgment to evaluate which economic benefits and costs can be determined with sufficient accuracy (in monetary terms) to be included. Besides the unit costs, it can also be challenging to determine quantum with any accuracy: for example, it is difficult to estimate the number of sick-person-days avoided through a new wastewater treatment plant that only partly solves water supply contamination. Though this may seem trivial, like demand forecasting it is prone to optimistic inflation by project promoters.

Some benefits are better left unquantified and considered qualitatively as a complement to the calculated ERR. This qualitative analysis may have a significant impact on the lending decision.

A useful approach is to reverse-calculate what value the unquantifiable benefits would need to be to achieve an acceptable ERR: for example, the health benefits would need to be €X per person per year to have an ERR of 5% (the typically used threshold). [217] The ERR threshold can be considered satisfied if the value of X is within a realistic range. Given the many uncertainties in the building blocks of CBA, a sensitivity analysis is needed to test the robustness of the findings.

The physical life is usually 25 years and above for water projects, depending mainly on the ratio of pipes and cement versus electromechanical content. The economic life is usually deemed in line with the physical life because the service is monopolistic and has limited foreseeable substitutes.

39.1.3 Cost-effectiveness analysis

In the European Union, sector investments are strongly driven by the need to comply with EU directives such as the Water Treatment Directive, the Urban Wastewater Treatment Directive, and the Water Framework Directive. Since the Commission imposes fines for lack of compliance, the economic case is straightforward and justification for EIB funding may rely on just CEA if it would not be feasible to carry out CBA. The Bank uses CEA to compare the relative merits of project options where benefits are identical or similar to one another (even if difficult or impossible to quantify) and costs can be established with some confidence. In these cases in the water sector, the least-cost option for achieving the compliance objective should be identified.

The key step in such CEA is a thorough options analysis, which should normally take place at the feasibility-study phase. The intended objective should be defined broadly, so as to avoid overlooking more efficient alternative solutions. The solutions should also be sufficiently well designed, paying particular attention to demand forecasts and the inclusion of alternatives with appropriate (incremental) phasing to avoid unnecessary and expensive over-dimensioning. Once the options have been identified, options can be ranked based on the PV of costs.

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[213] OECD: Benefits of Investing in Water and Sanitation; World Bank (Scatasta): Indirect Economic Impacts of Dams
[214] Hutton G. /Haller, L. (2004), Evaluation of the costs and benefits of water and sanitation improvements at the global level, WHO, Geneva, (http://www.who.int/water_sanitation_health/wsh0404.pdf).
[215] Ecotec (2001) "Study on the Economic and Environmental Implications of the Use of Environmental Taxes and Charges in the European Union and its member States". The Ecotec values were established against a background of ineffective wastewater treatment and bad systems for projects realising substantial improvements which is generally no longer the case (in CEE at least). The values also need to be escalated to take account of increased income levels and increased environmental/social awareness in the countries since the study was undertaken. The Ecotec report is available online:
https://ec.europa.eu/environment/enveco/taxation/pdf/ch1t4_overview.pdf
[216] It is recommended not to take the "total compliance values" offered by Ecotec but rather, to look at the individual components used by the Ecotec to perform the Benefit Transfer, meaning it can be replicated for any country.
[217] The minimum required ERRs are subject to change. Please contact the EIB for the latest rates.

In feasibility studies, it is not uncommon for even this basic options analysis to be preceded by, supported by or simplified to an MCA. Though less quantitative, such an analysis enables comparison between options with wider implications and benefits (e.g. for politically sensitive decisions on treatment plant locations) or for pre-screening options before CEA. In cases where the analysis goes no further, affordability becomes the critical last step (see section 39.1.4).

Most countries beyond Europe have legislation requiring compliance with environmental and other standards, irrespective of their economic and technical capacity to sustainably attain these standards. Accordingly, some form of phasing of investments is often required.

CEA can be extended by AIC analysis, which involves dividing the PV of project costs by the PV of water or wastewater volumes to estimate the average cost per unit of service provision. This tool allows the comparison and ranking of options with different cost effects while also providing a rough indicator of the unit cost per cubic metre. Cost-effectiveness is evaluated by comparing this value against reference unit costs.

39.1.4 Affordability

Price elasticity of domestic demand is low for water services (especially for lifeline quantities of water). Nonetheless, affordability is a key determinant of a project's political sustainability and of water demand. Full uptake of the service through affordable tariffs, while not directly an input to economic profitability, undoubtedly affects the realisation of benefits. Affordability also signals the appropriateness of solutions or their components.

The affordability ratio measures the share of monthly household income (or expenditure) spent on water and wastewater services.[218] Internationally, the most commonly quoted affordability thresholds are 4% of average household income for water services and 1% for sanitation; wealthier countries often apply lower thresholds. The EIB uses 5% as the total for water and sanitation in African, Caribbean, and Pacific countries, and otherwise employs the national standards where these exist and are reasonable (e.g. Hungary: 3.5% to 4%; Czech Republic and Slovakia: 2.5%; Poland: 3%).

Affordability analysis can be done at two levels of detail: macro (average cost of the given service level) and micro (for the poor and vulnerable). Macro-level analysis evaluates the ratio of average household water charges to average household income or spending, whereas micro-level analysis considers how costs are (or should be) allocated between users within the service area, taking into account income levels (e.g. lowest income decile) and tariff structures (e.g. rising block tariffs) and completes the analytical picture in regards to true "sustainable cost recovery."[219]

39.1.5 JASPERS

The JASPERS approach also commences with an options analysis to ensure the project is cost-efficient. Before calculating the funding gap (to determine the level of justified subsidy) for the selected option, full CBA is carried out. The CBA is also built up using the financial projections as a basis, mainly for the cost component, whereby certain line items such as non-traded goods and unskilled labour are converted from financial to economic costs using conversion factors to eliminate market distortions. This is a perfectly valid approach when reliable conversion factors are available. However, in a number of countries this factor approaches 1, as distortions had been disappearing over time, at least until recently.

[218] Frankhauser/Tepic (2005) suggest using household expenditure which is higher in low-income countries where there is a larger informal sector.
[219] Scatasta, 2008: Pricing Water Resources and Water and Sanitation Services (OECD)

39.1.6 Multipurpose schemes

Some water-resource projects presented for funding are multipurpose, combining water supply, hydropower, irrigation, flood control, and/or navigation. However, projects involving desalination plants or treatment for reuse in agriculture are increasingly common. Like the options within a project, any complex water-resource project requires a full economic analysis of all components, This analysis should be carried out at an appropriate scale, usually the river basin, and apply multiple decision criteria. Demand forecasts under different tariff scenarios and the valuation of environmental benefits further complicate the analysis. The Bank normally assesses the quality of analyses performed by others and, where necessary, insists on additional studies to fully justify the selected option.

39.2 Case study 1: Water and wastewater project in the European Union

This project concerns the extension and rehabilitation of water and wastewater systems in an EU Member State. It aims to improve environmental protection and public health in eight agglomerations with a total population of 520 000. The project will expand and rehabilitate the water and wastewater networks, construct and refurbish pumping stations and treatment facilities for waste and wastewater,.The project cost includes also the necessary technical assistance for project implementation. The project's economic analysis was conducted by consultants on behalf of the promoter, using the relevant European Commission guidance as adapted for the project country with assistance from JASPERS assistance.[220]

To calculate the economic costs behind the investment costs, replacement costs and O&M costs, a shadow wage rate [$(1-u)*(1-t)$] was calculated and applied to every year of the analysis period, with u denoting the regional unemployment rate, and t the rate of social security payments and relevant taxes. The average shadow wage rate for this project amounts to 0.50. The financial costs of labour are, therefore, multiplied by 0.50 to reflect the economic costs. All other potential conversion factors are set to 1, as no major distortions in the prices of traded and non-traded items are expected. Also, no externalities on the cost side need to be accounted for.

The project's main economic benefits derive from improved compliance with the environmental acquis, bringing a direct environmental impact, improved drinking water quality and positive effects on public health. Furthermore, it is assumed that by rehabilitating and extending the water supply and sewerage system, the life quality of the population will be enhanced through improved health and comfort. To quantify the project's economic benefits, the WP and WOP scenarios were compared. The economic benefits were grouped as follows:

- Improved access to water and sewerage services: The relevant measure is the additional volume of water sold per year as a result of the project, which can be valued economically using the average fee per cubic metre paid by customers (applied for water and wastewater according to the respective incremental connections).
- Resource cost savings**:**
    - Resource cost savings to customers are avoided capital and O&M costs for drinking water wells and septic tanks. Residential users are assumed to use, on average, 0.5 well units and 1 septic tank unit per household; non-residential users are assumed to use, on average, 3 well units and 4 septic tank units per economic agent. It is also assumed that connection to the water supply system substitutes the consumption of one bottle of mineral water per person each day.
    - Resource cost savings to the operator have two major components: avoided O&M costs through reduced water losses and avoided emergency replacement cost of obsolete equipment. As avoided O&M costs are already implicitly considered by applying the incremental approach, these benefits are valued at zero in this specific case. The emergency replacement cost for outdated and obsolete equipment, which the project would avoid, is considered in the WOP scenario from 2013. A provision for this cost (approximately €2 million/year) is already included in the O&M costs of the WOP scenario, so it is set to zero in the project benefits section.

[220] "Guidance on the methodology for carrying out Cost-Benefit Analysis." Working Document No 4. The Programming Period 2007 – 2013. European Commission. 08/2009.

- Avoided carbon emissions through production of electricity in the wastewater treatment plants: The specific emission factor for the project country — considering its power production mix — was estimated at 0.9 tCO_2 per MWh. The electricity to be produced with methane gas in the treatment plants would avoid a total of 186 thousand tCO_2 between 2010 and 2036.
- Avoided opportunity cost of water: Through loss reduction and other efficiency measures, less raw water has to be abstracted, meaning more water will be available for alternative purposes or left in the natural environment.
- Benefits of compliance with the environmental acquis: Publicly avalble values are used to evaluate benefits to human health; impact on aquatic environments, mostly concerning fish and shellfish resources; benefits to ecosystems via biodiversity protection; social benefits, such as access to clean bathing waters and rivers for recreation; and wider economic benefits, such as tourism. The benefits of full compliance with EU water-related directives were estimated to have a total value ranging between €400 million and €1 250 million per year in 1999 prices. This would be equivalent to a range of €22 to €68 per year for each inhabitant in 2006 prices. For the present analysis, a yearly value of €68 per person was chosen, based on a separate assessment identifying high access to service benefits in the project country.

The project is the first phase of a series of investments targeting full compliance with EU legislation in the region; its contribution to achieving full compliance was estimated at about 38%. This value was stepped according to the approximate percentage of population progressively benefitting from the improved water and wastewater systems, in line with the rate of connection to sewer systems. Project ERR was calculated to be 6.8% (considered satisfactory), based on 30-year projections from 2007 to 2036.

39.3 Case study 2: Water and wastewater project beyond Europe

This project is expected to improve the water supply service in the east zone of a town, including population not yet properly served. Specifically, it will finance a number of works included in the investment programme of the town C water company (TCWC) over a five-year period. These works aim at improving the reliability and efficiency of existing systems, reducing non-revenue water and expanding the water supply to concession areas not yet served.

The project’s main benefits are (i) improved reliability and efficiency of the water supply service, with optimisation of system performance and reduction of illegal connections; (ii) improved use of scarce existing water resources, with reduction of leakage in the distribution system; and (iii) better quality of life, including reduced health risks, for the local population through increased coverage of the water supply service.

For items (i) and (ii), the main project impact is to reduce the percentage of non-revenue water from 34% to about 30%. TCWC estimates this reduction at 56 megalitres per day (20.4 million m^3/year). Assuming that most of this reduction is achieved through reduced leakage, the economic value of this benefit is given by the variable cost of production per cubic metre, which is about 1.03 local currency units (LCUs) per m^3, or €0.3 million/year.[221, 222] There are also savings in O&M costs resulting from equipment renewal and preventive maintenance, which have not been quantified.

Table 39-1: Key consumption and customer spending data before project

Beneficiaries	
Area A	372 000 inhabitants
Area B	144 000 inhabitants
Area C	150 000 inhabitants
Total	666 000 inhabitants
Consumption	50 l/c/d
From private wells	25%
From vendors	50%
Price	
Private wells	LCU 40/m^3
Vendors	LCU 125/m^3
Average	LCU 104/m^3
Monthly spending	LCU 936
Monthly spending	€14.60
% of household income	11.1%

For item (iii), the most important from an economic perspective, the main project impact is new customers' continuous access to safe water at an affordable price, and the accompanying effect in reducing incidence of waterborne diseases. Specifically, the project will provide access to safe water for a population of about 666 000 (in approximately 111 000 households) that currently source water from a combination of private wells, vendors, and retailers of bottled water. Current water consumption of these households is somewhat difficult to assess, but comparable situations suggest that consumption is no more than 50 litters/capita/day (l/c/d). Using this average consumption and an estimated price currently charged by private wells and vendors, what these households pay for water can be roughly calculated at LCU 104/m^3 — about ten times the tariff charged by TCWC to residential customers and equivalent to 11% of recipients' household income. The described consumption and spending data are summarised in Table 39-1.

221 Basically, energy cost and chemicals.
222 That is, non-revenue water in fact has two components: physical losses and administrative losses (i.e., illegal connections). Given that the economic value of water supplied to an illegal connection is the tariff, which is higher than the variable cost of production, the assumption made is on the conservative side.

After project completion, the beneficiaries are expected to increase their consumption to about 135 l/c/d, a conservative assumption consistent with the average consumption in other areas of the east zone served by TCWC. Despite this increase in consumption, the significantly lower residential tariff means these new customers' average spending on water will fall below the recommended affordability threshold of 4% of household income. The described future consumption and spending data are summarised in Table 39-2.

Table 39-2: Key consumption and customer spending data after the project

Beneficiaries	666 000 inhabitants
Consumption	135 l/c/d
Residential tariff:	LCU 10.67/m^3
Monthly spending	LCU 259
Monthly spending	€4.04
% of household income	3.1%

In this scenario, the economic benefit of this project component can be measured by the increase in economic welfare of new customers. This is based on their increase in consumption at a lower price with lower monthly spending for a service that is now reliable and safe. The specific quantification of this benefit involves the following calculation, which results in €57.35 per beneficiary and year:[223]

$$EB = Qw*Pw+Qwo*(Pwo-Pw)+0.5*(Qw-Qwo)*(Pwo-Pw)$$

where *EB* is the economic benefit (€/beneficiary/year); *Qwo* is the WOP consumption (m^3/beneficiary/year); *Qw* is the WP consumption (m^3/beneficiary/year); *Pwo* is the WOP tariff (€/m^3); and *Pw* is the WP tariff (€/m^3).

After deducting the O&M costs associated with providing water to new customers (LCU 6.82/m^3), this component of expanded coverage has a net economic benefit of €34.7 million/year.

Comparing the total investment cost (€201.7 million) with the above-calculated economic benefits of reduced non-revenue water (€0.3 million/year) and increased coverage (€34.7 million/year) results in a project ERR of 13.1%.[224] The benefits also include reducing waterborne diseases by delivering better quality water to new customers; this was not included in the calculation because it cannot be easily quantified. Overall, the proposed project has high economic profitability and Bank financing is justified.

[223] Technically, this is the measurement of the project incremental revenue plus the increase in the consumer surplus before and after the project assuming that the demand function is linear.
[224] This figure corresponds to the project base cost plus the cost of other investments being financed by TCWC outside the project (i.e. the phase 1 of the Area A component and the construction of a new water treatment plant in the W river for the Area B-Area D) that are necessary to fully deliver the economic benefits considered in the calculation.

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