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Transport cost-benefit analysis: critical evaluation and improvement

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ABSTRACT

Cost–benefit analysis (CBA) remains the dominant framework for the ex ante evaluation of transport policies and infrastructure investments, grounded in welfare economics and aimed at maximizing aggregate social welfare. However, a growing body of literature questions whether CBA adequately captures the multidimensional objectives of contemporary transport policy, including effectiveness, efficiency, and equity. This paper addresses this debate by systematically identifying and structuring criticisms of CBA in transport, drawing on a scoping review of 75 publications and insights from two expert workshops involving 16 specialists from multiple disciplines. The analysis categorizes criticisms into four groups: (1) fundamental limitations of CBA; (2) shortcomings in practical application; (3) issues related to debatable policy questions; and (4) decision-making challenges. Building on these insights, the paper discusses potential avenues for improvement, including better integration of distributional and accessibility effects, refinement of valuation methods, and alternative approaches. The results suggest that many shortcomings attributed to CBA stem from how it is applied within policy processes. The continued use of CBA in transport policy contexts requires an understanding of inherent weaknesses, their improvement, and appropriate use.

1. Introduction

Cost-benefit analysis (CBA) is a dominant framework for the ex ante evaluation of public investments, including transport infrastructure (Annema et al., 2017; Hutton, 2013). A CBA quantifies all (relevant) effects and expresses them in monetary terms and finally presents the results in overarching indicators like the benefit-cost ratio, or benefits minus costs. Most price tags are based on consumer preferences, price tags for CO_2-emissions being the main exemption (these are generally derived from policy goals). Grounded in welfare economics, CBA aims to help decision-makers to maximize aggregate social welfare by monetizing and comparing the costs and benefits of investments and other policy options. In practice, it is widely applied in transport, where infrastructure investments are evaluated. Increasingly, the aim is to include as many as possible relevant effects, including project costs (building, maintaining), the value of travel time savings, operating cost, safety and environmental impacts (Daniels et al., 2019; European Commission, 2019; Rotaris et al., 2010).

There is an ongoing debate regarding the adequacy of cost–benefit analysis (CBA) as the dominant evaluation framework for transport policies and infrastructure investments. While CBA has long been used to support decision-making in the transport sector, a growing body of literature has raised questions about its limitations and the extent to which it adequately captures the diverse objectives of contemporary transport policy (e.g., Gössling, 2013; van Goeverden, 2022). This has led to increasing interest in whether improvements to CBA are possible, or whether alternative or complementary evaluation frameworks might provide more suitable support for policy assessments.

Against this background, there remains a need to systematically review and structure the various criticisms of CBA that have been raised in both academic literature and professional practice. This paper aims to contribute to filling this gap by providing an overview of critiques identified in the literature as well as those expressed by professional experts in the field – the latter based on the assumption that experts have

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practical experience and consequently can add criticisms that would add to the literature, or that could help to understand the criticisms found in literature better. More specifically, the paper aims to answer next questions:

1. Which criticisms on CBA applied to candidate transport policies can be found in the literature?
2. Which additional insights with respect to these criticisms do experts in the area provide?
3. How can the criticism be categorized?
4. Which solutions would reduce the negative impacts of these criticisms?

Note that we are not so much interested in the distinction between the first two questions, but in the list of criticisms that results from both literature and experts.

Rather than presenting a new evaluative framework, this study is an exploratory study, and the paper seeks to map and organize these criticisms in order to better understand where weaknesses arise and which aspects of evaluation they relate to. More specifically, the organization of criticisms allows for a structured discussion on 'solutions' for the weaknesses, ranging from inherent weaknesses of CBA, reductionist[1] applications in transport practice, or debatable policy questions to be evaluated making use of a CBA. The novelty of the paper consequently is first of all in combining a systematic literature review with opinions and experiences of experts in the area, secondly in the categorization of criticisms, and thirdly in presenting solutions for all criticisms.

The criticisms should not necessarily be interpreted as the authors' own position, nor does the paper aim to provide a balanced assessment of the strengths and weaknesses of CBA. In particular, it does not systematically review the advantages of CBA, and it does not arrive at an overall verdict on whether CBA should or should not be used in specific decision-making contexts. Rather, the goal is to critically assess the use of CBA against criteria for 'good' transport policies (see following section), and to discuss possible solutions.

2. Theoretical framework: 'Good' transport policies

A central normative question underlying this paper concerns what constitutes a 'good' transport policy. While different traditions emphasize different policy objectives, there is considerable agreement that transport policies should satisfy several fundamental criteria related to societal welfare and public decision-making. Among the most widely cited criteria are effectiveness, efficiency, and fairness (or equity) (Anderson, 1985; Young and Tilley, 2006; Van Wee, 2026). Van Wee (2025) notes that these three criteria are broadly recognized in the policy analysis literature as key elements of good policy-making, although they may not be sufficient on their own to fully assess transport interventions, adding that ease of implementation, a positive balance of benefits minus costs, flexibility, and long-term robustness also need to be considered.

Effectiveness refers to the extent to which a policy achieves its intended objectives. In the context of transport policy, this means evaluating whether an intervention actually delivers the outcomes it is designed to produce, such as improving accessibility, decreasing emissions, or enhancing safety. For example, if a policy aims to reduce environmental impacts through modal shift, effectiveness concerns whether the measure indeed leads to a measurable reduction in environmental pressures. Importantly, effectiveness involves not only the presence of an effect of a policy intervention, but also the magnitude of the effect, as different policy instruments may vary significantly in their ability to achieve policy goals (van Wee, 2025).

Efficiency concerns the relationship between the resources used and the benefits generated by a policy. In public policy analysis, efficiency is commonly interpreted in economic terms, referring to the maximization of social welfare given limited resources, or in terms of cost-effectiveness. An efficient policy is consequently one that produces the greatest possible benefits relative to the resources invested, or that achieves policy objectives at the lowest possible cost. Within transport policy, efficiency is often defined in terms of cost-effectiveness, for example: the cost to save one life due to improved safety, to reduce a ton of CO_2 emissions, or to save a certain level of travel time reductions (van Wee, 2025).

Fairness, often also referred to as equity in the transport literature, is widely recognized as a fundamental normative criterion for transport policy. A dominant aspect of equity concerns the distribution of benefits and costs across individuals, social groups, or geographical areas. Policies that are efficient overall may nevertheless produce unequal or socially undesirable distributions of impacts. Equity issues arise in many areas of transport policy, such as accessibility changes, environmental exposure, and safety risks. For instance, transport investments may disproportionately benefit certain regions or income groups, while others may bear a greater share of negative impacts. As a result, evaluating the distributional implications of policies has become an important component of transport appraisal (Golub and Martens, 2014; Martens, 2006).

These criteria can be applied to (almost) all candidate transport policy options and dominant effects (outcomes of interest): *accessibility* (the reachability of desired services); *environmental impacts*, *safety*, *health* (public health); and *quality of life* (urban livability and well-being) (Abelson, 2020; de Rus et al., 2022; Gascon et al., 2015; Golub and Martens, 2014; Hutton, 2013; Lucas et al., 2016; Martens, 2006; Nieuwenhuijsen, 2020).

Accessibility, often defined as the ability of individuals to reach desired goods, services, activities, and destinations, is widely regarded as a central goal of transport policy (Geurs and van Wee, 2004; van Wee and Geurs, 2011). In contrast to traditional transport planning approaches that focus on mobility (i.e., the movement of people or vehicles), an accessibility perspective emphasizes the extent to which transport and land-use systems enable participation in economic and social activities. Accessibility depends on several interrelated factors, including the spatial distribution of activities, the performance of transport networks, travel cost, and individual characteristics such as income, physical ability, and time constraints. Improving accessibility can involve not only investments in transport infrastructure but also, amongst others, land-use planning, changes in digital accessibility (Geurs and van Wee, 2004).

Transport systems have *environmental impacts*, ranging from climate change (mainly due to CO_2-emission, a global problem), via acidification (a regional problem), to polluting emissions and noise (local problems). These impacts strongly vary by mode (walking, cycling, motorized two-wheelers, micro mobility modes, car, public transport, aircraft, lorries see going ships, barge, rail goods transport, pipelines).

Safety is another important effect of transport system and is generally expressed in numbers of fatalities and injuries. Road transport by far dominates these numbers. Safety effects depend on the occurrence of collisions, the severity of collisions, the question of who is involved (for example, older people are more vulnerable than younger people) and the quality of the health system (for example, how soon after an incident are people treated by the health system, and with which quality).

Transport systems also have significant implications for *public health*, both through direct and indirect pathways (Glazener et al., 2021). One of the most widely studied mechanisms is the impact of transport-related air pollution, including emissions of particulate matter and nitrogen oxides from road traffic. Exposure to such pollutants has been linked to a

[1] "Reductionist" is here used in the sense of reducing a complex societal phenomenon om such a way that related policy questions do not cover all relevant aspects, or of applying an evaluation method that does not provide all relevant information about the expected impacts of a related policy intervention.

range of adverse health outcomes, including respiratory and cardiovascular diseases. Transport policies can influence public health by reducing harmful emissions, for example through modal shifts toward public transport, cycling, and walking, the adoption of cleaner vehicle technologies, or traffic management measures that reduce congestion and emissions (Khreis et al., 2023). In addition to air pollution, transport systems affect health through other channels such as traffic safety, noise exposure, and physical activity. Policies that promote active modes of transport, such as walking and cycling, may generate additional health benefits by increasing daily physical activity levels (Nieuwenhuijsen et al., 2016; Nieuwenhuijsen, 2020).

Lastly, transport systems affect *quality of life/wellbeing and urban liveability*. Transport infrastructure and traffic conditions shape the physical and social environment of cities, and transport policies that reduce car dependency and promote sustainable modes can enhance urban environments not only by improving air quality and reducing noise, but also by freeing space for public uses such as green areas, pedestrian zones, and social interaction. Quality of life considerations therefore extend beyond traditional transport performance metrics and involve broader societal and environmental outcomes. In recent years, these considerations have become increasingly central to policy discussions on sustainable mobility and urban development, reflecting growing recognition that transport systems play a key role in shaping the overall livability of cities.

Note that there is overlap between some of these effects. For example, health effects partly depend on environmental effects (pollution) and safety effects. And quality of life depends, amongst others, on health and accessibility effects. Risks of double counting need to be considered, because overlapping effects should be counted only once.

Taken together, these criteria highlight that assessing transport policies requires a multidimensional perspective. While economic appraisal tools often focus primarily on efficiency, broader policy evaluation frameworks increasingly aim to incorporate effectiveness, equity, and other governance-related criteria. This broader perspective is particularly relevant in contemporary debates on the role and limitations of traditional appraisal approaches such as cost–benefit analysis.

3. Methodology

This study adopts a multi-step exploratory, qualitative research design. The approach combines a scoping review of the literature with expert input, allowing the analysis to identify both well-established academic critiques and concerns emerging from professional practice. Criticisms are categorized, expert perspectives captured in a series of workshops.

3.1. Literature review

The aim of the literature review was to obtain an overview of criticisms on CBA addressed in the literature. It follows the methodological principles of a scoping review, as outlined by Arksey and O'Malley (2005). Scoping reviews are particularly suited to mapping broad research areas where concepts are heterogeneous, and evidence is distributed across different academic fields. Rather than aiming to produce a comprehensive systematic review of all publications on CBA, the objective is to identify, map, and synthesize the main strands of critique directed at transport-related CBA. Consequently, only selected representative references are cited to underpin each criticism.

The review process consists of several steps (Arksey and O'Malley, 2005). First, the research objectives and guiding questions were defined (see introduction), focusing on identifying the types of criticisms raised regarding the use of CBA in transport policy evaluation.

Second, a search protocol was developed to define the search strategy, including the selection of databases, search terms, and screening criteria. The search relied on Google Scholar, a platform that indexes a broad range of sources across disciplines and has a high recall rate that makes it effective for exploratory searches. Google Scholar is also known to include documents not covered by Scopus or Web of Science and was for this reason considered the most comprehensive database. The search focused on publications available up to September 2025.

A combination of keywords was used to capture literature discussing both CBA and its critiques in a transport context. Core search terms included combinations of "cost-benefit analysis" OR "CBA" AND "transport" OR "transportation"; "cost-benefit analysis" OR "CBA" AND "evaluation" OR "appraisal"; "cost-benefit analysis" OR "CBA" AND "critique" OR "criticism" OR "limitations" OR "challenges".

The initial search focused on publications with relevance for this research, i.e. only including references that included a critique of CBA or highlighted its limitations. This yielded more than 100 references, which were subsequently screened more closely based on relevance to the research objectives. Publications were included if they explicitly discussed methodological, conceptual, or practical critiques of CBA in transport policy and transport infrastructure evaluation. Studies focusing exclusively on technical modelling aspects without broader evaluative discussion were excluded, unless they raised broader methodological concerns about the use of CBA. Both conceptual and empirical papers were considered. This yielded a total of 75 publications, including peer-reviewed journal articles and selected policy-oriented reports such as DfT, 2024, CE Delft (2019), NZTA, 2021. Iterative searches and related references known to the authors added to the literature search and selection process.

3.2. Expert input

To complement the literature review, insights from a group of 16 invited transport experts were considered. We selected experts with experience in the area of the application of CBA in practice, to complement the literature which has a focus on academic contributions. The background for this was the EU-funded Urban Burden of Disease (UBD) Policy project (January 2023 to December 2026), with the aim to estimate the health and socioeconomic costs and benefits of changes in air quality, noise, lack of urban green spaces, heat and temperature, physical activity, inequity for nearly 1000 European cities in the EU. Transport, as an important source of related costs, as well as CBA as the dominant approach to assessing these costs, is an important area of investigation. Transport CBA was for this reason considered in two workshops, 'Cost-benefit analyses in transport: applications and developments' (9 April 2024, online) and 'Critical perspectives on CBA – and ways forward' (3 December 2024, online). Participants to both workshops included UBD Policy members as well as invited speakers and experts. While the two facilitated workshops provided the basis for a structured expert elicitation to generate novel perspectives across disciplinary boundaries - including welfare economics, public policy, urban planning, critical geography, and environmental justice -, discussions between experts continued even after the workshops.

Invited experts were identified on the basis of their contributions to transport CBA, i.e. through searches on the Internet for highly cited papers and subsequently contacted and asked for participation. Within the field of transport studies, these experts have very different backgrounds, including economics, transport planning, civil engineering, public health, or spatial planning. The nature of the process implies that most of the experts are European (Belgium, Germany, Spain, The Netherlands, UK) or North American (Canada, USA) academics. Two individuals (Canada, The Netherlands) are academics but predominantly work as consultants.

The first of the workshops, "Cost-benefit Analyses in Transport: Applications and Developments" focused on how CBA is used across different domains (social, health, environmental, regulatory) and its methodological challenges. It specifically addressed persistent uncertainties in CBA practice (e.g., unit costs for safety, travel time valuation, indirect outcomes). The second workshop, "Critical Perspectives on CBA – and Ways Forward" brought together researchers and external

experts to critically assess traditional transport CBA practices. Key topics included discounting practices in the context of climate and pollution impacts, and whether CBA should primarily be applied in contexts already prioritizing accessibility, health, and livability.

Specifically, experts were asked to reflect on their experiences with transport appraisal and to identify perceived limitations or challenges associated with the use of CBA. In some cases, expert perspectives reinforced critiques already identified in the literature, while in others they highlighted additional concerns or provided further nuance to existing debates. Discussions and viewpoints were collected by one of the authors (workshop notes, videoconference chat screenshots).

3.3. Analysis

By combining the scoping review with expert insights, the methodology aims to provide a broad and structured overview of critiques of transport CBA, capturing both established academic debates and perspectives emerging from professional practice.

Identified publications (scoping review) were analyzed using a thematic analysis approach. Each publication was reviewed to identify the specific critiques raised regarding the application of CBA in transport policy. These critiques were grouped into broader categories reflecting recurring themes in the literature. For the categorization we used a hybrid methodology. First, the full list of criticisms was based on inductive coding by one of the authors and validated by the other authors. Specifically, the identification of CBA frameworks in use in different countries and their categorization was proposed by one of the authors and checked/validated by all contributors. Secondly, for the four main categories, a distinction between 'fundamental CBA problems' and 'practical application shortcomings' is meaningful - if open for debate -, and has been earlier made by Van Wee (2011). Thirdly, the two other categories, 'debatable policy questions' and 'debatable decision making' was made inductively based on the uncategorized list of criticisms. The categorization was proposed by one of the authors and checked/validated by the others.

In a consecutive step, expert input was considered, based on an analysis of the workshop notes and videoconference screenshots. These were checked against the literature, and novel perspectives added. Many issues highlighted in the literature were reiterated by experts. Controversial opinions on issues such as the value of travel time reflected on the subjective nature of some aspects, and the difficulty to present a generally acceptable or 'validated' transport CBA. Participants first presented and discussed their respective views and the evidence underlying them. Areas of agreement and disagreement were then identified and considered in turn. Where differences in assessment remained, the relevant arguments and available evidence were weighed collectively, with the aim of identifying a position that could be supported by the participants. Consensus was considered to have been reached when no participant raised a substantive objection to the resulting formulation. The results section combines the literature review with the expert insights, based on iterative rounds of discussion between the authors of this paper. This provides a basis for an improvement of CBA use in transport policymaking. Results refer to the literature where they are substantiated by references; otherwise, they draw on expert input, which is often additionally highlighted.

4. Results

The findings from the literature review and expert elicitation, summarized in Table 1, point to four categories of problems: fundamental issues with CBA, shortcomings in its practical application, debatable policy questions, and challenges related to decision-making. Problems related to practice and policy questions appear to be the most prominent; all are discussed in more detail in subsequent sections.

These four categories match the four core stages of policy making, evaluation and decision making. In the first step policy questions are formulated and consequently criticism on which questions are formulated is possible ("Formulate policy questions", Fig. 1). Secondly, since ex ante evaluations of candidate policies make use of frameworks, a choice for which framework to apply needs to be made ("Select evaluation framework", Fig. 1). Fundamental CBA problems, the first category, may result in not choosing a CBA rather than an alternative, for example Multi-Criteria Analysis (MCA). Thirdly, if it is decided to employ the CBA framework, several other criticisms emerge (Table 1). Finally, a decision needs to be made, and part of the criticisms identified

Table 1
Criticisms on CBA as found in literature and the workshops.

Category	Aspect	Origin[a]
Fundamental CBA problems	Fundamental problems with monetizing effects	ML
	The neglect of distribution effects	ME
	Neglect of wider ethical aspects	L/E
	Fundamental problems with the estimation of travel time savingsand related implications	L/E
Practical application shortcomings	Biases in transport models used - general	ML
	No LUTI model used whereas land use changes can be expected	ML
	Accessibility effects are largely ignored	L/E
	Practical problems with monetizing effects	ML
	High discount rates or no differentiation in discounting based on the type of effects	ML
	Some effects are missing	ME
	Debatable value of travel time savings	L/E
	Unclear if positive utility of travel is correctly dealt with	L/E
	Optimism bias with respect to cost and benefit estimates	ML
	Biased effect estimates if cause - effect relationships are non-linear	ME
Debatable policy question(s)	Systemic blindness/projects/policies considered in isolation	ME
	Alternatives not or too limitedly considered	L/E
	Preference for easy to implement policies	ML
	Avoidance of controversial policies	ME
	No explicit check on policy goals	ME
	Equity concerns ignored	ML
	Planning overlooks important trends	ML
	Data availability leads to prioritizing roads	ME
Decision-making	Debatable decisions, at least partly due to making use of CBA	ME

[a] ML: Critique mainly derived from the literature; ME: Critique mainly derived from experts; L/E: Critique derived from both literature and experts.

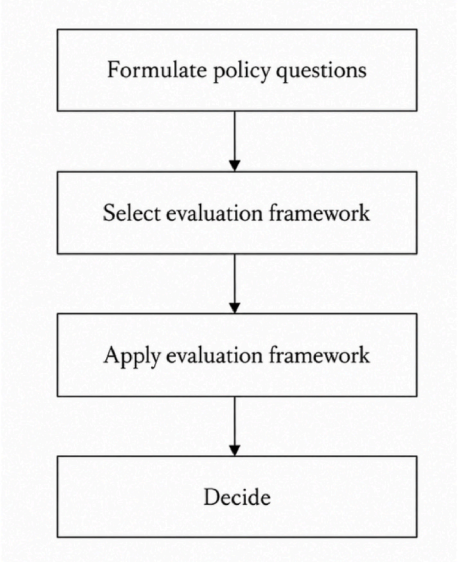

Fig. 1. process flow of the use of CBA for ex ante evaluations and decision making of candidate policy measures.

relate to this category ("Decide", Fig. 1).

We realize that in practice, the process is not always as linear as Fig. 1 suggests. For example, outcomes of evaluations can lead to reformulations of policy questions. And we also realize that decision making is not only based on the outcomes of ex ante evaluations. Mouter (2021) even concludes that political decisions are not statistically significantly related with monetized effect estimations in CBA studies. Note that the order of the categories of criticisms in Table 1 and Fig. 1 differ. In Table 1 we first present the two main categories of CBA related criticisms, which are related to the middle two categories of Fig. 1. This has been done to start the discussion with the core criticisms.

4.1. Fundamental problems with monetizing effects

CBA monetizes as many effects as reasonably possible by making use of the idea that consumers are sovereign and that price tags can be derived based on their choices and preferences – which may change over time. A first category of criticism is that this assumption of monetizing welfare effects should be rejected. The strongest variant of this criticism suggests that monetization is reductionist per definition, as the value of a human life is incommensurable, while the integrity of ecosystems is a basis for human survival and its value ultimately infinite (for instance, Costanza et al., 1997).

A second criticism is the flavor of technical neutrality which obscures the normative assumptions underlying valuation methods (Anderson, 1995; Nyborg, 2014; Turner, 1979). Mouter et al. (2021) developed a methodology called Participatory Value Evaluation (PVE) which ask respondents to make decisions as if they would be policy makers, a perspective that can be labelled as 'respondents as citizens', not 'respondents as consumers'. Individuals weigh travel time savings and safety differently when making personal travel decisions compared to when they assess such trade-offs in their role as citizens (Mouter et al., 2018).

4.2. Fundamental problems with the estimation of travel time savings and related implications

Below we present practical problems with the estimation of travel time savings. A more fundamental challenge of travel time savings is systemic. The question is whether 'saved' travel time implies an overall reduction in the time spent travelling, or if higher speeds will increase travel distances (Metz, 2008; Yan, 2021; Boussauw, 2023). Van Goeverden (2022) shows that time "saved" is likely to translate in additional travel, as on aggregate levels, people seem to spend a given amount of their total time on travel. This was originally proposed more than 50 years ago (for example, Zahavi, 1974) and shown statistically by many studies (such as Schafer and Victor, 2000), though considerable differences may exist between individuals (Mokhtarian and Chen, 2004). New roads that reduce travel times (faster road types, mainly motorways; roads that decrease distances between places; or expanding road capacity to reduce congestion) for this reason increase traffic volumes, and to not or limitedly lead to an overall reduction in time spent travelling (Duranton and Turner, 2011). Related: such new roads (or railroads) often lead to land development in the form of urban sprawl (Avin et al., 2025), effects that are generally ignored in transport models – see below. CBA addresses the value people attach to this additional travel by the 'rule of half': induced travel should be valued at half of the travel time gains that induce this additional travel. This approach implies that induced travel generates additional welfare gains equal to half the generalized cost reduction for new users. Experts did not reach agreement whether this rule adequately addresses travel time monetarization outcomes.

Where speed is over-valued, this has consequences for transport systems, as faster modes are favored in transport planning over slower but more affordable, inclusive and resource-efficient modes; mobility over accessibility; and sprawl over compact development (Martens and Di Ciommo, 2017). Should travel time be tiered to favor specific groups in society, as suggested by Sieg (2024), this will also undermine principles of equity in traffic, ultimately creating transport systems favoring individual, motorized transport at the expense of already marginalized population groups. Some experts note that ignoring these interrelationships can bias CBA, as congestion reduction benefits can be exaggerated as these are often short-term. Within a few years after roads are expanded congestion usually returns to previous levels. Furthermore, external costs including downstream congestion (for instance in cities), road and parking facility costs, crashes and pollution emissions can increase.

We now continue discussing practical problems related to applying CBA. We start with three problems that are related to the fundamental problem related to travel time savings discussed above.

4.3. Biases in transport models used - general

Travel demand models that provide CBA inputs are often biased in ways that lead to overvaluing roadway expansions and undervalue the benefits of other modes and transport demand management incentives. For example, models tend to be well calibrated for travel speeds and travel time savings but not for convenience and comfort, reliability and resilience, which underestimates the travel impacts and benefits provided by active mode improvements, more comfortable transit, and better network integration (Rodier et al., 2002).

4.4. No LUTI model used whereas land use changes can be expected

Next, as made clear above, land use changes can result from transport infrastructure expansions and related reduction in travel times. Land use changes are ignored in conventional land transport models, a criticism addressed by the experts. If land use changes can be expected, a LUTI (Land Use Transport Interaction) model is usually – but often not – used.

4.5. Accessibility effects are largely ignored

Above we discussed fundamental problems with the estimation of travel time savings. While increasing speeds is an important part of many transport projects, the sometimes resulting urban sprawl can lead to a decline in accessibility for important travel purposes, such as shopping (van Goeverden, 2022). And it can also result in a change (often: a decline) in equity of accessibility. Ignoring these effects may lead to narrowly calculated effects. A focus on accessibility is thus often more relevant, specifically in urban contexts, and including children or older population groups. The goal of most travel is to access services and activities (Levinson and King, 2020). It has for this reason been argued that planning should evaluate transport performance based on accessibility (Martens, 2016; Handy, 2020), recognizing benefits provided by slower but affordable and resource-efficient modes, better transport connectivity, and compact development (Table 2).

Shifting from mobility-to accessibility-focused policy questions (and the ex ante evaluation of such policy options) will affect CBA results, as roadway expansion benefits decline while the value of multimodal planning, improved transport network connectivity, or transport demand management incentives increase (EPMM, 2025; ITF, 2019). Consumer surveys and real estate markets indicate significant latent demand for accessible multimodal communities (NAR, 2023).

4.6. Practical problems with monetizing effects

A first category of practical criticism related to monetizing effects are practical problems with monetizing effects, frequently mentioned in the workshops as well as literature, The criticisms relate to the specific data and methods used to derive price tags, leading, for example, to the undervaluation of quality-of-life considerations, despite their direct

Table 2
Factors affecting accessibility.

Accessibility Factor	Description	Current Consideration in CBA
Mobility (vehicle traffic conditions)	Motor vehicle traffic speed, delay, safety, operating costs and parking convenience.	Generally considered. These are usually the main impacts considered in CBA.
Multi-mobility (non-auto travel conditions)	Quality of walking, bicycling, taxi/ride-hailing and public transit.	Some CBAs consider transit speed, but other factors are generally ignored.
Transport demand management	Policies that favor higher-value trips and more efficient modes.	Some CBA consider some TDM strategies.
Mobility substitutes	Telecommunications and delivery services that substitute for physical travel.	Seldom considered in transport planning.
Network connectivity	Path and road densities, and connections between modes.	Only considered if traffic speeds increase; other factors are often ignored.
Proximity	Distances between destinations and therefore development density and mix.	Transport CBA seldom evaluates the costs of sprawl or Smart Growth policy benefits.
Affordability	Transport costs relative to incomes, and the quality of affordable modes.	Often limited to vehicle operating costs and transit fares.
Convenience	Quality of user information, payment systems and connections.	Sometimes considered for individual modes, but seldom comprehensive.

Source: Levinson and King (2020).

influence on other aspects, such as health outcomes and urban well-being (Gascon et al., 2015; Hickman and Dean, 2018; Hwang, 2016; Mouter et al., 2019). Monetary comparison also means to compare potentially contradictory goals, such as higher speeds entailing an increase in the number of traffic deaths (Gössling et al., 2024).

4.7. The neglect of distribution effects

CBA typically relies on efficiency, focusing on aggregate net benefits while disregarding how costs and benefits are distributed. Distributions can relate to (groups) of people, such as by income or car ownership level, but also by location (areas or area types) (for example, Van Wee, 2011). But equity or fairness is only included in a CBA if one supports a utilitarian view on fairness. Other ethical principles are ignored, and the utilitarian perspective can conflict with other principles of equity and distributive justice (Boardman et al., 2022; Martinez-Alier et al., 1998).

4.8. Neglect of wider ethical concerns

Although equity-related criticisms often focus on distributions, not all ethical concerns are distributional (Van Wee, 2011). Other critiques include the obligation to keep promises - for example, when a national government commits to a transport infrastructure project, it should follow through or provide compensation. CBA is also criticized as undemocratic, as the principle of "one person, one vote" does not apply; individuals with greater financial resources exert more influence on outcomes. Additionally, not only outcomes but also the evaluation process itself matters, as stakeholders may value participation in problem definition and the selection of alternatives. Such non-distributional concerns are typically not addressed by CBA. Whether this constitutes a valid criticism lies beyond the scope of this paper, as these ethical issues may fall outside the remit of CBA or similar evaluation methods.

The first two categories of valuation problems, along with the neglect of distributional and other ethical concerns, are considered fundamental issues of CBA. More practical criticisms are discussed next, noting that some valuation problems also have practical dimensions.

4.9. High discount rates or no differentiation in discounting based on the type of effects

People generally prefer 'now' over 'later'. For example, most people prefer to receive an amount of money now over, say, the same amount of money (corrected for inflation) in ten years. Politicians and companies have similar preferences. The discount rate, a kind of interest rate, expresses this preference. The choice of discount rate profoundly shapes outcomes, often biasing decisions against long-term environmental protection and future generations (Stern, 2008). High market-based discount rates can render climate mitigation or biodiversity protection economically unattractive, despite their systemic importance (Dasgupta, 2024). This temporal bias is particularly problematic in addressing irreversible or catastrophic risks, or the rights of future generations. For example, there is a trend towards the use of lower discount rates in climate change contexts (Tol, 2023), indicating that high discount rates have distorted CBA in the past. Discounting is also a standard practice in transport CBA (e.g. European Handbook on the External Costs of Transport, European Commission, 2019), often using comparably high discount rates at 3% and higher (European Union, 2021).

4.10. Some effects are missing

A CBA should consider all relevant outcomes. To follow up on this expert notion, a comparative analysis of current CBA frameworks was carried out (Table 3), suggesting that important cost dimensions are often overlooked in transport contexts. There is also a focus on social costs. Private costs should also be included in a CBA, but in several cases not all private costs are included in practice, examples being vehicle ownership or parking costs, which are substantial (Gössling et al., 2022). CBA outcomes are also heavily influenced by travel time, which is the major benefit associated with infrastructure projects (Gössling et al., 2024). This suggests that CBA is often applied in ways that are too narrow.

4.11. Debatable value of travel time savings

Travel time is considered an opportunity cost, as the time spent travelling prevents people from engaging in other activities. The value of travel time is supported by evidence that travellers are willing to pay money to save time, for example by choosing (faster) toll roads as opposed to other roads leading to longer travel times. People are willing to pay more to reduce commuting times than travel times for social and recreational trips. For business travellers, travel time affects productivity. Longer commutes are also associated with lower life satisfaction (Clark et al., 2020). There is consequently a long-standing consensus in transport economics that travel time negatively affects welfare, making travel time a relevant category for investments. Nevertheless, the way travel time savings are monetized has been criticized (van Goeverden, 2022). Conventional transport planning often assumes that speed provides proportional travel time savings, which are valued at 30-60% of wages for personal travel and far more for business travel (Wardman et al., 2016). Even where travel time savings are valued at moderate cost levels, this implies that this parameter will usually dominate CBA outcomes (Gössling et al., 2024).

4.12. Unclear if positive utility of travel is correctly dealt with

Many travellers also derive positive utility from travel (Mokhtarian and Salomon, 2001) to separate home from work, to pass time, for the excitement of driving fast, to have time alone or with family, or as an act of rebellion (Gössling, 2017). Commuters often favor slower transport, such as bicycling, for safety and health reasons – even where this implies detours (Broach et al., 2012; Menghini et al., 2010). For many drivers, productive time could also be maximized by choosing alternative modes such as trains, which allow them to do work while travelling. This

Table 3
Scope of impacts considered in CBA frameworks.

Impacts	ATAP, 2020	CE Delft (2019)	DfT, 2024	European Commission (2014)	Litman (2025)	Swiss Federal Office for Spatial Development (2021)	U.S. DoT, 2022	NZTA, 2020
Usually Considered								
Public infrastructure costs	M		M		M		M	M
Construction externalities	Q	Q	M	Q	D	Q	D	M
Travel speed and delay	M	M	M	M	M		M	M
Vehicle operating costs	M		M	M	M		M	M
Crash rates	M	M	M	M	M	M	M	M
Tailpipe emissions	M	M	M	M	M	M	M	M
Noise	M	M	M	M	M	M	M	M
Wider economic benefits	D		M	D	D		M	D
Often Overlooked								
Affordability	D		D		D			D
Parking costs	M				M			M
Vehicle ownership costs	D		D		M			M
Public fitness and health	M	D	M		M	Q	M	M
Embodied resources		M	D	D	D	M		M
Induced travel effects	M	M	M		M		M	M
Barrier effect					M		M	D
Basic mobility	D	D	M	D	D			D
Resilience							D	M
User comfort	M	D	M	D	M		D	M
Amenity values	D		D		D		D	D
Impervious surface costs		M	D		M	M	M	M
Equity impacts	Q	D	Q	D	D			Q

D = described; Q = Quantified; M = Monetized.
Source: own analysis

questions whether travel time savings are per se equivalent to a benefit, or whether travel time is partially a positive utility of travel. Notably, a cost may also be "imposed" from one transport mode on another, as in the case of cyclists making detours to avoid risks and pollution from cars and other motorized vehicles. Workshop participants made it explicit that it often is unclear if the positive utility of travel is correctly dealt with in CBA practices.

4.13. Optimism bias with respect to cost and benefit estimates

CBA is also criticized by the experts for *optimism bias*, which refers to the tendency for project appraisers to underestimate costs (see Flyvbjerg et al., 2018) and overestimate predicted demands, revenues and benefits (Flyvbjerg and Bester, 2021). Arguably, this latter point is about debatable estimates of costs and benefits, not the integration in CBA per se.

4.14. Biased effect estimates if cause - effect relationships are non-linear

CBA often makes use of effect estimates that ignore non-linear relationships between transport policies and effects. There is little evidence that in mature transport systems, marginal roadway expansions increase productivity (Murray and Welch, 2021). There is also evidence that rural areas are vulnerable to spatial reorganization initiated by investments in highways, which can have negative impacts on local growth (Holl, 2025).

4.15. Systemic blindness/projects/policies considered in isolation

Traditional CBA evaluates projects in isolation, often neglecting cumulative impacts, network effects, and path dependencies. A project may in itself appear to be meaningful yet increase systemic risks. A narrow framing can consequently result in flawed welfare effect estimates (positive or negative) and overlook broader structural transformations required for (sustainability) transitions.

4.16. Alternatives not or too narrowly considered

Experts and literature mention that policy makers rarely ask for comparisons of investments in roadways with alternatives, such as other transport modes or traffic demand management, again pointing to ambiguous policy questions (Gössling et al., 2019).

4.17. Preference for easy to implement policies

While practitioners recognize several of the limitations of CBA discussed above and attempt corrective measures (CE Delft, 2019; DfT, 2024; Swiss Federal Office for Spatial Development, 2021; Thune-Larsen et al., 2016), structural biases persist, as policy makers may favor easy-to-implement policy options (van Wee, 2025), or shy away from the more controversial policies (Gössling and Cohen, 2014). These biases are however general biases in policymaking and not solely related to the evaluation method (CBA or another method).

4.18. No explicit check on policy goals

There is often no follow-up on policy goals, i.e. whether these have been met or even how candidate policies score on effects for which there are policy goals. Many governments also have committed to broader societal sustainability goals, some of which may even be national laws. In transport contexts, this may include international agreements such as the Paris Agreement or the European Union Green Deal, urban air quality goals (WHO Air Quality Guidelines), or traffic safety (Vision Zero). Governments are bound, sometimes legally, to consider such

guiding principles, but these may be ignored or sidelined in CBA focused on specific projects.

4.19. Equity concerns ignored

Equity concerns are also often ignored in CBA (Martens, 2011). To evaluate impacts of policy options on equity goals, such goals need to be established, and CBA would have to consider the degree that a planning decision supports or contradicts them. Depending on planning principle, equity objectives may consider fair shares, minimize external costs, advance inclusivity, affordability, or social justice. Improving accessibility for mobility-constrained travellers, such as people with disabilities and low incomes, can provide large productivity gains by improving their access to employment and education (Stanley et al., 2022). CBA tends to overlook or underestimate these interrelationships.

4.20. Planning overlooks important trends

Transport demand refers to the amount and type of travel people choose in specific conditions. Current demographic and economic trends – aging populations in Europe and elsewhere, increasing concerns about affordability, health and environmental quality, changing consumer preferences, electric bicycles, delivery and ridesharing apps, or autonomous mobility service offers – are causing automobile as well as non-auto demands to shift (Goodwin, 2020; ITF, 2021). CBA-based planning often overlooks these trends as it is concerned with a status quo, or the continuation of recent pathways (Denham and Dodson, 2018; Hutton, 2013).

4.21. Data availability leads to prioritizing roads

The experts state that planners usually have relatively complete data on automobile travel demands but much less for other modes. Census and older travel surveys tend to undercount non-commute and off-peak travel, shorter trips, non-motorized travel, travel by children and visitors, recreational travel and active links of motorized trips. Multi-modal trips are classified as trips made by the main transport mode, ignoring that often considerable distances will be covered by other transport modes. Similarly, although there is often detailed information on roadway quality and traffic conditions, most have little data on the quality of non-auto travel conditions. As a result, roadway improvements are often prioritized, also because comparative CBAs are rarely carried out (Gössling, 2013).

4.22. Debatable decisions, at least partly due to making use of CBA

Now that fundamental and practical criticisms on CBA, as well as 'debatable policy questions' have been discussed, a resulting ulterior criticism is that policy makers make debatable decisions based on CBA practices. Copenhagen is instructive of how decision-making should ideally be organized. The city employed comparative CBA to understand the welfare gains from investments in bicycle infrastructure vis-à-vis welfare losses associated with expanding car-oriented systems. These results informed political decisions to prioritize cycling infrastructure over private car use, and the approach remains a notable example of effective CBA practice aligned with appropriate policy questions (Gössling and Choi, 2015).

5. Solutions

The results of our analysis suggest that the critique of CBA is often not directed at the method, but to its use in policy making (debatable policy questions or decisions). Consequently, there is a need to ensure that the appropriate policy questions are formulated before the stage of ex ante evaluations (making use of CBA, MCA or another method) (see preceding sections for discussion). If CBA is used, there are various options to improve the method. Table 4 lists these options, one to one linked to the problems listed in Table 1). Note that Table 4 does not include the criticisms related to policy questions and decision making.

If monetization is rejected in principle, then CBA should not be applied at all. However, in some cases, monetization may not be categorically rejected, but fundamental objections may be raised in assigning monetary values to specific effects. In such situations, those effects should still be included in the CBA framework, even if they are not monetized. Where possible, quantitative estimates may be provided; if this is not feasible, qualitative descriptions remain valuable. Importantly, rejecting the quantification of some effects does not imply that switching to other methods is a better solution, as non-monetary quantification is part and parcel of most of these alternative methods.

Although CBA is primarily designed to assess efficiency rather than fairness, this does not preclude the explicit reporting of distributional impacts. Effects across income groups, regions, or other relevant categories should be clearly documented (Martens, 2011). Some of these distributional effects can even be monetized using the concept of

Table 4
Possible ways to address CBA problems.

Fundamental CBA problems	Solutions
• Fundamental problems with monetizing effects	• If one rejects monetizing: do not apply a CBA • If one has fundamental problems with monetizing some effects: do not monetize but list effects that are not monetized in a CBA
• Neglect of distribution effects	• Explicitly report important distributions in a CBA • Some distributions can be monetized making use of the concept of the Willingness to Pay For Fairness • Add a separate equity analysis to a CBA
• Neglect of wider ethical aspects	• Check explicitly if these occur, and if so: report separately and add to a CBA • 'Undemocratic' nature: replace values and use other principles than consumer preferences
Problems in CBA practice	**Solutions**
• Practical problems with monetizing effects	• Reduce these problems by developing and applying better methods
• High discount rates or no differentiation in discounting based on the type of effects	• Adapt discount rates, differentiate discount rates by effect types • Add sensitivity analyses making use of different discount rates
• Some effects are missing	• Add if possible, report separately if not possible
• Value of travel time savings	• Use appropriate values or do not include travel time savings in calculations
• Biases in transport models used - general	• Improve transport models and apply for ex ante evaluations (CBA and others); correct by making use of expert judgment
• No LUTI model used whereas land use changes can be expected	• Develop (if not available) or apply (if available) LUTI model if substantial land use changes can be expected; correct making use of expert judgment
• Unclear if positive utility of travel is correctly dealt with	• Communicate explicitly if included. Correct estimations of travel time gains if not included.
• Accessibility effects are largely ignored	• Report accessibility effects • Monetize if possible
• Optimism bias regarding cost and benefit estimates	• Develop and apply better methods for cost estimates • Develop better models for benefit estimates, or include more realistic assumptions in modelling
• Biased effect estimates if cause – effect relationships are non-linear	• Apply state-of-the-art scientific methods that enable estimates of non-linear effects • Do more research

Note that the solutions are not empirically validated, so they must be seen as first ideas for how to possibly deal with the criticism.

Willingness to Pay for Fairness (WTPFF; see Van Wee, 2026), which captures how individuals may trade off efficiency against equity. Such reasoning enables explicit trade-offs between efficiency and equity. However, not all distributional or equity effects can be incorporated through WTPFF. In those cases, a separate equity analysis should be conducted alongside the CBA. Furthermore, for those who object to the biased nature of CBA - namely that individuals with higher incomes have greater influence on outcomes - it is possible to replace consumer preferences as the basis for valuation with citizen preferences, as done in participatory value evaluation (PVE; Mouter et al., 2021). Whether such an approach still qualifies as CBA is open to debate.

Concerns about the practical challenges of monetization can be addressed by improving the methods used to estimate monetary values. Discount rates are often contested, and the solution can be to apply different discount rates for different types of effects. For example, there are good reasons for applying lower discount rates for climate change effects (Stern, 2008), which is common practice in some countries. Where discount rates are used, particularly for long-term infrastructure projects, sensitivity analyses using different rates should be standard practice.

If important effects are missing from a CBA, they should be included wherever possible. When inclusion is not feasible due to difficulties in quantification or monetization these effects should at least be reported separately. Likewise, if key parameters such as values of time (VOTs) are considered inaccurate, efforts should be made to develop improved estimation methods and collect better data – though there remains a general question whether travel time savings are a meaningful inclusion in CBA, given multiple issues (notably that higher speeds are translated into longer travel distances rather than time savings; as well as the question whether small time savings have any value at all) and their implications for outcomes.

More generally, the quality of ex ante evaluations depends heavily on the underlying models and assumptions. If transport models do not adequately represent travel behavior, they should be improved; however, since model development is resource-intensive, interim solutions may involve correcting model outputs through expert judgment.

In cases where infrastructure or policy changes are likely to induce substantial land-use effects, it is preferable to apply land-use transport interaction (LUTI) models, if available. Developing such models can be costly and time-consuming, so an alternative is to rely on expert judgment to estimate land-use changes and incorporate them into transport models, for example by adjusting origin–destination matrices.

The positive utility of travel should be, and often probably is, expressed in terms of the (average) values of travel times. If the estimates are correct, they also include trips with low negative or even positive valuations of travel times. A CBA, or the studies used for the valuation of travel times, could make explicit if and how all trips, also with a positive value of travel time, are included.

A further limitation of many CBAs is the insufficient treatment of accessibility effects, beyond simple travel time savings. Accessibility changes should therefore be explicitly reported and, where possible, monetized. One way to achieve this is by using logsum indicators, which express accessibility in utility terms, also considering positive utility derived from travel (see, for example, Geurs et al., 2010).

Finally, improving the reliability of cost and benefit estimates is essential. If cost estimates are flawed, they can substantially bias the outcomes of both CBA and alternative evaluation methods. Better forecasting techniques, such as Reference Class Forecasting (Flyvbjerg, 2006), should therefore be applied. Similarly, if benefit estimates are inaccurate, these need to be addressed. In many cases, inaccuracies stem not from the models themselves but from unrealistic assumptions, for example regarding access and egress times in transport models (Van Wee, 2007). In such cases, the solution lies in adopting more realistic assumptions. Where estimates of costs and benefits are uncertain, sensitiveness analyses are recommended. Where cause–effect relationships are non-linear, state-of-the-art scientific methods should be applied if available (e.g., Kerkman et al., 2017); if not, further research is needed to improve effect estimation.

6. Conclusions

A central finding of this paper is that both the academic literature and expert opinions contain numerous criticisms of cost–benefit analysis (CBA) and its practical application. These criticisms can be grouped into four categories: fundamental problems inherent to CBA; issues related to its practical implementation; concerns regarding the formulation of policy questions; and challenges associated with decision-making processes. The majority of criticisms pertain to CBA practice and the nature of the policy questions posed.

Several principal fundamental criticisms of CBA are identified. First, some scholars reject the monetization of effects altogether. Second, distributional effects are frequently overlooked. Third, broader ethical considerations are often insufficiently addressed. In cases where monetization itself is rejected, no direct alternative within the CBA framework exists, implying that one of the key criteria for evaluating "good" policies – efficiency – cannot be adequately assessed, particularly when policies produce multiple effects. For those who accept monetization but critique the reliance on consumer preference-based valuations, alternatives to consumer-based valuation methods may be used.

The omission of distributional effects can be addressed by explicitly reporting these impacts within CBA reports or in accompanying documentation. A similar approach applies to other ethically relevant considerations. In certain cases, distributional concerns may be incorporated directly into CBA through concepts such as willingness to pay for fairness.

In addition to these fundamental critiques, a wide range of concerns regarding CBA practice has been identified. However, many of these issues are not unique to CBA and would also arise in the application of alternative evaluation frameworks. Consequently, these challenges must be addressed irrespective of the chosen evaluative method. This observation does not imply that CBA should always be preferred over alternative methods; rather, it highlights that different methods may be appropriate depending on the context.

More fundamentally, the analysis also reveals numerous criticisms related to policy-making processes. While CBA and policymaking are not entirely independent, CBA cannot be held responsible for poorly formulated policy questions. Instead, improvements should be sought within the policy-making process itself.

A final question concerns when CBA should be used and when alternative methods may be more appropriate. A comprehensive discussion of the respective advantages and disadvantages of these different approaches, as well as practical guidance on when to apply them, is beyond the scope of this paper. As a rule of thumb, we argue that the use of CBA is well justified when most of the important effects of a project can be quantified and monetized with reasonable reliability. However, where projects involve important effects that are difficult to monetize - such as impacts on nature and landscapes, or when projects are expected to have substantial positive or negative distributional effects across groups - alternative methods may be more appropriate.

Several limitations of this research should be acknowledged, partly in line with the exploratory nature of this study. First, the identified criticisms depend on the literature search and selection process, as well as the choice of consulted experts; alternative approaches may yield additional or different critiques. Above we explained that we used Google Scholar for the literature search, plus why. Nevertheless, the use of other databases, like SCOPUS or WoS could result in other findings. Next, most literature and practices come from OECD countries. It is possible that results for non-OECD countries could be different, for example because of the nature or challenges and equity issues. Next it is possible that the acceptance of candidate experts for his study is subject to selection bias: maybe experts who are relatively critical towards CBA accepted our invitation. And maybe other experts would add additional

criticism or experiences. To add an example: as one reviewer of the version for review of this paper hypothesized: it is possible that the probability of an effect being included in a CBA correlates with the ease with which the effect can be monetized (e.g., travel time savings). Second, the validity of the identified criticisms has not been systematically assessed. Some critiques are subject to debate - for instance, one could argue that CBA was not originally designed to address issues of fairness and thus should not be criticized on these grounds. Nevertheless, this position implies that CBA may be incomplete when fairness considerations are central. Thirdly, the classification of criticisms is the result of the related methodology chosen. Other methods could result in other classifications. Fourth, the proposed solutions are not exhaustive, and additional approaches to addressing the identified criticisms may exist. Fifth, we did not report on the importance of criticisms, whereas some criticisms could be more important than others. We made this choice because we think it is quite arbitrary to do this based on the results. We consider the number of times a criticism is mentioned in the literature or by experts as a poor indicator for the importance of criticism and therefore did not rank criticisms by the level of importance based on this criterion (or any other criterion) – prioritizing criticisms is beyond the aims of this paper. Finally, some of the effects cannot simply be converted into costs and benefits. This applies, for example, to the results of LUTI modeling, the estimation of impact on regional accessibility, and addressing distribution effects. So, the improvements suggested cannot all be easily included in CBA. Separate listing of such benefits in parallel to CBA results could be a solution. Alternatively, and especially if such effects are dominant, the use of another evaluation method could be considered.

Will CBA still be relevant in the future? In the transport policy literature, it is recognized that for long the 'predict-and-provide' paradigm dominated debates, especially in the decades after World War II (Banister, 2002). Due to population and income growth, travel increased. Forecasts were made to see where infrastructure capacity would fall short, leading to proposals for increasing this capacity (mainly roads and airports, and to a limited extent rail). CBAs were often used to forecast the pros and cons of such capacity increases. During the past decade the 'predict-and-provide' paradigm has increasingly been criticized, leading to the suggestion to move to 'decide-and-provide' (for example, Lyons and Davidson, 2016): decide what is desirable, and act accordingly. Notably, even the OECD's International Transport Forum (ITF) recently released a new guide for policymakers, Vision-led Transport Planning (ITF, 2026). It is possible that this will lead to a declining role of ex ante evaluations, or the use of CBA in new contexts.

CRediT authorship contribution statement

Stefan Gössling: Writing – original draft, Project administration, Methodology, Formal analysis, Conceptualization. **Bert van Wee:** Writing – original draft, Methodology, Formal analysis, Conceptualization. **Todd Litman:** Formal analysis. **Karel Martens:** Writing – review & editing, Investigation. **Kees van Goeverden:** Writing – review & editing, Formal analysis. **Mark J. Nieuwenhuijsen:** Writing – review & editing.

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No data was used for the research described in the article.

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