Chapter

Cost-Benefit Evaluation Tools on the Impacts of Transport Infrastructure Projects on Urban Form and Development

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Abstract

This study reviews literature for identifying the methods in order to evaluate the impacts of key transport infrastructure provisions on urban form and peri-urban development in European Union (EU) member countries. Key impacts and linkages of transportation provision on urban development trends are identified through the international literature. These include direct impacts of transportation infrastructure provision, socio-economic impacts, transportation network effects and energy and environmental impacts. Among the evaluation methodologies, cost-benefit analysis (CBA) is the most common approach for transport policy impact assessments both in the national project appraisal guidelines and in scientific analysis and research. Considering its extensive usage in the appraisal work, the main focus will be on the evaluation tools used within the CBA approach. The corresponding data requirements for the valuation of indicators will be also discussed in order to assess the impacts of costs and benefits of transport investments, particularly rapid rail investments, on urban form and development.

Keywords: urban form, transportation-land use relationship, transport infrastructure investment, impact assessment, cost-benefit analysis, Europe

1. Introduction

Following the growing world population and associated need for increased transportation, there has been growing interest in some aspects of transport policy such as sustainability in infrastructure provision. The increasing rates of fossil fuel dependency, global warming, poverty and social inclusion are highly relevant for the transport sector [1]. Accordingly, there appears to be a common policy consensus on the need to achieve socio-economic development and environmental protection. Urban development policies internationally now increasingly depend on sustainable transport systems, which include increasing shares of walking, cycling and public transport such as metro and light rail systems [2].

Cost-benefit analysis (CBA) is a tool conventionally used to evaluate potential costs and benefits of a given public investment such as major rail or road investments. The CBA methodology is based on early welfare economic theory [3] where the idea is to achieve efficient allocation of resources and maximise public benefits for general social welfare. In the CBA approach, the effects of public investments are valued in monetary terms and expressed as costs and benefits to represent an overall aggregated value of individual well-being. This approach provides a basis for the evaluation of impacts of various transport projects and policy changes, particularly the rail infrastructure investments in a wide variety of the appraisal work [4]. From this literature, the CBA methodology applied to transport project appraisals consists of a quantification of changes in user costs, infrastructure costs and selected external costs. These are expressed as monetary values, market prices and shadow prices which are then used for the valuation of benefits. The overall result gives guidance on which investment and which alternative are most feasible according to the selected economic criteria.

Based on its wide coverage of impacts and indicators utilised in the appraisal framework, the CBA methodology has increasingly been used as a key tool for a comprehensive assessment of the impacts of major transport investments and associated policy changes not only in the European Union (EU) but also overseas countries such as US, New Zealand and Australia [5]. Regarding the EU countries, the European Commission's (EC) existing European Research on Transport (EURET) programme has constructed a common basis for research on European transportation-related issues prior to the development of a 'common transport policy'—the Trans-European Network (TEN) programme 2007–2013. This programme aims for more balanced spatial development across the EU by assigning greater importance to regional interconnection, interoperation and access to national and international networks. Within the context of the aims of TEN, EURET proposes a wide appraisal spectrum for the evaluation of transportation investments across EU countries.

For EU member states, CBA is required for receiving funding from Cohesion Fund or Structural Funds [6]. In a previous EURET Report, it is noted that a majority of European countries rely heavily on CBA in their national appraisal strategies (EURET Concerted Action 1.1., see [7]). The report provided a basis for establishing common appraisal guidelines for EU countries. The 2008 EC report is a 'Guide to Cost Benefit Analysis of Investment Projects' which contributes to shared Europe-wide project appraisal guidelines in a broad conceptual framework [8]. A more recent report was published by EC [9] named 'Guide to Cost-Benefit Analysis of Investment Projects: Economic Appraisal Tool for Cohesion Policy 2014–2020'. These reports demonstrate an attempt at the European level to develop a common appraisal approach for major public investments.

This chapter reviews literature to identify common impacts and indicators and to examine the methodological approach concerning impact-indicator calculation and valuation methods in the CBA applications of EU countries. The existing literature on these issues is limited since previous research has mainly focused on a general comparison of transport policy appraisal techniques across the EU countries and internationally [5, 10], a general review of existing tools and methods used for transport infrastructure evaluation [6, 11] or a valuation of specific indicators in a country-specific or European context [12, 13]. Less attention has been paid to specification and evaluation of the assessment methods for the priority indicators commonly used in cost-benefit assessments. To fill this gap in the literature, this chapter focuses on key impact and indicators and the techniques utilised in their assessment methodologies in a CBA framework.

2. Assessing sustainability of urban form and transport relationship

The process of globalisation and the progress achieved in telecommunication technologies have led to significant changes both in economic and spatial structure of cities [14]. The literature can be divided into two main groups: the first group points out a decline in the significance of space and distance resulting from advances in telecommunication technologies [15], while the other group supports the continuing importance of proximity and agglomeration economies [16]. Despite the existence of two different polar views in the theory, what is clear is that there is considerable migration to the metropolitan areas since the mid-1970s globally. These metropolitan centres have experienced dispersed or polycentric type of development in contrast to their monocentric structures that were common previously[1] [17]. This implies that CBD has lost its primacy and that many trip-generating activities are dispersed in clusters within peri-urban areas.

Considering its wide variety of effects on the urban area, population growth can provide benefits to the residents and the governments by attracting more specialised services, and enhancing economic and social diversity. However, there is also a growing perception among planners and policy-makers that urban growth may not provide net gains to the society considering its negative impacts on the urban environment. An example of such an impact is uncontrolled urban growth that is associated with dispersed patterns of urban development commonly known as 'urban sprawl'. Development on the periphery, and this new form of urbanisation is seen to be problematic for several reasons: first, it necessitates providing infrastructure and services to the low-density population on the urban periphery reflecting the main cost of infrastructure provision on the society as a whole; second, it causes loss in the productive agricultural land and reduction of landscape amenity; lastly, it is related to indirect externalities such as negative effects on the air and water quality, increased travel and accessibility costs and unwanted social equity costs.

Given this framework, sustainable urban development and urban growth management have become a central issue both in planning theory and practice. Here, the main issue is the search for linkages between rural and urban spatial structure and transportation systems which will achieve sustainable urban form and efficient transport provisions (see for example [18, 19]). Efficiency in transportation which is closely related to the urban structure is generally achieved by reducing *trip lengths and times, enabling efficient transit as the dominant mode of transport, and reducing transport-related emissions, pollution and accidents* [20]. The theory suggests that compact city is preferred to more dispersed patterns in terms of sustainable spatial development and transportation efficiency [21]. The reason is related to the reduction in travel demand and travel time since most of the activities are closely located in the compact form [19, 22]. It is also argued that compact form can support public transport services better than dispersed form since population densities (e.g., critical mass) in the former case are high enough to provide efficiency in different modes of public transportation[2] [20]. In the literature, there are also studies questioning the sustainability of the compact form [18, 23] and suggesting that decentralised or polycentric solutions would be better. One reason for this is that multi-centred cities provide significant transport benefits by locating residences close to employment centres [21]. Gordon et al. [24] named this as the co-location of workers and jobs.

In contrast to the previous research supporting co-location hypothesis, Gordon et al. [25] have concluded that polycentric type of development is not necessarily associated with shorter commuting distances as it is verified through the empirical work carried out for the metropolitan areas in France [26]. The results from this

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[1] Here, monocentricity is related to the single central business district, which dominated the hierarchy of business entrees by being the focal point of the transportation system while the polycentric structures are the decentralised employment centres connected by the relevant transportation networks.

[2] The notion of 'critical mass' is related to high population and job densities, which are interlinked with a greater demand and usage of public transport services, hence supporting the viability of public transport. By contrast, low densities are inefficient in terms of public transport provision, thereby creating a greater dependence on private car use.

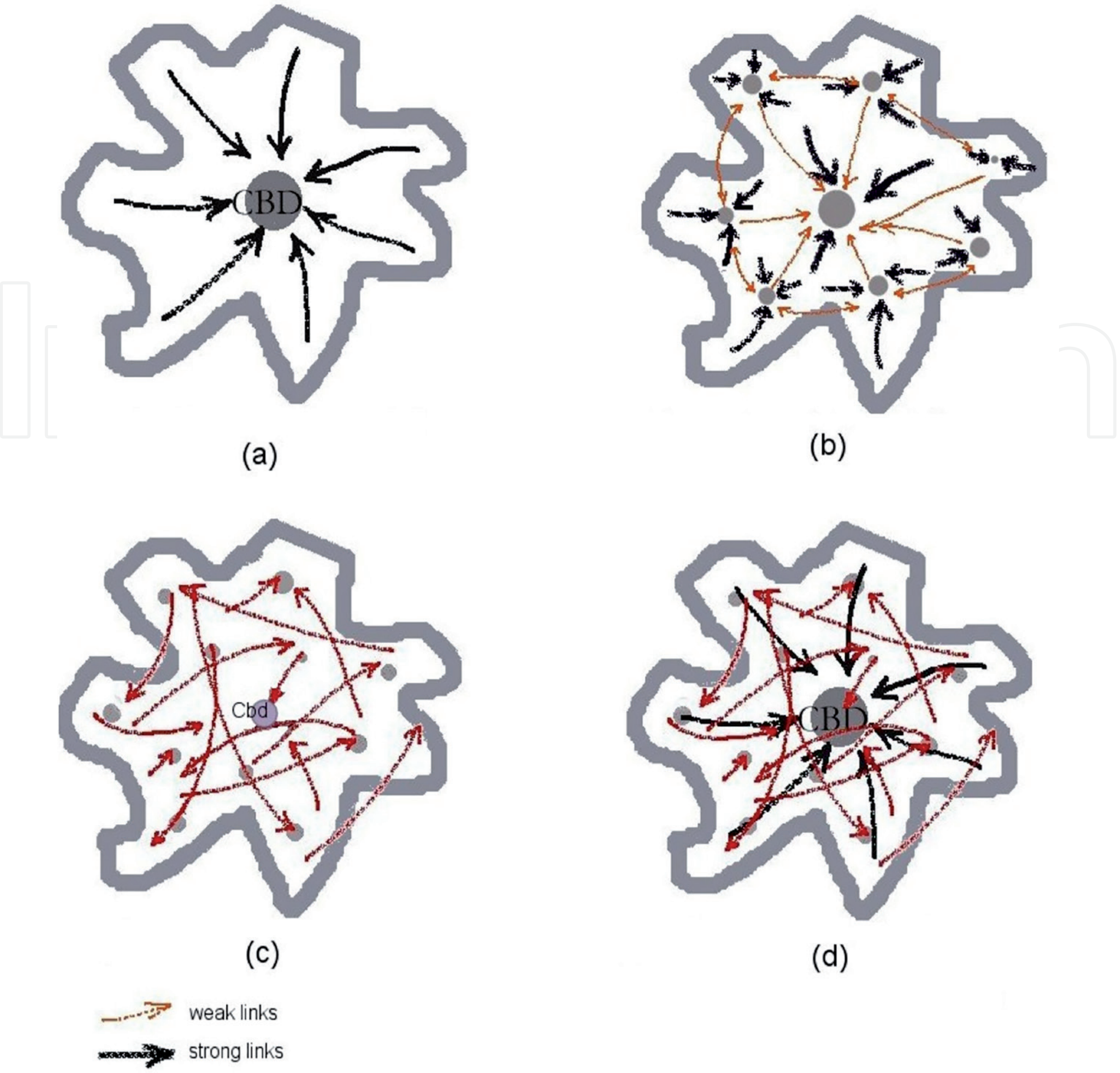

Figure 1.
The trip patterns observed in different urban forms. (a) The monocentric model, (b) The polycentric model: The urban village version, (c) The polycentric model: The random movement version, and (d) The mono-polycentric model: Simulateous radial and random movements. Source: Bertaud [22].

work indicated that employees living in a sub-centre work outside their sub-centre of residence. This implies that there are other factors rather than the urban form determining the commuting behaviour. The differences in commuting patterns are generally explained by differences in socio-demographic factors and different preferences [27]. These factors affecting the commuting behaviour constructed a base to explain the relationship between urban form and commuting patterns. Following Van der Laan [28], four different types of commuting flows are identified: centralised,[3] decentralised,[4] exchange commuting[5] and cross commuting[6] (**Figure 1**).

The first one is the monocentric model with radial travel patterns from the periphery to the central core where a great majority of economic activity takes place

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[3] The workers live either in the suburban areas or in the City centre, and in both cases, they commute to the central city.

[4] Suburban areas attract commutes from other suburbs and the central city.

[5] People living in the central city commute to suburban areas while residents of the suburbs commute to the central city.

[6] There are separate labour markets in the suburban and central areas indicating that suburban residents have jobs in the suburbs while central city residents work in the central city.

(**Figure 1a**). The existence of public transportation along radial routes results in short trip distances and travel time. The second model (**Figure 1b**) is a theoretical model of polycentricity consisting of self-sufficient 'urban villages' surrounding the CBD. In such a model, house-to-job distances are very short considering that most people are living and working in the same sub-centre, and even could go to work by walking or cycling. However, there is no example of self-sufficient sub-centres as described by this model; and therefore, the model is subject to criticism among academics (see for example Bertaud [22]). The random movement version of the polycentric model, on the other hand, could better represent the real situation as there is wide dispersion of trip origin and destinations with highly complex and random trip patterns in a multi-centred area (**Figure 1c**). The absence of radial routes and the existence of random movements, however, make it more difficult and inefficient to operate public transportation when compared with the first two models in **Figure 1(a)** and **(b)**. This stems from jobs-housing imbalances where jobs and residences are relatively far from each other and dispersed in an urban area implying a wide variety of trip origin and destinations. The last model is the mono-polycentric model (see **Figure 1d**), which refers to a multi-centric structure with a strongly dominated central core. The model provides radial movements between sub-centres and the CBD while reducing random flows between the sub-centres. In this sense, public transportation could be provided along the radial routes, but to a limited extent considering the existence of inter-suburban random flows. To sum up, these four models provide potential explanations for the relationship between urban structure and travel patterns which may exist in an urban area.

Based on these varied relationships, the concept of transport efficiency has gained increased importance. The potentially strong relationship between urban form and transportation efficiency constructed a base for the studies evaluating the economic aspects of various urban forms which will provide efficient transport systems. The literature that is related to the land use-transportation interactions can be examined under two main groups: the first group analyses the impacts of transportation networks on the structure of land development by applying methods of economic appraisal in either qualitative or quantitative framework. For instance, it evaluates the costs and benefits of transport provisions by carrying out empirical research in a given urban area in a specified time period. The examples can be found in Donaldson [29], Perl [30] and Ustaoglu et al. [31, 32]. The second group of literature derives indicators to measure and evaluate the costs and benefits of transport provisions. Under the second group, there are analyses of the appraisal of transportation projects through examining the effects on real estate property prices [33]; studies on relationships between transportation investments and land use development through deriving accessibility measures [34], and examinations of the transport-land use relationship incorporating the accessibility measures on different land development scenarios [35].

3. Transport project and policy evaluation in academic literature

The impact evaluation of transport projects and policies is to a large extent subject to technical, socio-economic, environmental and policy-based value judgements. There is no single best methodology for the evaluation of transport policy impacts; but a wide variety of methods is used depending on the nature of objectives and the characteristics of value judgements. Within the international literature, various approaches concerning transport impact evaluation can be found (for a detailed review, see [36–38]). These include economic analysis techniques such as cost-benefit analysis (CBA) [39, 40], cost effectiveness analysis

(CEA) [36, 41], and lifecycle cost analysis [42]. Additionally, transport projects can be subject to evaluation through application of specific approaches such as multi-criteria analysis (MCA) [43], social-based analysis (i.e., based on environmental impact assessment—EIA and strategic environmental assessment—SEA approaches) [36], decision-analysis [10] and other specific applications including land suitability analysis [44], rapid assessment methods [43], resource management approaches and simulation/mathematical modelling [45].

Among others, CBA is the core of most assessment procedures and has an extensive use in the national appraisal frameworks of most countries in Europe and internationally (see [46, 47]). As the OECD suggests, the CBA assessment can consider a large set of criteria including financial impacts for transport providers, effects on transport user benefits, socio-economic impacts, transport network effects, energy and environmental impacts and policy impacts beyond the transportation system [48] (see also [49]). As a result of the difficulties in quantifying some of the impacts in monetary terms and the existence of objectives which are not always related to economic efficiency, CBA may not be a desired option for project evaluation in every case [50, 51]. In order to address some of these issues, other approaches outlined above have been introduced and applied internationally either as modified alternatives to CBA or in a complementary analysis framework [10, 36, 38].

Related to the transportation evaluation methodologies provided in the literature, Litman [52] points to some of the weaknesses of transport-land use impact evaluations and suggests using a more comprehensive approach for evaluating the impacts of transportation provisions on land use, travel activity, land development patterns, and land use accessibility and transport diversity relationship. This has been initially highlighted by many studies in the literature (see [48, 53, 54]) indicating that a wider scope for the assessment of transportation projects is increasingly needed to cover externalities of transportation investments which were previously not included in the traditional cost-benefit assessment methodologies.

Additionally, there is further research criticising standard cost-benefit appraisal techniques as they do not consider wider economic benefits of transport investments [55]. One of the key recent studies carried out in this area is that of Graham [56], who investigated external agglomeration benefits arising from the provision of transport infrastructure. This study is based on Venables' [57] earlier research regarding the impacts of transport investments on agglomeration of industries and further impacts on the economy. In this respect, agglomeration effects are crucial for both manufacturing and service industries as they create connections between firms for achieving benefits from labour market pooling, the sharing of intermediate inputs, and knowledge sharing or technological spillovers [58]. Graham's [56] research points out some positive externalities from increasing urban densities associated with a transport investment supporting Venables' [57] argument concerning the significance of agglomeration externalities in urban economies.

Contrary to these arguments highlighting beneficiary impacts of transportation investment on economic growth, literature is unclear on the degree to which economic development benefits stem from the transportation investments (see for example, [59]). The general argument in the literature is that benefits from economic growth are mainly represented in travel cost savings which result from improvements in the efficiency of the transportation system. Travel cost savings include the savings in travel time, vehicle operation costs and costs of accidents, reduction in traffic congestion, etc. Some studies argue that inclusion of economic growth effects will lead to double counting since 'economic growth benefits are the manifestation of capitalised travel cost savings' ([48], p. 19). Despite a lack of consensus on transport infrastructure investment and economic development relationship, there is an increasing number of studies in the literature focusing on development and assessment of wider economic impacts in transport project and policy appraisals (see [49, 60]).

In addition to the wider economic benefits, some other impacts of transport proposals were specified by Nash and Preston [61] aiming at a more comprehensive assessment in a conventional CBA approach. They argued that financial appraisal frameworks of transport investment programmes should be extended to cover external benefits including traffic congestion, environmental and developmental benefits and others. Related to developmental benefits, empirical evidence has shown that development of a transportation system results in changes in property values along the transport corridors [62]. These studies point out that the results indicate the short-term impacts of the development of a new transport system rather than the long-term market effects. The degree to which increases in property values stem from transport investments is unclear due to the existence of other forces influencing real property markets. These may include the changing planning and policy settings within the area, regional economic development trends and forces, and the availability of other transit connections and developable land within the area [63]. It is also important to mention the existence of relocation effects stemming from local development, that is, the gain achieved by one area may be lost in another area in the region implying a net zero effect overall. Based on these issues, property values, on general basis, are evaluated separately in the transportation impact evaluations on land development.

Many studies in the literature have argued that transportation systems can play a critical role in strengthening or weakening the problems posed by the dispersed or sprawl type development patterns [52]. Dispersed development necessitates providing public services to the low-density population; causes loss in agricultural land and reduction of landscape amenity. It is also related to indirect externalities such as: negative effects on the air and water quality, increased travel and accessibility costs. In order to represent land development impacts of transport provisions, there are a group of indicators suggested to be included (e.g., public service provision costs) for the cost-benefit evaluation of transport investment assessments. The details of the indicators can be seen in Litman [52].

Concerning environmental impacts, transportation system, particularly road transport is accepted to be a main contributor to the increasing levels of greenhouse gas emissions [64]. The dramatic increase in private vehicle ownership, which is also encouraged by the provision of large-scale urban motorways, has led to air/noise pollution and increasing amounts of transport-related energy consumption. In contrast, the average rail and transit passenger tends to produce less carbon dioxide than a road transport user [65]. Although there are examples of counterarguments, the general research has been in favour of compact urban form in comparison to the more dispersed urban development largely on the grounds of transportation energy savings (see [18]). Energy and environmental impacts, that is, energy consumption, air/noise pollution exposure, climate change emissions (greenhouse gas emissions) are all important for the transportation evaluation process and are generally covered internationally in transport project assessments.

Alternatively, the study of Nash and Preston [61] points out some possible changes in other public transport revenues (e.g., bus) following a shift from existing public transport use to the newly introduced public transport network (e.g., rail). Such changes in public transport revenues need to be included in evaluations as a newly introduced public transport infrastructure results in revenue losses for the existing public transport operators resulting from a reduction in demand and consequent reductions in services and costs to compensate (see [61]). Another issue is the changes in tax revenues resulting from shift of demand among various modes of transportation users. As an example, introduction of a new rail system can have influences on car tax revenues possibly implying a loss in revenues from taxed road transport since a number of road users may shift to untaxed rail.

Another issue which is of great concern in benefit-cost evaluations of transport investments is the assessment of public funds associated with a project proposal [8]. Projects have impacts on public funds through the need to finance capital expenditures and the impact of the project on taxation receipts [66]. The tax revenues generated by the project (i.e., direct and indirect tax revenues) can be evaluated in two ways: either they may decrease the need to finance budgetary deficits by public debt or taxation, or they provide the opportunity to increase public expenditure [66, 67]. Estimation of marginal benefits of additional public expenditures is cumbersome; therefore, it is suggested to apply the marginal costs imposed on the economy by the collection of additional public revenues [66, 67]. One of the main sources of public revenues is tax collection; consequently, the marginal cost of public funds can be calculated as the cost to the economy of collecting an additional unit of tax revenue (see [67]). From the perspective of project finance, a shadow price of public funds exceeding a unitary value implies that each €1 raised through taxation gives rise to a social cost in excess of €1. The EC Final Report [8], p. 57, defines the marginal cost of public funds as 'the ratio between the shadow price of tax revenues and the population average of the social marginal utility of income'. These are country-based values depending on the taxation system and suggested to be used to adjust the flows of public funds to and from the project.

In line with this literature, the key impacts and indicators in the evaluation of transportation-land use relationship are summarised in **Table 1** with the examples of studies particularly focusing on these specific impacts in their detailed research. The literature may also cover some other impacts and indicators to be included in transport policy and project evaluations. As these are not fully covered in this paper, their details can be seen in related literature including Litman and Burwell [98]; Marsden et al. [99]; Sinha and Labi [38]; UN [100]; and Litman [97]. The comprehensive approach summarised in **Table 1** can be considered as an enhanced approach in evaluating the impacts of transportation policy and provisions. The variety of impacts given under this method implies that there are various interest groups which will be affected from the development and implementation of transportation policies in different ways. Janic [96] identifies these groups such as: users; systems' operators; public, semi-public and private investors; policy-makers at local (regional) and national level; and local community members (see [96], p. 496).

The policies and their impacts—namely costs and benefits—can be conflicting for particular groups. For example, new transportation investments such as rapid transit systems will benefit direct users by reducing time and money spent for transportation; operators by increasing their profitability; investors of transportation infrastructure by increasing their rate of return, policy-makers by improving the efficiency of the transport sector and the economy; and community members by improving their local socio-economic conditions. On the other hand, transport investments can imply different costs to different interest groups: travel costs may increase for the direct users whereas it may become costly for operators to run a high-tech business. Investors and policy-makers may come up with high infrastructure costs while community members may

Impacts/indicators[*]

1. Direct impacts of transportation infrastructure provision:

- *Transportation facility land values:* The cost of land used for transportation infrastructure construction and other public facilities dedicated for transport vehicle use [52, 57]
- *Infrastructure development and construction costs:* The cost of designing and constructing transportation facilities including land and transport infrastructure construction [68]
- *Traffic services:* These refer to the costs of police, emergency response, law enforcement, planning, street lighting, parking enforcement and driver training [52]
- *Adjacent property values:* The change in real property values resulting from the provision and operation of the new transportation infrastructure [69]

2.Socio-economic impacts:

a. Land development impacts:

- *Green space preservation:* Refers to effects of transportation activities and facilities on the green space, e.g., parks, gardens, farms, woodlands, etc. [52]
- *Public service costs*: These point to how costs of public service provision tend to increase with dispersion of urban activities [70]
- *Urban sprawl*: Land development impacts vary by mode since private car-based transport requires more space than other modes for travel and parking, and tends to encourage more dispersed patterns of land use. By contrast, alternative modes such as bus transit and rail systems are more likely to contribute to more compact and mixed-use land developments [71]
- *Regeneration*: The provision of a new transport system associated with corresponding land use plans and policies can be influential in promoting urban renewal particularly in unfavourable urban areas [72]

b. Transportation-related impacts:

- *Safety*: The ability of the transportation system to allow users to move freely without damage and harm [73]
- *Vehicle ownership and operation costs*: Direct user expenses for the ownership and use of private vehicles [74]
- *Transit fares*: Costs and revenues of public transport fares to the users and system providers [75]
- *Travel time*: Time spent on transportation including waiting and actual travel [76]
- *Comfort and convenience*: This refers to the quality of transport service including ride quality, crowding and quality of information, cleanliness and ambience [77]
- *Traffic congestion effects*: Refers to incremental delay, vehicle operating costs, transport-related pollution and stress resulting from interaction among vehicles in the traffic [13]
- *Transport diversity*: Quantity and quality of travel options (particularly of non-drivers') are considered [78]
- *Barrier effects*: Delays, discomfort, lack of access that roads and traffic cause to non-motorised travel [79]

c. Socio-economic development impacts:

- *Affordability (housing)*: Potential expansion of accommodation choices for all individuals to increase mobility and lower the combined cost of housing and transportation [80]
- *Affordability (transport)*: People's ability to access basic goods and activities (housing, medical care, food, education, work and social facilities) by means of transportation [81]
- *Social inclusion*: Transport-related factors influencing individual's ability to access education, employment and public services, social and recreational activities [12]
- *Socio-economic growth*: The development and growth impacts of transportation infrastructure on the economy and the society [82]
- *Wider economic impacts*: Introduction of a local transport investment is influential in changing the effective density of employment and jobs that are accessible to the local economy. This will have further impacts on productivity and efficiency, i.e., agglomeration externalities, competition effects, output effects (of imperfect competition) and labour market effects [83]
- *Land use/transport accessibility*: The ability of the transportation system to connect people to goods, services and activities, and to meet needs of different populations [84]
- *Area property values*: Transportation policies and planning decisions have influences on property values as well as the location and type of real property development [62]

Impacts/indicators*
d. Impacts on government fiscal balances • *Changes in tax revenues*: These represent changes in transport-based tax revenues following a demand shift among different transport modes [85] • *Marginal costs of public funds*: Refers to the impacts of transport projects on public funds through the need to finance capital expenditures and the impact of the project on taxation receipts [86]
3. Transport network effects: • *Reliability*: Variation and consistency in travel times and the reliability related to external factors [87] • *Quality of transport service*: Relates to ride quality, crowding, ambience and quality of information [88] • *System operating and maintenance costs*: Refer to expenditures to maintain the transport facilities including maintenance and operations [89]
4. Energy and environmental impacts: • *Climate change emissions*: Refers to the greenhouse gases (i.e., CO2, NOx, CH4) emitted from transportation vehicles and related facilities that increase atmospheric solar heat again [90] • *Air/noise pollution exposure*: The noise and air pollution associated with transportation system construction/operation [91] • *Resource consumption costs*: These refer to various direct and indirect costs of energy produced, distributed and used in vehicle and transport facility construction and operation [92] • *Water pollution*: Pollution (surface and ground water) associated with transportation facilities and vehicle use [93] • *Waste disposal*: External costs resulting from vehicle waste disposal activities [94] • *Ecological impacts*: Transport infrastructure and operation impacts on flora, fauna and their habitat such as wetland [38] • *Landscape and heritage*: Transport networks and related facilities, vehicle traffic and low-density development can be a threat to cultural heritage and often degrade landscape beauty [95]

**Adapted from: OECD [48]; Janic [96]; Sinha and Labi [38]; Litman [97].*

Table 1.
Summary of impacts and indicators for the transport infrastructure evaluation.

suffer from local impacts on their environment. It is clear from this example that implementation of new transport policies represents a trade-off between gains and losses within and between different interest groups. Therefore, it is important to consider these trade-offs by including as many of the policy impacts into the transport project evaluations. Accordingly, Litman [52] points out to some of the weaknesses of current project evaluations and suggests using a more comprehensive approach for evaluating the land use impacts of transportation provisions [52]. The main steps in the evaluation of transportation-land use relationship are summarised in **Table 2**.

It is obvious from **Table 2** that transportation provision has various impacts on land use; and as empirical evidence has shown, it is difficult to quantify most of these impacts. Some of the impacts and indicators can be represented in monetary values while the others can only be expressed in a more qualitative way. Here, an important issue to consider is that there may be correlations among various indicators such as the positive correlation between land use accessibility and land values, or the negative correlation between air pollution exposure and area property values. Considering the correlation effects, indicators should be kept as orthogonal as possible in order to prevent the double counting problem in the transport policy evaluations. Therefore, selection and confirmation of the most relevant indicators is an important stage within the project evaluation process.

Transport provision results in:	Physical effects	Impacts	Examples of indicators	Expected direction of change for stakeholders
Direct changes in land usage	Amount of land devoted for transportation facilities	1.Green space preservation	1.Per capita green area used for transportation facilities (QN)	Down: P, C
		2. Transportation facility land values	2. Estimated value of the land used for transportation facilities (QN)	Down: I, P
		3.Development costs/ capital investments	3. Costs of demolition, levelling, reinforcement, etc. of land (QN)	Down: I, P
		4.Adjacent property values	4. Estimated value of the adjacent properties (QN/QL)	Up: LC, P
Changes in development patterns	Location, density and compactness of development	5. Green space preservation	5. Per capita impervious surface land (QN/QL)	Down: P, C
		6. Public service costs	6. Costs of providing public services such as roads, utilities, etc. (QN/QL)	Down: P, C
Changes in land use accessibility and transport diversity	Dispersion of common destinations, and quality of travel options	7. Changes in per capita vehicle travel	7. Changes in (QN/QL):	
			7.a. vehicle operation costs	Down: U, C
			7.b. travel time	Down: U, C
			7.c. risk of accidents	Down: P, C
			7.d. comfort and convenience	Up: U, C
			7.e. traffic congestion	Down: P, C
		8. Area property values	8. Estimated value of the properties within area (QN)	Up: P, C
		9. Socio-economic benefits		
		9.a. Affordability (housing)	9.a. Affordable housing accessibility	Up: P, C
		9.b. Affordability (transport)	9.b. Portion of households' budgets needed to provide adequate transport (QN)	Down: P, C
		9.c. Social inclusion	9.c. Employment/income/education, etc. levels (QN/QL)	Up: P, C
		9.d. Socio-economic growth	9.d. Growth in output, employment, etc. (QN)	Up: P, C

Transport provision results in:	**Physical effects**	**Impacts**	**Examples of indicators**	**Expected direction of change for stakeholders**
Changes in land use accessibility and transport diversity	Dispersion of common destinations, and quality of travel options	10. Land use/ transportation accessibility	10. Quality of land use/transportation network accessibility (QN/QL)	Up: P, C
		11. Transport network effects		
			11.a. Reliability/quality of transport service (QN/QL)	Up: O, P
			11.b. Systems' operating cost (QN)	Down: O, P
Changes in travel activity	Per capita motor vehicle ownership and use	12. Consumer transport costs	12. Generalised travel cost (QN)	Down: P, C
		13. Accidents	13. Crash death and injuries/related economic costs (QN)	Down: P, C
		14. Energy and environmental impacts		
		14.a. Energy consumption	14.a. Total vehicle emissions (QN)	Down: P, I
		14.b. Air/noise pollution exposure	14.b. Ambient air quality/noise levels (QN/QL)	Down: P, C
		14.c. Climate change	14.c. Climate change emissions (CO_2, CH_4) (QN/QL)	Down: P, C
		14.d. Water pollution		Down: P, C

Note: P: policy-makers; C: wider community members; I: investors; LC: local community members; U: users; O: operators; QN: quantitative; QL: qualitative.
Source: Adopted from: Janic [96]; Litman [52].

Table 2.
Impacts of transport provision on land use.

4. Key base indicators for the cost-benefit applications

Based on the literature focusing on transport project and policy appraisals, this section reviews several key impacts and indicators which can be utilised for CBA applications in European countries. Scenario analysis—comprising a baseline scenario (reference scenario) which is compared with several alternative scenarios—can construct a base for the impact evaluation of public transport investments (e.g., rail-based transport). As a priority, two alternative scenarios can be defined: a baseline *business-as-usual* and alternative *with rail* scenarios. According to the baseline scenario, it is assumed that the urban area would continue to grow with the present trends and there would be only sufficient maintenance and renewal investments to maintain the existing infrastructure. Therefore, rail services in future years would be broadly comparable to the current level potentially leading to a more dispersed urban form. Considering the land development impacts of rapid rail investments, it can be expected that the *rail* scenario will generate more compact forms of urban development. By encouraging a transfer from private transport, rapid rail investments can assist in improving accessibility and land use change which supports compact and mixed developments (see Litman [52]).

The potential for efficiency and environmental impacts can be examined through the impacts and indicators specified in the previous sections. The economic appraisal process can be summarised in six stages (see **Table 3**). In accordance with the estimations from the transportation model specified for the study and the parameters/values specified for the capital costs, costs of accident, vehicle (and system) operation, public service provision, travel time and global and local air pollution, **Table 4** presents the related data requirements for the scenario analysis of baseline and *with rail* cases. Based on the impact evaluation data given in **Table 4**, some specific issues in impact-indicator valuation methods are then explained in the following sections.

4.1 Capital cost estimation of transport investments

A broad estimate of the capital costs for any public transport provisions is normally obtained at project initiation stage. These estimates are expressed in constant prices and are generally built up using unit cost data, expert advice and experience

1. Forecasting transportation demand with a transportation model consisting of:
    - Forecasts of future growth and land use change (population, employment, economic activity, income)
    - Assumptions of the supply side of transportation activities
    - Assumptions and scenarios for external conditions
    - Four-stage method: trip generation, trip distribution, modal split, network assignment
2. Quantifying, where possible, incremental costs and benefits relative to the baseline scenario
3. Identifying unquantifiable impacts
4. Adjusting quantified costs and benefits for:
    - Inflation
    - Relative price changes
    - Risk and optimism bias
5. Undertaking sensitivity analysis
6. Calculating the net present value

Adapted from: EC Final Report [8].

Table 3.
Stages of economic appraisal process for public transport investments.

Impacts/indicators	Impact evaluation data requirements of *with rail* vs. baseline scenario
1. Capital costs of transport infrastructure investment	Direct construction cost estimates include the following: land acquisition costs, railway infrastructure, stations, civil engineering works, operational systems, planning and design
2. Provision of public services	Future estimated numbers for new residential development (numbers of new housing units) in the case study area within the appraisal period specified for rapid rail investments
3. Accident rates/future accident risks	Three types of data are required: • The most recent data related to the number of personal fatalities, serious injury, and minor injury accidents along the catchment area of the newly proposed transport line • Estimated numbers for future accident risks from the national and local accident rates and trends • Quantification of changes in the number of fatalities, serious injuries, and slight injury accidents due to a rapid rail investment by using country specific risk functions
4. Change in road vehicle operation costs	For the calculation of the economic benefits (costs) associated with vehicle operating costs, two types of data are required: • Demand: the number of private vehicles (cars) making a particular origin-destination trip for the baseline scenario and the alternative *with rail* scenario (peak/off-peak traffic flow data for the baseline and alternative scenarios) • Vehicle kilometres: total change in vehicle kilometres from the local highway network for the baseline and *with rail* cases
5. Change in travel time	Estimates related to: • Travel time-change in travel time for private vehicles (cars) in peak/off-peak traffic for the baseline and *with rail* scenarios • Demand: peak/off-peak traffic flow data for the baseline and *with rail* cases
6. Public transport operating costs and revenues	• Expected operating pattern and service frequency of newly proposed rapid rail system • Key characteristics (route length, journey time, peak and off-peak headway, etc.)
7. Change in emissions	• Total change in greenhouse gas emissions (i.e., CO_2, in particular) and local air pollutants for the baseline and *with rail* cases.

Source: Authors' own research.

Table 4.
Impact evaluation data for rail-based infrastructure investments: with rail vs. a baseline scenario approach.

of similar projects in the past. Given the inherent uncertainty at this stage, a detailed risk analysis is necessary to reduce uncertainty around the expected infrastructure costs of transport projects. In the literature, there are examples showing that cost escalations are common in transport infrastructure projects, particularly in urban rail projects. Flyvbjerg et al. [101] showed that transport infrastructure projects worldwide experience large construction cost escalations; and among them, rail projects incur the highest cost escalation. The average cost escalation for rail projects is 44.7%, followed by fixed-link projects (bridges and tunnels) by 33.8% and road projects by 20.4% [101]. Practical methods for risk assessment and management in urban rail projects are provided in Flyvbjerg and COWI [102] where UK transport projects were grouped and evaluated. This research developed capital expenditure up-lifts for urban rail projects in the UK. Other studies in the US, for instance, have also found that the mean overrun of light rail transport projects is around 42% [103] while the mean value is more than 20% regarding rail projects in the US [104].

Based on this research, adjustments for capital cost bias should be added to the initial cost estimations in the countries where public transport projects (e.g., rail-based transport) are being constructed. However, a detailed risk analysis can also reduce the uncertainty in cost estimations, and therefore, the need for bias adjustments can be reduced. For EU countries other than the UK, HEATCO [105] (a EC 6th Framework Programme) suggests an average of 34% capital expenditure up-lift on original cost estimates for the rail projects based on the results in Flyvbjerg et al. [101] representing average cost escalations in Europe.

4.2 Valuation of traffic safety

It can be argued that any limited economic analysis underestimates the value of human life to family and society more generally. However, for the purpose of CBA evaluation of transport projects, this must be considered even if the approaches may be limited and contested. In the literature [105–107], some measure of the statistical value of human life (SVHL) is often used and has been determined using three methods: cost of restitution, human capital and stated preference approaches. The first method represents the direct costs generated by accidents. Human capital approach measures discounted loss of production due to injury or death of the individual member of the workforce while the last method is used for estimating willingness-to-pay (WTP) values of individuals indicating their preferences to reduce the risk of being injured or dying in an accident. The literature examining the methods for estimating the statistical value of life is vast. Some examples are Viscusi and Aldy [108]; Treich [109] and Woods et al. [110]. This literature critically reviews the existing methods utilised in a specific country or cross-country comparisons which were undertaken based on safety valuation considerations. It is shown that there is no single method used to determine the statistical value of human life, but a variety of methods have been used by different countries.

The literature points towards the WTP approach as being a widely used methodology in the EU. Considering this, Grant-Muller et al. [46] identify some factors which may contribute to the variations of WTP values across EU countries. These include: (1) income (per capita) variations among member countries influencing an individual's WTP values for safety; (2) cultural differences which have an impact on government attitudes and individual tastes and preferences for accident reduction measures; (3) inclusion or exclusion of some costs, that is, legal costs, and other public sector costs and (4) differences in the nature of the measurement methods used, that is, problems of bias in WTP measures. Based on the existence of these factors, HEATCO [105] suggests using the human capital measures and WTP studies carried out in the countries for which they are applied. Based on the existence of these factors, HEATCO [105] suggests using the human capital measures and WTP studies carried out in the countries for which they are applied. Considering the country-specific differences, another EC research project—UNITE—also sets recommendations which allow adjustments to EU countries of a common European set of values. EC [111] has provided updated accident costs for the EU countries which were initially provided by HEATCO [105] (**Table 5**).

Increasing values for future years is based on the estimation of a country-specific rate of growth in real GNP (or GDP) per person employed. HEATCO [105] recommended a default inter-temporal elasticity to GDP per capita growth of 1.0. In contrast to cross-sectional elasticity, inter-temporal elasticity to GDP considers underlying changes in individual preferences and technology over time. Further to

	Accident type		
	Fatality (Million €)	**Serious injury (Million €)**	**Slight injury (Million €)**
France	2.070	0.2892	0.0216
Germany	2.220	0.3071	0.0248
Ireland	2.412	0.3056	0.0233
Italy	1.916	0.2462	0.0188
The Netherlands	2.388	0.3164	0.0255
Poland	1.168	0.1567	0.0113

Source: (see) EC [111] for all EU country values.

Table 5.
Examples of EU values per casualty avoided (2010, purchasing power parity, market prices).

this, sensitivity testing with an income elasticity of 0.7 is suggested by HEATCO [105] if accident costs contribute a significant part of benefits in cost-benefit assessments. Bowland and Beghin [112] is an example of a meta-analysis based on contingent valuation studies examined in the literature. Their results show statistically significant income elasticities of 1.7 and 2.3. Viscusi and Aldy [108] carried out a comprehensive meta-analysis for the value of statistical life estimates throughout the world. Their results point to estimates of the income elasticity in the range of 0.5–0.6. Considering that the literature on the income elasticity of value of statistical life is controversial, country-specific values are recommended for the value of statistical life analysis. The cross-country differences in socio-economic factors, particularly variations in income, and the type of safety projects considered in a specific country can show considerable variations in the value for assessing risk. This raises the issue of development of a specific methodology by each country through utilisation of the related data and application of value of statistical life analysis.

4.3 Vehicle operation costs

4.3.1 Road vehicle operation costs

Vehicle operating cost savings are associated with user benefits indicating the shift of travel from private car to public transit. At a minimum, the shift from private car to public transport systems saves fuel and oil, which can be considered to have important impacts on energy consumption and environment pollution levels. In addition, there are costs of depreciation, insurance and parking which are affected from increasing car usage in the way that there are increases in repair and maintenance costs, reductions in vehicle resale value, increases in parking and traffic costs among others [113]. The unit vehicle operating costs are clearly dependent on the prices of goods within a region (i.e., price of oil, vehicle parts, etc.), the transport network characteristics and vehicle utilisation. However, operating cost relationships for road vehicles are more generic and transferable between countries [105]. There are generic models and computer software for the calculation of road vehicle operation costs in the absence of a local model. The Highway Design and Maintenance Standards Model (HDM) is an example of such a model which is recommended by HEATCO [105] and World Bank for both European and World Bank-funded transport projects. The HDM, developed by the World Bank, has been used for over two decades for the assessment of road investment programmes and analysis of road network strategies in many countries [114].

In the HDM, the costs to road users for a given country are represented as a function of vehicle fleet unit costs, utilisation and characteristics, and road characteristics [114]. The model provides annual estimates (for a given road strategy) such as the road condition and resources used for maintenance, the vehicle speeds, physical resource consumption of vehicles, individual vehicle operation cost components and total vehicle operation costs. Either consisting of all available road network data or use the road network aggregate data if detailed network data is unavailable. From this data set, a representative matrix of road classes is developed and utilised for the estimation of road vehicle operation costs. A considerable effort is needed to quantify the attributes of a road class, that is, the length, width, pavement type, climate zone type, geometry type, traffic composition, roughness, surface condition type, drain type and construction quality [114].

The road attributes, mostly based on aggregate data, can only be estimated through an expert judgement or can be obtained through statistical analysis of the data available in the road network database [114]. A further issue arises with the estimation of the network length when traffic load, road condition data and other road attributes are not collected by the same road agency unit or at the same time [114]. These are some issues of concern about the difficulties of the HDM applications in estimating an operating cost relationship for road vehicles. Following the estimation of parameters in maintenance and vehicle operation, unit costs and specified prices are applied to determine the maintenance and vehicle operation costs. In this respect, local relationships and prices are strictly recommended to be used for the calculation of vehicle operation costs [105].

HDM can be considered as a very useful tool for calculating the vehicle operation costs. HDM-III and HDM-4 are the later versions of the software which have been improved by adding new models for road deterioration and for operating costs of numerous vehicle types. These models predict the change in road roughness with respect to cumulative axle loads or maintenance actions by the road administration [115]. The estimation of vehicle operation costs requires both local data on vehicle ownership and repair costs and a generic relationship between road roughness and vehicle operating costs. This implies that both local models and default valued models are available and can be utilised in the HDM [114]. Some recent examples on the applications of HDM are Cutura et al. [116] and Perrotta et al. [117].

4.3.2 Public transport (e.g., rail) operating costs

Railway costs can be analysed as fixed and variable costs: fixed costs are incurred costs for operation, maintenance and replacement, which are independent of traffic volume changes. Variable costs, on the other hand, are those which depend on traffic volume. The elements of the costs for railways are specified by the World Bank [118] Infrastructure Reports (see **Table 6**). Unlike road vehicle operation costs, rail operating costs can be influenced by regulatory and institutional characteristics of the countries in which the rail system operates. Furthermore, physical characteristics of the rail network (depot locations, track alignment, etc.), operational characteristics and labour market conditions are all effectual in determining the operating costs [118]. Therefore, country-specific data and local relationships on rail operating costs will be the most appropriate to be utilised in operating cost estimations. The availability of such data will depend on the accounting practices within rail transport sector of each specific country.

It can be suggested that cost items given in **Table 4** can be calculated by directly assigning actual expenses to actual operations or through revenue analysis where revenue expenditures have changed historically with train operations [119]. Additionally, cross-sectional analysis of revenue accounts by train operations can be recommended

Cost type	
Vehicle ownership costs	
Locomotives/coaches	Replacement cost
Vehicle maintenance costs	
Locomotives/coaches	Unit cost/loco. Unit-km
	Unit cost/coach-km
	Unit cost/coach-year
Transportation costs	
Train fuel	Unit cost (gross tonne-km)
Train crew wages	Actual by cost centre
Locomotive crew wages	Actual by cost centre
Station operations	Unit cost/train-km
Billing	Unit cost/car load
Other	Unit cost/train-km

Source: Anderson [119], World Bank [118].

Table 6.
Elements of rail operating costs.

if there is geographical variation of accounts [118]. However, these analyses may not be appropriate in a situation where the cost base will be affected by the proposed transport investment. Examples for the latter case include ([118], p. 6): (a) the use of a new locomotive with unknown operating costs and reliability; (b) a considerable change in the level of service provision at the regional level (e.g., congestion effects may result in a requirement of new infrastructure with different utilisation rates) and (c) major policy reforms including privatisation or commercialisation of railways.

4.4 Value of time

There are two categories of time involved for valuing travel time savings of passengers including working and non-working trips. The former is related to commuting for working purposes while the latter comprises all other non-working activities such as retail and leisure. Travel time is evaluated by standard values of time for each vehicle category assuming a constant marginal unit value of time regardless of the time saved and the variance of income levels of individuals. The valuation is based on three sources: first, a cost-saving approach, which considers wage rates as a measure of productivity loss or gain by the labour force, is selected as a minimum approach for the valuation of work time savings [105]. Second, an alternative methodology proposed by Hensher [120] identifies work trips having two components: a business component (which assumes that not all travel time is unproductive) and a private component (assuming not all savings are transferred to extra work but any utilised for non-work purposes). An alternative approach is based on the idea of willingness-to-pay (WTP) which is used for the valuation of all non-work trips and the private component of work trips. Stated preference and revealed preference are the two methods used in WTP analyses for the purpose of generating a differentiated structure of values of time (for work and non-work activities).

The cost-saving approach is thus criticised as approach assumes no utility impact on transport users and that all travel time savings can be transferred to productive output [105]. Hensher's [120] approach, on the other hand, provides a more sophisticated assessment of work time savings by assuming that part of travel time is productive and there are utility impacts on workers as not all savings are transferred to extra work. As the latter approach is more comprehensive, such an approach can be preferred in the valuation of work time savings in the EU. However, the complexity of the analysis and data accessibility problems in some European countries limits the application of the Hensher's approach. A cost-saving approach is more practical; and there is evidence in the literature suggesting that the cost-saving approach is a reasonable approximation to the social value of work travel time savings [121]. Mackie et al. [122] claim that a cost-saving approach is reasonable for the estimation of commercial value of travel time. However, an appropriate estimation of social value requires an assumption of full employment of the relevant class of labour. In the case of widespread unemployment, there will be divergence between the commercial value of time savings to firms and the social value of time saving. Mackie et al. [122] recommend the use of a shadow price regarding this situation.

Given the above literature, the use of national values can be suggested for net average hourly wages for work time valuation, and for the non-work time valuation use, the values in national value of time studies published in the countries of interest. There are various countries that have already published national value of time studies including the Netherlands, Norway, Sweden, Finland and the UK [123]. There are issues of differences in the WTP analysis conducted in different countries. Mackie et al. [122] identified six key factors influencing individual's value of travel time savings. These include: journey time, characteristics of the journey (congested, free-flow or repetitive), journey purpose, journey length, mode of travel and size of the time saving. Correlations with personal characteristics are also required to be introduced to separate such impacts from the others. This approach is highly data intensive and a certain level of disaggregation is needed to carry out the choice experiments specified for any country. As an attempt to set a common guideline for the estimation of travel time savings in the EU countries, HEATCO [105] and Wardman et al. [124] identified a minimum disaggregation level for the calculation of travel time savings as well as the estimations which require local data or outcomes of research which can be transferred from some other sources. These studies specified national values for travel time savings by utilising meta-analysis models to estimate travel time values for each EU country. These are relevant for use in countries where there are no data and research conducted in the field of the value of travel time savings.

4.5 Environmental impacts

Global air pollution which is mainly caused by carbon emissions can be calculated by utilising the social cost of carbon approach. The social cost of carbon can be defined as the welfare loss due to an increase in carbon emissions [125]. Due to the uncertainty of future emissions and climate change, there is wide uncertainty among the SCC estimates. Kuik et al.'s [126] meta-analysis study is well known in the literature verifying this considerable variability across the SCC estimates (see also [127]). Following a review of some key studies on climate change, Tol [128] found a median estimate of €4 and a mean of €25 per tonne of carbon emitted. However, these estimates are conservative due to the fact that only damage which can be estimated with a reasonable certainty is included in the analysis and impacts such as extended floods and frequent hurricanes with higher energy density are excluded as there are data limitations explaining the possible relationships between global warming and these impacts (HEATCO D5, [105]).

Alternatively, HEATCO points to the research performed by Watkiss et al. [129] on the social costs of carbon. In this study, shadow price values for carbon are derived considering the future development expectations of damage and abatement costs of carbon. Damage costs were estimated on a general basis whereas abatement cost estimates are based on the UK Government's long-term goal of meeting a 60% CO_2 reduction in 2050. It is noted that the latter is consistent with the EU's target of limiting global warming to an increase of 2°C of the earth's average temperature above pre-industrial levels (HEATCO D5, [105]). This study is the most comprehensive exercise among others confirming the assumption that emissions in future years will have greater total impacts than emissions today, thereby stressing future increases in value estimates.

Local air pollution caused by road transportation is highly case specific since it has impacts on human health and the environment in local areas. The main pollutants (i.e., NO_2, SO_2, NMVOC, PM_{10} and $PM_{2.5}$) are directly related to the number of vehicles travelling on local roads, and therefore, the change in number of vehicles results in changes in concentrations of emissions in the affected areas. The country-specific estimated values which can be used in the absence of such research in any EU country were derived by using the methodology developed in the EU projects. The Impact Pathway Approach (IPA) is an example of the methodology which was developed for the environmental impact evaluation in the ExternE project series [130]. According to the IPA approach, a transport activity causes changes in concentrations of air pollutants, which have impacts on various receptors including human beings, materials or ecosystems. This results in direct and indirect impacts on the utility of affected persons. The valuation of these welfare changes follows the willingness-to-pay (WTP) or willingness-to-accept (WTA) approaches for the damages to human health. For materials or crops, market prices can be used directly to evaluate the damages. Concerning the health impacts, three components of welfare changes have been identified [130]. These are: (1) resource costs (i.e., medical costs); (2) opportunity costs (i.e., productivity losses) and (3) disutility. The first two components named as 'cost of illness' can be estimated by using market prices which are particularly case specific and require local data. The last component, on the other hand, implies a higher value than the cost of illness [105] and requires specific modelling to represent individual's loss of welfare.

In the ExternE projects (e.g., NEEDS project), country-specific impact and cost factors were calculated using the EcoSense software tool and impacts and resulting costs occurring in Europe were calculated for increasing the existing emissions of NOx, SO_2, $PM_{2.5}$ and NMVOC by 10% in each country [105, 131] (**Table 7**). Impacts and costs were compared to those calculated for the reference scenario, which implies that the difference between both scenarios is caused by the additional emissions. This methodology can be criticised on the basis that the estimates may not accurately represent local population density exposure and national vehicle fleet compositions. Therefore, a detailed case-specific exposure modelling can be provided where possible, taking into account the pollutant dispersion modelling and estimation of changes in the population's exposure to the related pollutants [105]. Concerning local air pollution assessment, trends in air pollution exposure are difficult to establish as software packages to measure repeated exposure are not yet available. Therefore, population-level estimates do not adequately represent extreme individual exposures [132]. There are differences in exposures since some people experience heavy traffic and influenced by higher level of pollutants than others. In addition to this, exposure to transport-related air pollution is difficult to separate from exposure to total air pollution [132]. These are some key difficulties in relation to developing a common methodology in the assessment of local air pollution across the EU countries. Country- and case-specific modelling is therefore essential for an appropriate estimation of impacts and resulting costs of local air pollution.

Like air pollution, noise pollution is also highly localised and area dependent and its measurement is difficult and expensive. In the context of rail-based transportation, noise nuisance is generally associated with network construction, depot activity

Country	NO_x	NMVOC	SO_2	$PM_{2.5}$		
				Rural	**Suburban**	**Urban**
France	13,052	1695	12,312	33,303	64,555	211,795
Germany	17,039	1858	14,516	48,583	73,221	222,461
Ireland	5688	1398	6959	16,512	47,420	194,660
Italy	10,824	1242	9875	24,562	50,121	197,361
Netherlands	11,574	2755	16,738	29,456	48,352	195,592
Poland	13,434	1678	14,435	47,491	74,215	221,455

Source: (see) EC [111] for all EU country values.

Table 7.
Examples of damage costs of main pollutants from transport, € per tonne, 2010.

and the noise of passing trains affecting adjacent properties. Where modal switch is significant, there may be significant implications for the change in the level of noise from road traffic, especially in the context of the number of cars in locally affected areas. Regarding noise pollution, there are two key issues of interest: first, compared to air pollution, noise pollution tends to have less severe effects on physical human health [133]. The second point of concern is the evidence showing that people tend to find noise from rail transportation less annoying than other modes of transportation [134]. The evaluation for noise pollution can be based on the number of people exposed to certain noise levels for the baseline and *with rail* scenarios. Some examples of noise exposure modelling can be seen in HEATCO and UNITE projects which utilised either WTP or Hedonic Price studies for the valuation of noise exposure (see also EC, [111]).

4.6 Public service provision costs

Public service provision costs are widely used as an indicator to demonstrate how costs of public service provision tend to increase with dispersion of urban activities. The literature has reached a consensus on this issue as there is growing body of research indicating that dispersed population expansion increases the costs of local public service provision [70, 135]. Research on increased density developments indicates such development tends to reduce per capita costs of providing public infrastructure and services [136]. Concerning land development impacts of rapid rail investments, building such infrastructure developments is generally accepted as preferable to an alternative to urban development that supports car-based travel [137]. The reason is that rapid rail developments can provide high-quality services in terms of reliability, speed, safety and reduced travel time, and can support higher density developments along the catchment area as required for the efficiency of rail service provision [136].

In order to represent land development impacts of rapid rail provisions, public service provision costs can be utilised as an indicator for the cost-benefit evaluation of each scenario indicating a negative cost impact of the automobile-oriented development in the baseline scenario compared to an urban form resulting from proposed rail investment and integrated land use/transport planning policies. Though this is not a commonly used indicator in the EU-wide transport project appraisals, the inclusion of this indicator in the CBA model is vital to represent possible benefits accrued to urban form resulting from rail transport investments and associated planning policies. Public service cost estimations are case specific and can be identified as the costs of road construction, housing and community facilities development, education, fire and police protection, water and electricity distribution, sewerage, and social and recreational facilities [136]. Unit public service costs can be computed where data are available on each of these different cost items.

Europe-wide research on a common assessment methodology concerning changes in public service provision costs stemming from a rail-based urban development and planning is limited. EC's project series such as ExternE [130] deal with a wide range of internal and external impacts of transport projects and policy changes in EU countries. However, research on land use impacts of major transport investments has not been fully covered. An EC [138] Report on Thematic Strategy on the Urban Environment Impact Assessment outlines integrated strategies for member states to the sustainable management of urban environment. In this report, the consideration of urban environment indicators relating to sustainable urban development and transportation systems were addressed for an integrated assessment and management of the urban environment across EU member states. There are European projects such as PROPOLIS and SCATTER focusing on the linkages between urban form and urban transport systems and the impacts of urban transport and land use policies. The outcomes of these projects contribute to the existing research on the issues of land use impacts of transport provisions in the European cities. However, case studies in these projects cover a limited number of urban areas and, therefore, more comprehensive analysis with wider European area coverage is needed. Therefore, this can be specified as a priority topic for future research considerations to develop a common assessment methodology for the subject indicator.

5. Cost-benefit evaluation

Given the methodological framework specified above for the assessment of key impacts and indicators, costs and benefits of rail investments can be calculated and assessed between two scenarios of baseline and *with rail* cases. The development of these scenarios is based on some European seminal sources highlighting scenario analysis as a tool to be used for the policy analysis in the EU [138]. As previously stated, a baseline scenario assumes that urban area would continue to grow with the present trends with sufficient maintenance and renewal investments to maintain existing infrastructure. A *with rail* scenario, on the other hand, consists of at least one new rail transport investment connected to the existing infrastructure in the area.

A general CBA approach implies that all costs and benefits are reduced to their present value and discounted at a standard rate over the pre-specified evaluation period through the formula given below:

$$ENPV = \sum_{t=0}^{n} a_t S_t = \frac{(b_0 - c_0)}{(1+r)^0} + \frac{(b_1 - c_1)}{(1+r)^1} + \ldots + \frac{(b_n - c_n)}{(1+r)^n} \tag{1}$$

where S_t is the balance of cash flow funds comprising flow of benefits b_t and flow of costs C_t; a_t is the discount factor; r is the discount rate and n is the evaluation period [8]. This is also used to produce a benefit-cost ratio (BCR) and internal rate of return (IRR). The former is the ratio of the discounted aggregate net benefits (i.e., benefits minus costs) to the discounted investment costs and the latter is the rate of discount equating discounted net benefits to discounted investment costs. There are differences among decision criteria used by different EU countries. Odgaard et al. [47] noted that all EU states, except Finland and Sweden, apply more than one decision rule for the CBA evaluation of a project. Among them, ENPV and BCR are the most widely used, which is followed by the IRR.

The social discount rates and project appraisal periods vary among countries reflecting the local variations in opportunity costs of capital, project risks and lifetimes of rapid rail investments. The UNITE project suggests the use of a European social discount rate of 3% while EC HEATCO suggests a rate of 5% (HEATCO D5, [105]). This implies the use of a range of discount rates between 3 and 5% in CBA. The use of a specific discount rate and an evaluation period depending on the characteristics of the project and the national assessment procedure is recommended for each specific country. In the absence of information regarding the evaluation period in national appraisal guidelines, the evaluation period of 40 years is suggested (as in HEATCO) as a default evaluation period (i.e., planning and construction period plus 40 years of operational period).

6. Conclusion

In conclusion, this research has reviewed literature and summarised the key methodological approaches in relation to cost-benefit analysis of transport investment projects and programmes used in the testing of various scenarios relating to urban form. The use of at least two different land development scenarios (such as *business-as-usual* and *with rail* cases) is required to allow the CBA process to be used in discussions of alternative development and investment decisions linked to urban form and development issues. Transformation from compact to more dispersed structures has significant implications on the urban environment and is generally associated with high social, economic and environmental costs. To address some of these problems, planning theory and practice have increased their focus on issues of sustainable urban development and urban growth management. In this context, the CBA approach is intended to allow for the development of an improved quantitative evidence base for decisions on infrastructure spending considering the potential costs and benefits of such an investment decision in comparison with alternative options and scenarios.

Regarding the selected inputs, we conclude that the issue of underestimation is a recurring feature of public transport projects, and based on the findings of literature, different averages of cost escalations can be added to national cost estimates based upon European average cost escalations. An issue highlighted in this paper is the potential transferability of the input data on vehicle operation costs between countries due to the existence of similarities in the operating cost relationships for road vehicles. Regarding national values for work and non-work travel time savings, we conclude that these can be identified through meta-analysis models in order to determine travel time values for the country of interest. Regarding values of traffic safety, the concept of inter-temporal elasticity to GDP has been introduced to estimate the future values. However, this issue seems to be less relevant considering the present economic climate of recession. An important conclusion relates to the area price impacts and wider economic benefits which are routinely not accounted for due to displacement issues despite their obvious importance. Considering environmental impacts, the use of carbon charges is suggested for the valuation, and environmental indicators can be estimated based on national labour cost data and inter-modal basis. Public service provision costs are more difficult to establish; however, it can be noted that evidence of utility provision costs provides useful data for the valuation of this input. **Table 8** summarises the main impacts and relative evaluation methods to be considered for the economic appraisal of transport infrastructure projects.

This chapter has reviewed and outlined key base indicators which can be utilised in a CBA methodology with information on data sources used in EU countries. Clearly, the methodology is adaptable in the sense that in specific states, other parameters that are crucial to any cost-benefit analyses can be added or removed. In this sense, this review suggests that the CBA methodology can produce a common set of base indicators which is sufficiently flexible to be adapted to country-specific contexts across the EU.

Impacts/indicators	Valuation methods
Travel time savings	• Stated preferences • Revealed preferences (multi-purpose household/business surveys) • Cost saving approach
Vehicle operation cost savings	• Market value
Operating costs of carriers	• Market value
Accident cost savings	• Stated preferences • Revealed preferences (hedonic wage method) • Human capital approach
Public service provision cost savings	• Market value
Costs savings: noise emissions	• WTP/WTA compensation • Hedonic price method
Cost savings: local air pollution	• Shadow price of air pollutants
Cost savings: GHG emissions	• Shadow price of GHG emissions

Source: EC [9].

Table 8.
Valuation methods of key impacts/indicators of public transport provisions.

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Conflict of interest

The authors declare no conflicts of interest.

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