A Benefit-Cost Analysis of Benefit-Cost Analysis

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By

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Statement of Originality

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Date: 29 December 2022

Author Attribution Statement

The work contained in the body of this dissertation, except otherwise acknowledged, is the result of my own research and investigations. Chapter 9 is published in Australasian Transport Research Forum 2022 (Wang and Levinson, 2022b). Chapter 10 is published in the *Journal of Benefit-Cost Analysis* (Wang and Levinson, 2022a). Both manuscripts were written by YW and supervised by DL.

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Abstract

Benefit/Cost Analysis (BCA) has a long history of being used as the primary tool aiding public decision-making. Two primary questions motivate this dissertation:

- Do the results output by BCA add value and impact decision-making? and
- Is BCA trustworthy enough that decision-makers should use it?

Grounded on more than 100 transport projects completed in Asian developing countries, the US, and Australia, this dissertation aims to understand and examine the benefits (if any) created by using BCA via five dimensions: accuracy, appropriateness & consistency, fiscal sustainability, transparency & replicability, and comprehensive.

The dissertation draws the following conclusions:

First, given the findings that the accuracy of BCA for road projects in Asian developing countries is better than that reported in other international evidence and that transport projects in the United States and Australia persistently underperform the original estimates, the accuracy of BCA varies depending on the context.

Second, the shadow price adopted by the road projects in Asian developing countries when calculating user benefits is determined fairly and adjusted realistically, and applying a uniform 12% social discount rate ensures the comparability of BCA results and secures the overall return on investment. In the US, the 'do-nothing' option is separated from the 'do-minimum' option, and appointing the latter as the baseline for evaluating other 'do-something' alternatives secures the realism of the appraisal of alternatives. All these findings corroborate that the social discount rate, non-market valuation method, and baseline case are appropriate and consistent to report and evaluate project performance.

Third, the lower-than-estimated ridership reported in the US and Australia imply the unlikelihood that revenues generated by the use of transport services, like tolls and fares, are capable

of justifying project financial viability and sustaining future spending, negating that the benefit assessment approach embedded in the existing BCA process contributes to fiscal sustainability.

Fourth, various challenges encountered when attempting to replicate BCA suggest that the current BCA processes are neither sufficiently transparent nor replicable to defend the justifiability of decisions made upon BCA.

Last, the findings based on the alternative history of US light rail project show that the travel-time-based user benefit assessment is unable to fully differentiate the worthiness of candidate alternatives. One particular mode is always preferred over other competing alternatives in the US and Australia. These phenomena cast doubt on whether the present BCA is free from manipulation or bias.

The findings that in the US and Australia the ultimate preferred alternative persistently underperforms the 'do-minimum' and second-best 'do-something' option remind us of the opportunity costs. More projects could have served more people with the same budget, and prospective demand could have been managed by more economical courses of action. More importantly, this restricts the BCA from contributing to *ex ante* decision-making because options with a higher rate of return were generally declined.

These findings corroborated some practical issues (i.e. measurement and valuation problems) underlying the application of BCA. These practical issues are classified into three categories: deficiencies in the inputs to BCA, the technique and empirical basis of BCA itself, as well as the limited role of BCA in decision-making. The poor quality of inputs to BCA, including various estimates and options under investigation, would likely result in poor quality results, compromizing the investment decisions made upon the results. Using NMV monetize various user benefits, as one of the core processes underpinning the conventional BCA, is also subject to various practical difficulties. The findings that in the US and Australia the ultimate preferred alternative persistently underperforms the 'do-minimum' and second-best 'do-something' options remind us of the opportunity costs. More projects could have served more people with the same budget, and prospective demand could have been managed by more economical courses of action. More importantly, this reveals that BCA carries limited weight in decision-making because options with a higher rate of return were generally declined.

Indeed, the wide investment decision-making process embraces many factors, and choices between alternatives are the responsibility of decision-makers, not BCA. BCA as an investment assurance tool typically assesses the relative advantages of alternative options (or projects) from the economic perspective. As such, BCA can inform but cannot direct decision-makers, particularly when objectives are maximizing aggregate social welfare (accounting for social equity and environmental sustainability) rather than cost-effectiveness. Discounting BCA in decision-making may not necessarily be navigating politicians to the wrong decisions. Multilateral financial institutions like Asian Development Bank (ADB) demonstrate sound value of using BCA to assist project decision making.

However, the problematic mobility-oriented and travel-time-based benefit assessment methodology embedded in the conventional transport BCA, as demonstrated by the empirical studies in the US and Australia, cannot leverage the value of the concepts underpinning BCA. Abandoning BCA and switching to other decision-making tools or frameworks are not risk-free solutions because the flaws of input quality and the limited role in decision-making potentially apply to all frameworks and tools. The feasibility of incorporating changes in land use and real estate value into project-specific incremental benefit assessment via access measures, as corroborated in the New York Second Avenue Subway project (in chapter 10) and many other empirical studies conducted in major cities across the globe (in chapter 4, could potentially mitigate some measurement and valuation problems. Using the access-based method potentially outsources the valuation issues related to NMV to the real estate market, as the unit dollar value of access changes is informed by property/land value uplift.

As a result, it should be noted that the research and findings in this thesis are not challenging the theoretical basis for BCA. Rather, this thesis proves that there are gaps between the theory and the practice. In theory, theory should have precisely captured the truly additional benefits ascribed to transport investment. However in practice, as demonstrated by numerous findings presented in this thesis, the empirical implementation of the theoretical practices, alongside the idealized assumptions, confronted many challenges. In a nutshell, as the quote says, “In theory, theory and practice are the same. But in practice, they are different”.

Acknowledgements

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Last, I want to thank my family for always being there and supporting me. I feel extremely lucky and grateful to have such a loving and wonderful family.

One of the biggest takeaways from this long journey is that "Persistence pays off in the end, if it hasn't paid off, it is not the end."

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$\mathbf{A_i}$ A series of independent variables indicating the access of parcel i

$\rho_{\frac{TSM}{LPA}}, \rho_{\frac{2nd}{LPA}}$ The Ridership to Cost Ratio of the Transportation System Management option or the Second-best Alternative over the Ridership/Cost Ratio of the Locally Preferred Alternative

$A_{B,i}$ The access to the locational characteristics of property i with respect to basic living need

$A_{D,i}$ The access to social groups or communities with specific qualities i

$A_{H,i}$ The access to the interior and exterior structural attributes of property i

$A_{N,i}$ The access to the quality of the surrounding neighborhood of property i

$A_{n,t,30}$ The number of jobs that can be accessed from Census Block that the property (n) locates within 30 minutes (30) by transit (t)

C_j The cost ratio of project j

C_{ij} The cost of travel from i to j

D_{After} The straight-line distance from the property to its nearest subway station after the opening of the Second Avenue Subway

D_{Before} The straight-line distance from the property to its nearest subway station before the opening of the Second Avenue Subway

E The percent error measuring the extent to which actual travel time differs from the estimates

E_{abs_i} Errors in absolute value for project i

E_{per_i} Errors in percent form for project i

F_i The forecast value of project i in *ex ante* stage

N_S, N_R The number of sold and rented properties, respectively

n_S, n_R Individual property that was either actually or assumed to be sold, and actually or assumed to be rented, respectively

O_i The observed value of project i in *ex post* stage

O_j The number of opportunities at destination j

P_i The price of parcel i

P_S,P_R Sales Price, Rental Income per m^2, respectively

r The discount rate

R_j The ridership ratio of project j

S The control variables for spatial effects not otherwise captured

U The number of Units per building, which exceeds one when more than one unit are sold (or rented) in property S (or R)

$V_{A,S}, V_{A,R}$ Value appreciation in sold and rented property due to change in access, respectively

$V_{D,S}, V_{D,R}$ Value appreciation in sold and rented property respectively due to change in distance

$W\%$ The average weight of cost or benefits out of the total costs or benefits

Y The control variables for temporal effects

Y_S, Y_R The year a property gets sold, Y_S=2014, 2015, 2016, 2017 and 2018, or rented, Y_R=2016, 2017 and 2018, respectively

y_S, y_R Years for sold properties and rented properties, respectively

Z Unit Size (m^2)

L_i A locational indicator variable assigned with a value of 1 if parcel i locates in the treatment area

T_i A temporal indicator variable assigned with a value of 1 if the price of parcel i is measured after a transport intervention

Chapter 1

Introduction

The need to make a decision emerges when a problem occurs. Decision-making is a cognitive and reasoning process where a particular course of action among multiple feasible alternative options is chosen to solve a recognized problem (Beach and Connolly, 2005). People make decisions all the time. Individuals make decisions to maximize (or minimize) benefits (or costs) directly accruing to them. Although the influence of individual decisions may not be limited to themselves, it is less likely to result in significant impacts on society as a whole. In contrast, a government makes decisions on behalf of a collection of individuals, where the effects of those decisions could be gauged by the sum of benefits and costs accruing to every single person who is affected in the short run and the long run. Governments continually confront decisions, but it is infeasible to undertake every project due to resource availability. In this circumstance, making rational decisions would be impossible without the aid of a proper tool that could contrast gains and losses associated with each option and justify the worthiness of choices. Benefit-Cost Analysis (BCA) aims to be that tool.

As a quantitative analytical tool, BCA synthesizes a basket of quantifiable primary elements directly relevant to a prospective project and produces multiple expected performance indicators as outputs to assist objective and rational decision-making (Joseph et al., 2020). Rational decision-making is characterized by minimizing subjectivity, leveraging objective knowledge and information, following a rigorous and logical reasoning process, and trading off the desirability of all possible courses of action (Snell, 1997). Creating and maintaining such a process require extensive investments and also receive various benefits.

Do the results output by BCA add value and impact decision-making? In theory, BCA as

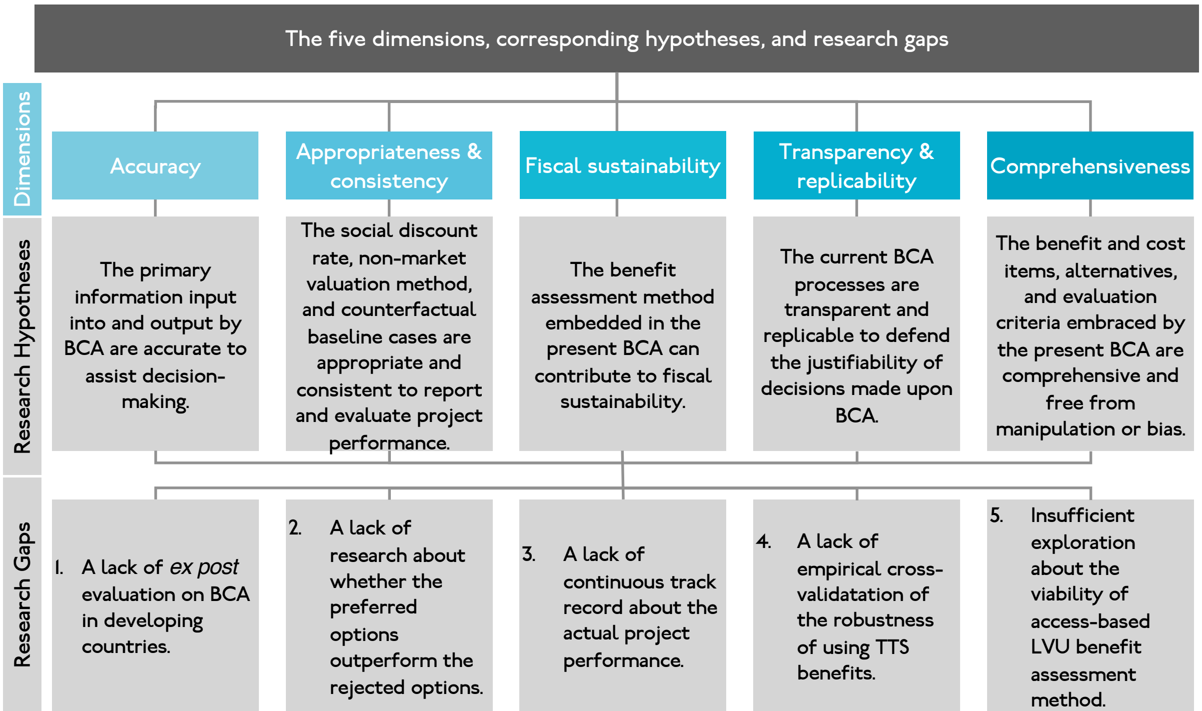


Figure 1.1 The five dimensions and hypotheses corresponding to the overarching research objective

an investment assurance tool adds value by facilitating effective resource allocation because the right choice can be made after the worthiness of a candidate's course of action is reliably analyzed and demonstrated. However, a wealth of literature examining BCA in developed countries has emphasized that projects' predicted performance persistently deviates from their actual performance, compromising the confidence in using BCA in practice. Most of the literature has been designed and undertaken in a way of locking in the final selected 'do-something' option and contrasting it against its actual performance, providing less evidence to justify whether the selected option outperformed other rejected candidate options. Further, the work practice of BCA in developing countries has received less attention. The lack of empirical findings hinders reaching a holistic view of the general BCA practice.

Then a related question arises - is BCA trustworthy enough that decision-makers should use it? This concern can be addressed by empirically cross-validating the results produced by the conventional travel-time-based user benefits assessment with other benefit assessment methods. The accessibility-based land (or real estate) value uplift method aims to disentangle and demonstrate the worthiness of transport investment, creating an opportunity to cross-substantiate the trustworthiness of the conventional method.

In response to the above questions and research gaps, this dissertation aims to understand

and examine the benefits (if any) created using BCA via five dimensions: accuracy, appropriateness & consistency, fiscal sustainability, transparency & replicability, and comprehensiveness (as shown by figure 1.1).

To achieve this objective, this dissertation is organized as follows. Chapter 2 illustrates the conceptual framework guiding through this dissertation and delineates the key hypotheses:

1. The primary information input into and output by BCA are accurate to assist decision-making;
2. The social discount rate, non-market valuation method, and counterfactual baseline cases are appropriate and consistent to report and evaluate project performance;
3. The benefit assessment method embedded in the present BCA can contribute to fiscal sustainability;
4. The current BCA processes are transparent and replicable to defend the justifiability of decisions made upon BCA;
5. The benefit and cost items, alternatives, and evaluation criteria embraced by the present BCA are comprehensive and free from manipulation or bias.

Chapter 3 reviews prior literature on transport projects' cost evaluation, benefit projection, the involvement of other comprehensive project benefits, and the overall project performances across the globe, explores how selection bias, funding incentives, assessment tools, and evaluation criteria impact project alternative analysis in which the locally preferred alternative is sorted out, summarizes critiques on the benefit assessment methods embedded in the present BCA process, and investigates the viability of the access-based land value uplift benefit assessment method.

There is a wealth of literature identifying the positive correlation between property price and proximity to transport infrastructure and demonstrating the capitalization effect of access benefits induced by transport improvements to property value. However, the access-based land or real estate value uplift method hasn't yet been widely recognized and employed as a benefit assessment method in BCA. Therefore, chapter 4 intends to discuss the practical practice and gaps in the access-based land value uplift method based on empirical studies and evidence.

In chapter 5, the focus on *ex post* BCA of transport projects has been expanded to the developing world. It does so by focusing on roadway projects funded by the Asian Development Bank (ADB), assessing the accuracy of the input elements (cost and benefit items) and output results (performance indicators) into BCA, and investigating the appropriateness & consistency of the social discount rate, shadow price, and counterfactual baseline case used when conducting BCA.

Chapter 6 prepares a complete 'alternative history' for 43 light rail projects in the US by evaluating and investigating the process of judging the robustness and viability of the selected option considering the competing alternatives that were ultimately discarded. It delves into the types of alternatives that were considered and assessed to support the identification of the locally preferred light rail alternative, the likelihood that the Locally Preferred Alternative (LPA) outperformed the other candidate alternatives in the light of the demonstrated cost-effectiveness, and the evaluation criteria upon which the LPA is filtered out.

Grounded on the same set of light rail projects, chapter 7 examines the criteria upon which the soundness and robustness of each alternative were gauged and the best project alternative was selected. We aim to complete this objective by investigating the criteria used to evaluate and justify alternatives and examining whether the degree of emphasis of these criteria has altered over time.

Chapter 8 elongates the time window of observing project performance, starting from the first official decision made in *ex ante* planning stage to multiple years post to project opening. The objective of this chapter is to explore systematic tendencies in cost and ridership estimates in multiple *ex ante* project stages coupled with subsequent observation and to retrospectively examine the accuracy of capital cost estimates, ridership forecasts, and transit travel times between paired origin and destination for studied US light rail systems.

Grounded on 6 Australian passenger rail projects, chapter 9 attempts to disentangle whether the alternative reckoned to be worthwhile outperformed other candidates in *ex ante* stage and materializes its potential value as envisioned.

In chapter 10, the hypothesis that unlike the traditional perspective of quantifying travel time and cost savings, the change in the value of real estate better captures the economic impact of transport services more quickly, directly, and properly is tested. Using the Second Avenue Subway in New York City as its case, the validity of the hypothesis is approached by revealing the extent to which the original benefit forecast conforms to the actual results, tallying up the accessibility gains capitalized into real estate value, and finally comparing the Benefit Cost Ratio output by both methods.

Chapter 11 summarizes the observations and findings presented in all the previous chapters, responds to the five hypotheses upon which the benefits created by using BCA are unraveled, and finally outlines future research directions.

Chapter 2

An Illustration of the Conceptual Framework for A Benefit-Cost Analysis of Benefit-Cost Analysis

Clearly identifying the costs and benefits is the foremost task to determine the value added by using BCA to inform public decision making. As shown in figure 2.1, in this chapter, costs and benefits are classified into tangible and intangible categories. *Tangible costs* are incurred when BCA analysis is carried out. *Intangible costs* are recognizable but somehow not appraisable or hard to attribute, which, like fixed costs, don't vary with the number of BCA produced but are required to ensure the usability BCA, including the costs of guiding and standardizing BCA practice, cultivating talents who work in relevant domains, and monitoring. *Tangible benefits* accrue when a right decision is made with the aid of BCA, which could be gauged by subtracting the total benefits of the best project (or project option) from that of the second-best one. *Intangible benefits* consist of maximizing social welfare, gaining public confidence, framing the ground of subsequent performance evaluation, and informing future analyses, which coexist with the tangible ones. This is because the precondition of realizing those intangible benefits depends on rational and correct decisions where benefits exceed costs and the project with the best return on investment is selected. Section 2.1 and 2.2 provide further descriptions of the costs and benefits created as a result of using BCA.

Considering that the majority of cost and benefit items are intangibles, reporting a quantitative benefit/cost ratio for the use of BCA can be hard. An alternative perspective on ascertaining

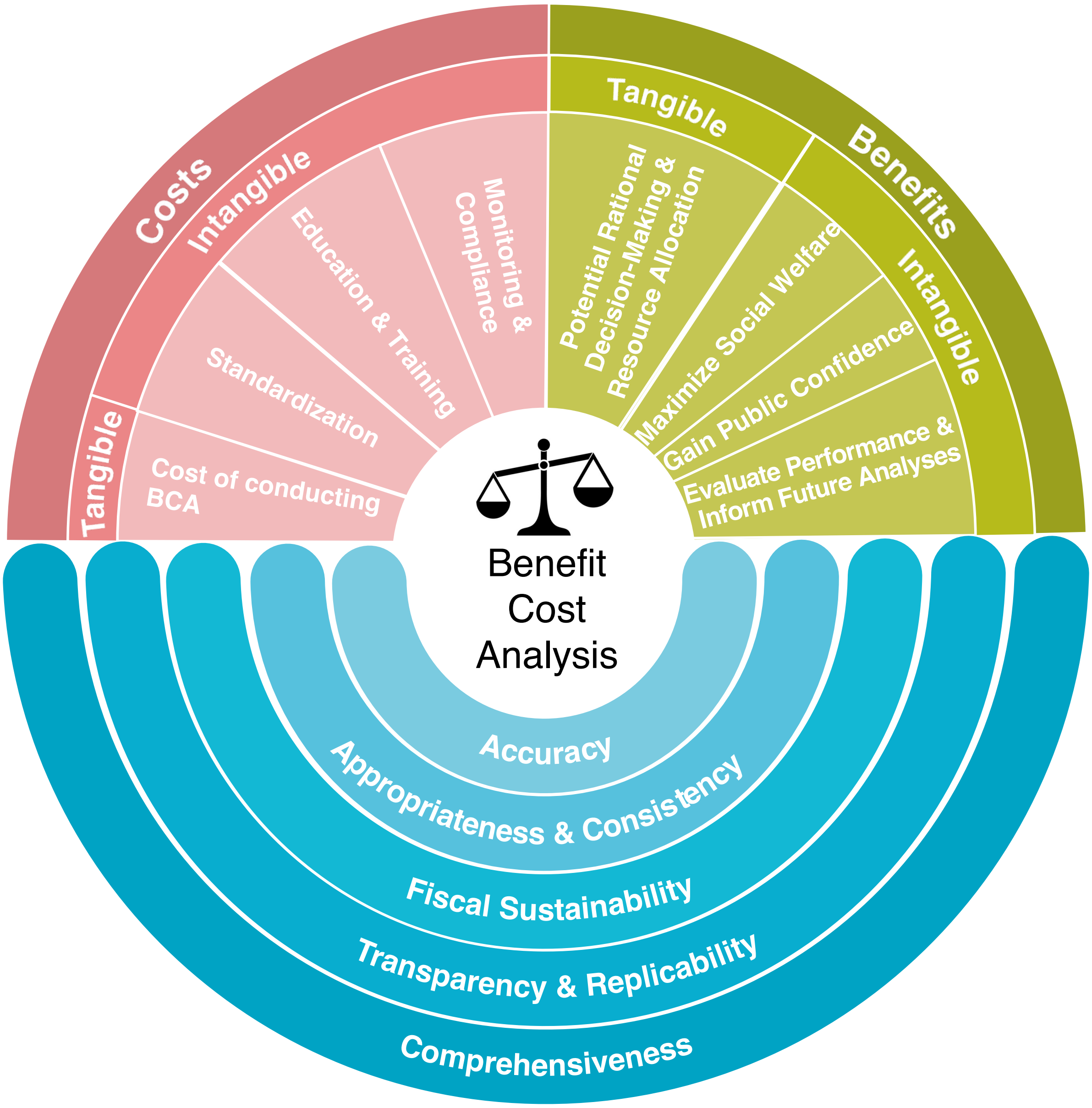


Figure 2.1 The Conceptual Framework of A Benefit-Cost Analysis for Benefit-Cost Analysis

the worthiness of engaging BCA is to corroborate that the tangible benefits of engaging BCA exceed zero. The rationale is that only when there are positive benefits of conducting a BCA can the various costs of doing it be satisfied. Inspired by the 'Best Practice Principles (BPP)' developed by the Organisation for Economic Co-operation and Development (OECD) (OECD, 2014) that is dedicated to governing and improving the accomplishment of significant public policy goals, a tailored five-dimension framework embracing accuracy, appropriateness & consistency, fiscal sustainability, transparency & replicability, and comprehensiveness is developed and engaged to inform the overarching research hypothesis of this thesis. This overarching hypothesis is decomposed and explained in sections 2.3 to 2.7.

2.1 Costs

Costs that are recognizable and quantitatively measurable are labeled as *tangible costs*. The primary tangible costs incurred as a result of conducting a BCA, which can be informed by the price of hiring someone to conduct a BCA for a particular project. As a data-intensive analytical tool, BCA for transport projects requires extensive input of quantitative information, tallying up all types of costs and deducting that value from the sum of all prospective benefits. Ensuring the successful delivery of a BCA gives rise to a range of intangible costs.

Intangible costs refer to costs that are inevitable but hard to quantify or allocate. Although many characteristics and fundamental theoretical principles are common when engineering and planning large projects in different public sectors, the application of BCA is well-organized and carefully demonstrated and argued. Relevant government bodies are obliged to establish and continuously refine guidelines and frameworks defining the BCA process to ensure that the current practice of BCA is consistently pragmatic, well standardized, and adapted to any newly emerging issues or concerns, where both systematic and sector-specific guidelines are needed. For instance, in Australian governance bodies at different levels, like the independent national-level institute - Infrastructure Australia and state-level agency - Infrastructure New South Wales (NSW), are responsible for establishing the overarching BCA guidelines and aiding the evaluation and appraisal of projects within the relevant jurisdiction. Furthermore, since 2018, NSW transport policy focus has shifted towards balancing mobility with the place function of transport infrastructure in future project planning, calling for a revision of the existing BCA practice. Those guidelines and frameworks are products of joint endeavors of many government divisions, where properly allocating the total costs of relevant intergovernmental collaboration to individual BCA can be extremely hard.

Then, pouring time and money into educating and training practitioners who are responsible for producing BCA is another crucial part to gear the operation. Last, to track the functionality and to safeguard the application of a BCA free from major defects, an evidence-based monitoring and compliance system or program that can identify any anomalous issues and make corresponding adjustments and corrections should be developed and maintained.

2.2 Benefits

The tangible benefits are sourced from the potential of proceeding rational decision-making with the aid of BCA, which could be measured by the benefits created by taking the best project option net of that to be delivered by the second-best option. Whereas if the chosen projects underperform the competing alternatives that were compared, which means that the results output by BCA have limited influence on final decision making, then this tangible benefit doesn't exist.

By pursuing projects that are demonstrated to be worthwhile, decision-makers could minimize misallocation or waste of resources, proceed to the mission of maximizing social welfare, and sustain public confidence. In addition, BCA is refined several times along the project planning cycle and preserves valuable project performance evaluation records for the entire project-specific decision flow, providing lessons learned which can inform future decision-making.

2.3 Accuracy

The second BPP centers on preventing public decisions from undue influences. This principle stems from the concern that different entities and authorities with vested interests may attempt to interfere in the decision-making process to ensure the decision is in favor of themselves.

In the BCA practice, undue influences can be approached by manipulating the primary inputs in BCA. As a quantitative data-driven analytical tool, BCA synthesizes and trades off two streams of quantifiable primary elements - costs and benefits - that are directly relevant to a prospective project - to inform decision-making. The relative goodness of candidate options and projects is elicited by comparing the performance indicators output by BCA, which are typically the Benefit Cost Ratio (BCR), Net Present Value (NPV), and Economic Internal Rate of Return (EIRR). The extent to which decision-making benefits from using BCA is hence largely underpinned by the accuracy of the primary elements and performance indicators.

Accuracy refers to the degree to which the forecast results (predicted costs or benefits) of a specific course of action conform to its actual results (out-turn costs and benefits) (Flyvbjerg et al., 2003). Therefore the hypothesis regarding this dimension is that: the information input into and output by BCA are accurate in assisting decision-making.

Accuracy directly affects the trustworthiness of public decisions. Transport projects are generally funded by the public sector, using taxes levied by the government on the public. Cost overrun and schedule delays imply extra financial burden and intrusion on people's life, and lower-than-expected level of usage could lead one to question the worthiness of government spending. Further, if the errors in the results output by BCA cannot be controlled within an acceptable margin relative to the differences between the performance of different alternatives, the woeful accuracy of BCA is highly likely to result in nominating less qualified options and ineffective resource allocation (Pickrell, 1992). If different projects appear to be uniformly good or terrible, it would be likely that the potential values credited to each option are not exploited to sufficiently differentiate them, leading to questioning the reliability of the specifications covered or even the evaluation tool itself (Pickrell, 1992).

Chapter 5, 8, and 9 delve into the accuracy of BCA in Asian developing countries (road projects), the US (light rail projects), and Australia (passenger rail projects).

2.4 Appropriateness & Consistency

The second BPP also highlights the importance of remaining an impartial and consistent framework in reducing the risks of undue influences and keeping integrity in decision-making (OECD, 2014). The general procedure of BCA encompasses a series of similar steps organized sequentially, guided by scientific and logical problem-solving thinking. These steps include problem identification, solution (or alternative) framing and analysis, costs and benefits (of each alternative) calculation, as well as solution comparison and recommendation. Among the above steps in a quantitative BCA, calculating the costs and benefits of each alternative plays an irreplaceable role in justifying decision-making. This step is closely bound up with the appropriateness and consistency of three key elements: counterfactual base case, non-market valuation, and social discount rate. So the hypothesis related to this dimension is that the social discount rate, non-market valuation method, and counterfactual baseline cases are appropriate and consistent for reporting and evaluating project performance.

2.4.1 Counterfactual Base Case

BCA is an incremental assessment approach, where the incremental costs and benefits generated by 'do-something' project options are measured against a base case - the 'do-nothing' option. The 'no-build', as the name suggests, refers to a counterfactual circumstance where the prospective project does not exist. It is the baseline upon which any extra outcomes (costs and benefits) stemming exclusively from undertaking the project could be measured accordingly. Given that the incremental approach is adopted in *ex ante* and *ex post* BCA, identifying proper counterfactual scenarios is required in both stages.

The 'do-nothing' baseline option is not equivalent to an effortless 'do-worse' option. For instance, if the 'no-build' option sticks with the level of maintenance (regular O&M expenditure) that has already been provided for the existing transit facility, the facility would possibly undergo reduced service quality, lower travel speed, longer headway, and poorer on-time performance, which would ultimately affect demand and travelers' benefits, resulting in a 'do-worse' baseline case (Mackie and Preston, 1998). In this case, the incremental benefits that could be achieved by taking the 'do-something' are amplified, skewing performance indicators reported by BCA and decisions made based on the results. Further, using a consistent baseline scenario when preparing *ex ante* and *ex post* stages for the same project is crucial to retrospectively examine and justify the plausibility of decisions made based on BCA. If the assessment of incremental cost and benefits hinges on distinct base scenarios, the output performance measurements are incomparable, thus negating the reliability of the conclusions on the accuracy of BCA.

Chapter 5 and 6 examine how the counterfactual baseline scenario is defined in *ex ante* BCA, and chapter 5 also explores its impact on *ex post* BCA.

2.4.2 Non-market Valuation

One of the central attributes of BCA is translating all benefit and cost items into monetary terms - a *common unit of measurement*. This progressive attempt to press economic values of outputs and inputs of a prospective project and yield a quantitative result simplifies the process of determining the rational choice, but it also worries scholars. The monetary value of relevant benefits and costs can be presumed when there is a market in which exchanges of goods and resources are facilitated by players from both the supply and demand sides and settled at market prices. Outside such markets, however, deriving the economic value of non-market goods and services, namely pricing the priceless, can be confused and doubtfully reliable (Self, 1970; Schumacher, 1973).

In the transport sector, monetizing benefits that are frequently expressed in the form of cost reduction relies heavily on Non-Market Valuations (NMV). When outcomes (costs and benefits) generated by a transport intervention are not exchanged or traded in markets, thereby lacking market prices, NMV is used as an alternative method to extrapolate how the unpriced outcomes impact the benefit to society as a whole (Snell, 1997). The process of translating the various outcomes in terms of their monetary equivalents and enabling analyses and comparisons of their impacts to net benefits to society is monetisation (Button, 2010). NMV typically includes stated preference methods (i.e., survey) and revealed preference methods (i.e., hedonic pricing and travel-cost analysis). For instance, grounded on the theoretical foundation that transport users are willing to pay a premium to shorten travel time, travel time savings (TTS) form the bulk of the direct economic benefits of transport projects in various modes, where assigning monetary values to time becomes a challenge. As non-marketable intangible resources, travel time is neither tradable nor priced by the market. The value of travel time is measured based on Willingness To Pay (WTP) or opportunity cost - the equivalent monetary value that would have been produced with the same time input as the shortened travel time, which is generally informed either by users' stated preference or wage (Jara-Diaz, 1990). WTP represents the maximum amount that a user is willing to pay for a good or service, which is elicited from a pool of stated preference surveys (Kneese, 2011). Wages are commonly used as a proxy to inform the (monetary) value of travel time saved because individuals generally trade off their time between different activities, including travel and work (Mackie et al., 2001).

Although tactics like using revealed WTP to calibrate the stated WTP or adjusting the value of time for changes in users' perception (of time) along project life have been used to safeguard the appropriateness of shadow price, arbitrarily pricing unpriced resources is a congenital defect (Ackerman and Heinzerling, 2002). Given that only by using fair and realistic shadow prices can project benefits be accurately and credibly measured, the benefits of using BCA are determined by the way it is performed. Chapter 5 scrutinized how shadow pricing is embraced when evaluating roadway projects in Asian developing countries.

2.4.3 Social Discount Rate

The decision-making rule of BCA is that a project is worth undertaking if the sum of benefits outweighs the sum of costs, demonstrated by a BCR exceeding 1, an EIRR higher than the pre-specified hurdle rate, or a positive NPV. In the process of calculating those performance indicators, if the upfront investment is weighed up against the future social well-being on a timeless basis, it would be in violation of the fundamental principle of the time value of money. People are not indifferent to the point of time when costs incur and when benefits can be received (Andersen et al., 2008). They prefer to receive benefits immediately rather than in the near future, implying that extra monetary return is required to compensate for potential earnings and risks in the interim. In turn this indicates that future values must be brought back to the present point in time by discounting them, which is critical when engaging BCA to evaluate the net present worthiness of a public project.

The accuracy and credibility of the BCA evaluation results are largely determined by the appropriateness and consistency of the discount rate used. In terms of appropriateness, applying a high discount rate could eliminate many worth-doing projects that appear to be less economically viable in the near future but may generate large inter-generational benefits in the distant future or that benefit disadvantaged or minority groups but cannot create fruitful financial returns. In contrast, adopting a low SDR might expose the lenders to excessive risks, failing to allocate and use resources effectively.

As discussed above, rewards received sooner appear to be more valuable, and the value of delayed rewards is penalized by a discount factor that escalates with the period of waiting. Time-consistent discounting methods are widely employed to model this behavior, where a fixed discount rate is used to reflect that the valuation of one dollar decreases by a constant rate with per unit increases in waiting, implying that the preference for immediate rewards is time-invariant. However, many studies have identified and corroborated the phenomenon that the drop of valuations actually decelerates when the time receiving rewards is distant from the present, which deviates from the posit that choice-making behaviors are time-consistent (Ainslie, 1974; Ainslie and Herrnstein, 1981). In this case, the tendency that people might dynamically change their decisions over time because the relative attractiveness of options depends on the period of waiting brings about hyperbolic discounting methods (Laibson, 1997). Hyperbolic discounting features a negative interplay between the size of discount rates and the time of waiting, simulating the time-inconsistent choice behavior that people reverse their initial preference for immediate but low rewards to a remote and higher rewards when both rewards occur in distant future (Laibson, 1997).

In a nutshell, the choice of discount function and rate applied in BCA affects the likelihood of a project being selected and implemented today, and the influence of this decision would result in inter-temporal influence on succeeding generations and social equity, where chapter 5 closely examine this issue.

2.5 Fiscal Sustainability

One particular aspect of the sixth BPP - Funding - is regulatory cost recovery that can secure public sources and levels of funding to support and sustain policy outcomes without placing unnecessary and inefficient burdens on regulated entities (OECD, 2014).

As mentioned previously, transport benefits are primarily assessed from the perspective of economic and social welfare and in the form of gains in users' utility, shedding limited light on financial viability and fiscal sustainability. Without sufficient justification for the financial viability of an investment, BCA could become a manipulative tool for occupying as much public resources as possible by pursuing capital-intensive but cost-ineffective projects, which is opposite to the initial intent of engaging BCA to facilitate effective resource allocation. The hypothesis in respect of this dimension is that the benefit assessment method embedded in the present BCA process can contribute to fiscal sustainability.

In addition, the demonstrated economic benefits cannot be directly collected and fed into future projects, which is challenged in its ability to create a seamless and sustainable rotation of capital and sustain future spending. Considering the fiscal pressure and the steep growth of the total costs required by the transport sector, BCA as an analytical tool could contribute to decision making by taking fiscal sustainability into account.

Chapter 4 and 10 examine the fiscal sustainability of the present BCA practice and look for alternative methods that are conducive to fill and sustain government coffers.

2.6 Transparency and Replicability

The fourth BPP is related to accountability and transparency, specifying that any individuals and social groups that are subject to the impacts of decisions made by a public authority should have ready access to systems and materials for questioning the exercise of that authority (OECD, 2014).

The demand for transparency in BCA arises from multiple roles who are directly imposed on the consequences of decisions grounded on BCA results, including policymakers, practitioners (or experts), and the general public. Sometimes these roles might have overlapping points of interest, but generally it is policymakers who make, carry out, and defend a decision, practitioners evaluate and advise policymakers, and the general public pay money and bear the consequences.

It will be a significant danger if BCA is manipulated to deliver whatever outcomes that are in favor of whichever party. A professional and honest practice should have transparency embedded in the full decision-making process, including data, evaluation criteria, models, as well as assumptions and the rationale behind them. Anyone who has questions is expected to have access to the necessary information, replicate the procedures, and examine the results. This could not only reinforce public confidence and support but also benefit future analyses.

The hypothesis regarding this theme is that the current BCA processes are sufficiently transparent and replicable to defend the justifiability of decisions made upon BCA. Challenges encountered when attempting to replicate BCA analysis are outlined in all the following chapters.

2.7 Comprehensiveness

The last BPP targets performance evaluation, emphasizing that policy outcomes evaluation should be undertaken against a comprehensive set of indicators with respect to the broader objectives and outcomes it is expected to deliver (OECD, 2014).

In an attempt to answer the question 'are the benefits generated by a project worth its costs,' the benefits and costs associated with each reasonable course of action (alternative) need to be fully captured and thoroughly analyzed in line with a set of systematic and well-balanced evaluation criteria. To be capable of delivering informative value judgment and assisting decision making, BCA is expected to be comprehensive, and the corresponding hypothesis is that the benefit and cost items, alternatives, and evaluation criteria embraced by the present BCA are comprehensive and free from manipulation or bias.

2.7.1 Full Benefits or Full Costs

The current practice of evaluating transport projects places overwhelming weight on the movement or mobility function of transport infrastructure, resulting in wide application of the mobility- or function-based evaluation framework. In reality, the impacts of transport initiatives go far beyond allowing people and vehicles to travel faster, and the stakeholders are far more than the direct demanders and suppliers of transport systems.

Under the current project planning and appraisal guidelines, the benefits of a transport initiative are approached from the impact of traffic function on users (typically including the reduction in vehicle operating costs, travel time, and traffic crashes). The evaluation and projection of these benefits are subjected to rigorous benefit identification and categorization rules to properly fragment the overall outcome, ensure the uniqueness of each benefit stream, and avoid capturing any benefit streams more than once. However, Wider Economic Benefits (WEBs) accrued to the rest of society are largely excluded or ignored from a standard BCA appraisal (Graham, 2007). In the transport sector, WEBs refer to the positive outcomes that a transport intervention can bring about for the overall economy beyond its direct impacts on the immediate transport users. Depending on the underlying land use assumptions, WEBs can be further classified into two groups: static WEBs and dynamic WEBs. Static WEBs are gauged by holding the locations (of economic activities, business clusters, and employment opportunities) constant, but dynamic WEBs assume location changes due to altered land uses. For instance, the clustering of business entities in the urban area, which is geared and facilitated by bettered transport connectivity and reduced costs of production inputs, can ultimately convert to productivity advantages triggered by agglomeration effects, namely economies of agglomeration (Wright et al., 1981; Graham, 2007; Legaspi et al., 2015). Spatial spillover effects emerge when the positive influence on local productivity and economy spills from the target region to surrounding areas (Munnell, 1992). Transport infrastructure's effect on housing prices and the land use patterns in adjacent and remote areas is normally analyzed in feasibility studies carried out at different project planning stages, it has typically only been performed qualitatively.

The evaluation of costs is just as complicated as that of benefits. In spite of the direct costs incurred as a result of building and operating a new transport facility, various negative externalities like noise, pollution, and destruction of the environment occur as the transport project progresses. No compensation is paid to groups bearing the extra costs of damage from those negative externalities, but the costs eventually pass on to the entire society.

Pragmatic compromises have been made by excluding some of the aforementioned externalities from the BCA, although those effects truly alter total net benefits and costs (induced by transport investment) to society as a whole. However, whether a decision-making process informed by the remaining narrow-based BCA could minimize resource misallocation and waste, maximize total social welfare, and sustain public confidence remains inconclusive.

Chapters 4 and 10 attempt to figure out how benefits missed or implicitly accounted for in the present BCA could be captured using alternative methods.

2.7.2 Alternatives

A decision is labeled as 'rational' when it is generated by minimizing subjectivity and intuition, leveraging objective knowledge and information, following a rigorous and logical reasoning process, and trading off the desirability of all possible courses of actions (Snell, 1997). The basis for making a rational choice to resolve an identified issue is the availability of more than one feasible alternatives that could narrow the gap between the present situation and the expected future situation. In transport planning, many efforts have been devoted to project alternatives analysis. It is an iterative process of conceptualizing, designing, valuing, and selecting the preferred action strategy (alternative), which is anticipated to encompass all reasonable courses of action and determine the best option to address the identified transport problems in the studied corridor.

In the history of transport development, it is not uncommon to observe a mania of striving to develop or revitalize a particular transport mode during a specific period of time. In Australia, trams (streetcars) were the pillar of public transport in the early 20th century, propelled by a worldwide trend towards electrification. The boom of trams gradually lingered after World War II, attributed to the financial inability to maintain public transport assets and the rise of the private automobile. Since the turn of the millennium, light rails - the advanced version of the vintage trams - have gradually come back to Australia aside from Melbourne where they never left, coupled with extensive retrofit and expansion of tramway networks in almost all major cities in Australia. One of the debates following the restoration and overwhelming advocacy of light rail in recent years is why light rail is always selected over other alternative transit modes like bus rapid transit.

If adapting to technology evolution was the predominant consideration in transport mode choice over the last century, why is the phenomenon of preferring one particular mode to another often seen in the present when both the technology and practice of different transit modes are much more mature? Locking in a desired option when using BCA erodes the rationality and trustworthiness of decisions made upon BCA, because other feasible alternatives are less likely to be seriously analyzed and considered, limiting the possibility of driving projects to a different or even better outcome.

Chapters 8 and 9 review the alternative analyses undertaken for light rail projects in the US and passenger rails in Australia.

2.7.3 Evaluation Criteria

When carrying out a BCA, the criteria upon which project alternatives are evaluated and approved (or rejected) are expected to be comprehensive and competent to reflect each option's level of fulfillment of project objectives and needs. The high-level evaluation criteria established for transport investment embrace environmental, socioeconomic, political, and financial effects, where an equal level of commitment to all these criteria would foster decisions that can service the whole society in a fair manner. However, pursuing an investment option with higher return (financial effects) reinforces the dominating position of cost and quantifiable user benefits in the current BCA evaluation criteria. In this case, decisions based on BCA may be driven away from taking care of minority or disadvantaged social groups who tend to rely on less expensive travel modes. The above example implies how important BCA evaluation criteria are to fit to the fundamental public decision-making rule of maximizing social welfare.

2.8 Conclusion and Discussion

Figure 2.1 illustrates the conceptual framework for evaluating the costs and benefits of using BCA. Given the constraint that the majority of cost and benefit items are intangibles, this primary focus on evaluating the value added by using BCA is narrowed to investigate whether the tangible benefits of engaging BCA exceed zero. This chapter discusses how intangible benefits can be extrapolated by assessing the performance of BCA through testing five hypotheses.

The accuracy of BCA, particularly the primary cost and benefit streams input into BCA analysis, underpins the justifiability of decisions, directly affecting the trustworthiness of public decisions. The appropriateness & consistency of the social discount rate, non-market valuation, and the counterfactual baseline case, coupled with the comprehensiveness of benefits/costs, alternatives, and evaluation criteria being considered, have great influences on the possibility of sorting out and implementing a worth-doing project, impacting on the effectiveness of resources allocation and the likelihood of maximizing social welfare rather than profit. Rooted in economic welfare analysis, BCA's ability to create a seamless rotation of capital that could be reinvested in future projects, namely fiscal sustainability, is challenged. The transparency and replicability of BCA influence not only public confidence in and support on decisions but also how future analysis could benefit from the existing lessons learned.

Chapter 3

Literature Review

3.1 The Current Practice of BCA in Developed and Developing Countries

For large-scale transport projects, their actual performance after project delivery draw attention. As documented by the existing literature, project cost evaluation and travel demand forecasts lie at the heart of the concern, with extensive research on how projects in developed countries behave in those two dimensions published. In recent years, a gradually growing literature on other comprehensive project benefits such as economies of agglomeration and impacts on land use and the overall project performances has been observed. The following subsections delineate the current research practice for each of the four topics.

3.1.1 Project Costs

Ex post evaluation on project cost performance pays attention to how the ultimate out-turn cost deviates from the budgeted amount that was stated at various *ex ante* stages, which is more popularly known as the extent of cost overrun. Cost overrun is measured in both absolute monetary value and percent error, enabling reporting of its severity and detecting the existence of systematic tendencies. In addition, statistical models (mainly regression models) are engaged to test and predict the correlation between cost overrun and factors like project-specific traits, temporal or geographical features, and external economic conditions. Although projects subjected to *ex post* cost evaluation spread all over the world, the detection, supervision and research on this issue initiated far earlier and are much more extensive in the developed world than in developing regions. Specifically, past academic studies and research addressing transport project cost performance include but are not limited to those published by Pickrell et al. (1989) on eight US rail projects; Sebastian (1990) on multisectoral public projects in India; Richmond (1998) ; Flyvbjerg et al. (2004) on roadway, rail, and fixed-link transport projects worldwide; Odeck (2004a) on roadway projects in Norway; Lee (2008) on multi-modal transport projects (including airports and ports projects) in South Korea; Lundberg et al. (2011) on road and rail projects in Sweden; Cantarelli et al. (2012) on roadway, rail, and fixed-link transport projects in Dutch; Park and Papadopoulou (2012) on land and marine transport projects in Asian countries; and Huo et al. (2018) on roadway, rail, and fixed-link projects in Hong Kong.

Those studies revealed the universality of transport project cost overruns and delved into the correlations between the magnitude of cost overruns and a series of variables representing project characteristics like transport project mode and the project size reflected by the planned capital investment. First, Flyvbjerg et al. (2004) observed the largest mean cost overrun of roughly 45% for rails, followed by 34% for fixed-links, and 20% for roadways based on 248 projects in Europe and North America. Similar tendencies that rails are more vulnerable to over-budgeting in comparison to roadways and fixed-links have been collaborated by Huo et al. (2018); Andrić et al. (2019); Park and Papadopoulou (2012); Lee (2008); Sebastian (1990). In contrast, the Netherlands study by Cantarelli et al. (2012) reported the mean cost overruns were approximately 22% for fixed-links, 19% for roadways, and 11% for rails. The authors explained that the rails sampled by their study were mainly up-grades to existing heavy rails instead of new construction, leading to a narrower cost overrun than rails elsewhere. Second, Flyvbjerg et al. (2004) and Andrić et al. (2019) statistically proved a positive correlation between the size of cost overruns and project size, considering that the planned investment volume rather than the out-turn is the suitable measure of project size. However, Odeck (2004a) and Cantarelli et al. (2012) yielded a negative correlation, accentuating that smaller projects have larger overruns. In addition, Park and Papadopoulou (2012) and Huo et al. (2018) did not capture any statistically significant correlations between cost overruns and project size.

Further, grounded on the responses to the questionnaires distributed to the companies that participated in project plan and build, Park and Papadopoulou (2012) insisted that the overwhelming weight of bidders' quotations in the contractor selection criteria and the type of construction contract awarded are identified as the major drivers of cost overrun for the 35 transport projects from a mix of developing and developed countries in Asia. By reviewing the contribution of the causes identified in project reports and ranking the frequencies that those causes were nominated, Andrić et al. (2019) concluded that the major sources of project cost overrun related to construction resources and works, alterations to project design, land acquisition, and the volatility of currency price.

Moreover, Odeck (2017) conducted a quantitative meta-analysis on 48 contemporary studies of transport projects, systematically testing how the reported project cost overrun (in percent error form) changes with specific characteristics at the study level (such as geographical location and publication year). Among the 48 studies, only 5 studies were performed in Asia (4 from India and 1 from South Korea), 3 in Africa (1 from Zambia, 1 from Tanzania, and 1 from African Development Bank), and 1 in the Middle East (Jordan), with the remaining 41 studies belonging to developed regions like Australia, North America, and Europe. As the only meta-analysis, he summarized, statistically integrated and critically extracted all comparable research findings in this field grounded on a sample size that triumphs over any single study. He concluded that the frequency of cost overrun exceeds cost underrun, that the percent error cost overrun drops over time, that cost overrun stated by published works is significantly higher than those in unpublished works, that roads are less likely to have cost overrun than other modes (rails and urban transport), and that cost overrun is found to be more severe in developed regions (except for Australia) than in Asia, Africa, and the Middle East.

The aforementioned studies measure cost overrun, no matter in the form of percent error or dollar value, grounding on one cost estimate disclosed at a specific point in time. Considering that project cost estimates have been modified many times along the planning phase, concerns regarding which estimate is the best basis for assessing cost overrun has been raised (Odeck, 2004a). Odeck (2004a) argued that cost estimates produced in the early planning stage (like feasibility study or corridor-level strategic study), owing to incomplete and imprecise information regarding project-specific characteristics. However, how cost estimates vary along the entire project preparatory phase are inconclusive. Comparing the actual capital outlay against cost estimates produced at various points in time may offer reference when inspecting and adjusting project cost estimates in the future.

3.1.2 Project Benefits

Travel Demand Forecast Modelling

Ex post evaluation on the accuracy of the demand forecast, which constitutes the basis for evaluating direct economic benefits like travel time saving (TTS) and vehicle operating cost (VOC) reduction, are ample. The accuracy is measured by how the envisaged demand differs from the observed demand, mainly reported in percent error. This difference is also commonly referred to as demand shortfalls. The statistical analysis on demand shortfalls is similar to cost performance. Nevertheless, the models engaged may differ since travel demand is time-series data, requiring consideration of actual traffic states at various points in time, spread across the observable project operation period.

Previous studies on this topic have covered transport projects in various modes (mainly roads and rails) worldwide, but there is significantly more research in developed than developing countries. Those academic publications include but are not limited to US transit projects by Pickrell et al. (1989); Voulgaris (2019a) and Voulgaris (2019b), Australian toll roads by Li and Hensher (2010), roadways in Minnesota by Parthasarathi and Levinson (2010), toll and toll-free roads in Norway by Welde and Odeck (2011), toll roads across the world by Bain (2009), roads of all types in the US and Europe by Hoque et al. (2022a), and transport projects in various modes across the globe by Flyvbjerg et al. (2005); Hartgen (2013); Cruz and Sarmento (2019) and Nicolaisen and Driscoll (2014).

The second findings related to demand forecast in developed countries are that the over-estimation of travel needs is more prevalent than the underestimation, and that the extent to which the forecast travel needs are overestimated varies depending on the time, size, location, and type of transport projects dataset used. For example, the discrepancy between forecast and actual travel demand is more extensive for transit projects than for roads (Cruz and Sarmento, 2019; Flyvbjerg et al., 2005).

Second, controversial findings of whether the size and direction of forecast errors vary over time exist. Flyvbjerg et al. (2005) argued that over the three-decade period they covered, the size of the demand forecasting errors for rail projects remains constant and that the accuracy of roadway demand forecasting even got worse. The authors stressed that the crux of the matter is not fixing the forecasting models but calibrating the underlying assumptions by engaging the lessons learned in a systematic and proactive manner. Cruz and Sarmento (2019) also confirmed the failure to reduce forecast errors over time grounded on 21 studies established between 1978 and 2017. Nevertheless, Hoque et al. (2022a) reported that based on 1291 roads in the US and Europe, the traffic estimates of more recent roads were closer to the actual traffic counts in comparison to roads opened earlier. The authors explained that modified forecasting modeling and more sufficient data may be attributable to this change. In addition, the size of forecasting error for the same transport project is expected to gradually decrease as the project operation time becomes longer because the ramp-up effects fade away (Cruz and Sarmento, 2019; Li and Hensher, 2010; Bain, 2009). For the direction of error, the propensity for understating actual travel needs for roads opened before the early 2000s has turned out the opposite for roads opened more recently (Hoque et al., 2022a). Overstating travel demands implies that the prospective transport facility may reach capacity later than expected while understating are just the opposite. The authors believed that the Great Recession had contributed to such an apparent shift. In addition, the authors noticed an interplay between the direction of demand forecasting error and aggregate Vehicle Miles Travelled (VMT). VMT per capita grew in the two decades before 2000, during which a trend of underestimating road demands was observed. After 2000, VMT per capita decreased and then increased, and the estimated traffic demands on average exceeded the actual ones. Fuel price fluctuation and changes in economic conditions that impact VMT may also influence the changes in traffic demand forecasts.

Third, the inaccuracy of demand forecasts can be attributed to:

1. Defects in modelling engendered by imprecise estimation on exogenous variables (like unemployment rate (Hoque et al., 2022a), growth in car ownership and energy price (Nicolaisen and Driscoll, 2014; Jacoby and Minten, 2009), and the way that households access transport services (Fafchamps and Hill, 2005)) or on project-specific features (such as adjustment to project design (Nicolaisen and Driscoll, 2014) and delay of project delivery (Parthasarathi and Levinson, 2010; Voulgaris, 2019b);

2. Scant awareness of the impact imposed by the bureaucratic environment (Hartgen, 2013; Flyvbjerg et al., 2005);

3. Bias caused by psychological restrictions like optimist bias (Bain, 2009; Nicolaisen and Driscoll, 2014); and

4. Insufficient consideration about or the intrinsic unpredictability of the impact of the project

on land use and integral network arrangement (Parthasarathi and Levinson, 2010; Nicolaisen and Driscoll, 2014).

Though using ridership statistics in initial operation years is the common practice in retrospectively assessing the accuracy of demand forecasts (Pickrell, 1992; Federal Transit Administration Office of Planning and Environment U.S. Department of Transportation, 2003, 2008), it ignores the fact that projects may undergo a ramp-up period longer than one year to adequately penetrate the present traffic system and catch up with the full forecast demand *ex ante* (Li and Hensher, 2010; Chang et al., 2010). Flyvbjerg (2005) pointed out that using the ramp-up effect as an argument in favor of underperforming projects is less robust because projects carrying a lower-than-expected number of passengers in initial years are prone to experience lower patronage in subsequent years, which is also corroborated by Pickrell et al. (1989) and Richmond (1998). Shinn and Voulgaris (2019) find that a surge in ridership in the initial 2 operation years may be ascribed to the ramp-up effect.

Travel Time

In spite of ridership, the shortened travel time (compared to the baseline case) between key origin and destinations is another fundamental element captured and considered when projecting benefits associated with prospective transit projects. Compared to other predictors of travelers' mode choice, such as household income level, fare, reliability, and level of comfort (Del Castillo and Benitez, 2012; Donald et al., 2014), travel time shows the most significant influence (Frank et al., 2008), which can be broadly categorized as in-vehicle travel time and out-of-vehicle travel time. Iseki and Taylor (2009) noted that trimming down out-of-vehicle travel time, namely the time spent in accessing and waiting for transit service as well as transferring between transit lines or stops, improves the connectivity of the overall transit network, strongly promoting the uptake of public transport.

The discussion about the importance of the two types of travel time has been extended to transit accessibility which is increasingly perceived to be an imperative measure engaged in transport planning and evaluation (Currie, 2010). Accessibility to transit service or station is regarded as a primary component when assessing the impediment to transit travel from the temporal dimension, which is encompassed when considering the cost-side of transit accessibility (Polzin et al., 2002). Although the physical access from the origin to the nearest transit stop is significant, overlooking the on-board transit travel time to the final destination is likely to overstate accessibility (Lei and Church, 2010).

However, existing literature focusing on the ramp-up effect in transit ridership and *ex post* evaluation on transit travel time are sparse, calling for more empirical evidence to assist decision-makers in regards to forecast projection and post evaluation.

3.1.3 Other Comprehensive Project Benefits and Disbenefits

In spite of the concerns about direct benefits relying on demand forecast modeling mentioned, we observed that discussions on other comprehensive benefits generated by transport investments are gradually increasing. These comprise: 1) wider economic benefits like economies of agglomeration and spatial spillover effects, and 2) influence on land use which may be reflected by changes in transport accessibility and in housing prices.

Economies of agglomeration and spatial spillover effects induced by transport investment, which are vital components of wider economic benefits generated by transport projects, have been one of the most persistent topics of interest for western scholars, and many excellent empirical studies include but are not limited to Venables (2004)'s study in London, Legaspi et al. (2015)'s study on Sydney North West Rail Link, Graham (2007)'s work grounded in the UK, Kernohan and Rognlien (2011)'s study in New Zealand, Cohen and Paul (2004)'s research in the US, and Alam et al. (2022)'s work covering 40 transport projects funded by Asian Development Bank (ADB), Japan International Cooperation Agency, and World Bank.

However, in the developing world, adjacent regions and countries that should have been the beneficiaries of the positive spillover effects are likely to be replaced by overseas countries, especially when the pillar industries (like trading basic agricultural commodities and unprocessed natural resources) heavily depend on trading and logistics. For example, the sharp rise in transport infrastructure linking inland mines to coastal ports in Africa are primarily driven by facilitating bilateral international (hard) commodity trades (Bonfatti and Poelhekke, 2017). The countries or companies that do not have access to those particular transport networks are forced to confront higher trade costs, diminishing their competitive advantages and exacerbating their living environments (Bonfatti and Poelhekke, 2017).

In addition, the economies of agglomeration may lead to different industrialization patterns and polarised environmental consequences in wealthy regions and in poor regions in the long-run. The intensified expressway networks in China enable poor villages and towns to foster local economic growth by accommodating polluting industries that are rejected by and transferred from the wealthy regions (He et al., 2020). In contrast, after evacuating the environmental unfriendly industries, the rich areas undergo industrial modernization without losing industrial supply (He et al., 2020).

Those benefits and disbenefits account for a great portion of the long-run economic values delivered by transport projects and cannot be fully captured by assessing the actual usage of transport facilities. Unfortunately, they are generally excluded from the current state-of-the-art of BCA applied at the project level because of the lack of standardized methods of measurement and the presumed minor impact at the individual project level.

Transport infrastructure's effect on the land use pattern in adjacent and remote areas and housing prices is another topical issue. Although such an effect is normally analyzed in feasibility studies carried out at different project planning stages, it has typically only been performed qualitatively. The change in accessibility caused by a transport project is increasingly acknowledged as the kernel of quantitatively capturing such an effect. Accessibility is measured as the ease of reaching valued destinations (COTAM, 2020; Hansen, 1959), encompassing not only how fast people and goods can travel around (mobility) but also the spatial distribution of opportunities (Levinson and King, 2019). The dynamic interplay between the level of change in accessibility and that in housing price provides an opportunity to assess how much economic benefits are materialized as a result of the construction of a transport project (Mohring, 1961; Beenstock et al., 2016; Adriano Borges Costa and Zheng, 2021) and are illustrated in chapter 10. Substantial efforts have been carried out by scholars in developed countries, such as the work by Riekkinen et al. (2015) in Finland, by Dewees (1976) in Canada, by Agostini and Palmucci (2008) in Chile, and by Hess and Almeida (2007) in the US. However, other comprehensive project benefits are popular mainly in research instead of in practice, restricting the presence of comprehensive large-N studies comparing *ex ante* estimation and *ex post* observation.

3.1.4 Overall Project Performance

Overall project performance, focusing not just on individual elements of BCA but also on integral performance indicators like NPV, EIRR or BCR, is the last area of research interest, which is also our primary concern. It is notable that the literature covered here do not overlap with those listed in previous sections.

Participants in this research field include government agencies and academic researchers. Nicolaisen and Driscoll (2016) summarized eight existing *ex post* evaluation programs hosted mainly by national government agencies in OECD countries and conducted further analysis on the programs in UK (Post Opening Project Evaluation scheme) and Norway. The authors ruled out the *ex post* evaluation program carried out by multilateral development organizations such as the World Bank because inconsistent performance measures are adopted by different organizations and the ability to verify data is restricted. The authors' concerns about the quality and efficiency of those programs are addressed by developing a typology based on characteristics of each program, such as the type and number of transport projects subject to *ex post* evaluation, the time point of *ex post* analysis and etc. For instance, for projects operated by Highways England, the authors identified a proclivity for understating costs, but that does not appear in the context of benefits evaluation. In the case of Norwegian roads, the likelihood of cost overrun is the same as that of cost underrun, and more than anticipated benefits are materialized. In addition, Nicolaisen and Driscoll (2016) also underlined that data unavailability, difficulties in consistently determining counterfactual scenarios in *ex ante* and *ex post* stages, and incomparability among projects in different regions due to the adoption of highly customized *ex post* evaluation approaches restrict research on *ex post* project evaluation.

In comparison to the aforementioned three research areas, the number of academic publications delving into this topic is relatively sparse (Boardman et al., 1994; Odeck and Kjerkreit, 2019; Nicolaisen and Driscoll, 2016; Ika and Feeny, 2022). To the best of our knowledge, studies at large-N level (cover at least 10 projects) typically target projects in OECD countries like France (Meunier and Welde, 2017), Norway (Odeck and Kjerkreit, 2019; Welde and Volden, 2018) and the Czech Republic (Halámek et al., 2021) or projects financially supported by the European Commission (Florio and Vignetti, 2013; Kelly et al., 2015; Jong et al., 2019).

By providing empirical statistical evidence, those studies are conducive to formulating a holistic view of how project outcomes shift from initial anticipation based on statistical evidence, thereby identifying defects in the evaluation approach applied during planning (Kelly et al., 2015). For example, in the study on Norwegian roads, Odeck and Kjerkreit (2019) confirmed the existence of systematic underestimation of benefits and added that *ex ante* project NPV were understated by roughly 50% because the extent to which costs were understated is too petty to counterbalance the underestimation of benefits. The authors subsequently highlighted the causes of benefit underestimation are the improper base for demand forecast (relying on regional forecast instead of the project-particular one) and the prolonged interval between official project decision-making and the completion of *ex ante* BCA.

Research at the case study level is prone to select high-profile transport projects in developed countries, which consume massive investment and are expected to persistently influence the local area decades into the future, like the Coquihalla Highway in Canada (Boardman et al., 1994), the Channel Tunnel linking the UK and France (Anguera, 2006), the Oresund Bridge in Denmark (Knudsen and Rich, 2013), the Bolu Mountain Tunnel in Turkey (Kocabas and Kopurlu, 2010) and the Stockholm Metro in Sweden (Börjesson et al., 2014).

From the above literature, the imbalanced input for research on it between developed countries (mainly European countries) and developing countries is prominent, calling for further research evidence of the latter.

3.2 Concerns about Alternative Analysis

Studies of transit project planning and appraisal processes date back decades. As one of the most critical tasks to be accomplished in *ex ante* BCA, identifying the best alternative by appraising all possible options is expected to be conducted fairly and objectively (Layard et al., 1994; Bristow and Nellthorp, 2000). Four primary concerns have been identified in the literature: selection bias, funding incentives, assessment tools, and evaluation criteria.

3.2.1 Selection Bias

The boom in light rail construction that has been noted throughout the last few decades seems to challenge the impartiality of project planning (Gomez-Ibanez, 1985; Mackett and Edwards, 1998). It is purported that light rail is more advantageous than bus mode in various aspects; examples include the ability to alleviate road congestion and improve mobility (De Bruijn and Veeneman, 2009), the impact on transport network integration and urban structure (Higgins et al., 2014), the facilitation to real estate prices (Weinberger, 2001; Debrezion et al., 2007; Mulley et al., 2018), emotional advocacy by different stakeholders (Hensher et al., 2015), as well as the attractiveness to media promotion and social appeal (Olesen and Lassen, 2016); yet that doesn't show up in the BCA.

Further, deceptive tactics have been taken proactively to secure the approval of the rail-based options. In the case of the US$ 2.6 billion worth 91-mile light rail system proposed by Dallas Area Rapid Transit (DART) in the late 1980s, Kain (1990) unveiled that initially DART prepared but hid the patronage estimate for the bus-based ('do-nothing' option) alternative (with the same forecast horizon as the light rail alternative) when the project proposal was opened for public involvement, because the bus-based system would serve slightly fewer passengers at a strikingly lower cost, threatening the promotion of the competing light rail option. Kain (1990) also stated that later when DART was forced to disclose this information, the spokesmen tried to deceive the voters by denying the relevance and significance of those information to the competition between bus and rail systems.

The phenomenon that light rail prevails over bus-based transit in most cases when they are proposed together despite an objectively higher cost per rider is a typical example of selection bias. Selection bias emerges when decision-making towards a favored alternative initiates at very early stages and continuously influences the entire project planning process in an irreversible manner, which triggers scholars to question whether the planning and selection process is free from tendentiousness or discrimination (Currie and De Gruyter, 2016; Hensher, 2016; Legacy, 2016; Bickerstaff and Walker, 2005). Locking in a preferred option may positively accelerate early-stage feasibility evaluation and hence control schedule delay, but it turns to the opposite when an option is firmly locked in because other candidate alternatives are less likely to be seriously analyzed and considered (Priemus, 2007) due to path dependency and sunk cost (Cantarelli et al., 2022), limiting the possibility of driving projects to a different or even better outcome (Arthur, 1989).

3.2.2 Funding Incentives

Some scholars have pointed out that the project funding scheme impacts project selection and thus might impair the fairness of project appraisal. In the US, the evaluation and appraisal of transport projects are bound by hierarchical government structure and funding mechanisms (Weiner, 2013; Lowe, 2014). Funding earmarked to transport projects are collected at the federal level by various user taxes and then allocated to state and local authorities who lodge project funding applications (Ubbels et al., 2001). The federal-level shares project cost pressure jointly with regional governments by channeling the bulk of project funds, and the state level makes up most of the remainder (Pickrell, 1992). As a result, local authorities are strongly motivated to secure as much as possible by pursuing capital-intensive projects regardless of cost-effectiveness and worthiness (Lee Jr, 2000; Chen, 2007).

3.2.3 Assessment Tools

Substantial attention has been paid to the analytical methods engaged in project appraisal and prioritization, where BCA is doubtlessly one of the core tools (Eliasson and Lundberg, 2012; Flyvbjerg, 2009). Considering that BCA is essentially a quantitative analytical tool, its current practice in assessing transport investment centers on comparing a few important quantitative project performance specifications: project capital costs and various user benefits. As the evaluation results generated by BCA are directly fed into decision-making, the first concern lies in the relative accuracy and reliability of the results. On the one hand, if the errors in the results output by BCA cannot be controlled within an acceptable margin relative to the differences among the performances of different alternatives, the woeful accuracy of BCA is highly likely to result in nominating disqualified options (Pickrell, 1992). On the other hand, if different projects appear to be uniformly good or terrible, it would be likely that the potential values credited to each option are not exploited to sufficiently differentiate them, leading to questioning the reliability of the specifications covered or even the evaluation tools themselves (Pickrell, 1992; Quade, 1981).

The other concern about BCA roots in its nature of being an incremental assessment approach, where the incremental costs and benefits generated by ‘do-something’ options are measured against a base case - the ‘do-nothing’ option (Garber, 2002). As such, a reasonable and feasible baseline option is critical. The ‘do-nothing’ baseline option is not equivalent to an effortless ‘do-worse’ option. For instance, if the ‘no-build’ option sticks with the level of maintenance (regular Operations and Maintenance expenditure) that has already been provided for the existing transit facility, the facility would possibly undergo reduced service quality, lower travel speed, longer headway, and poorer on-time performance, which would ultimately affect demand and travelers’ benefits, resulting in a ‘do-worse’ baseline case (Mackie and Preston, 1998). As a result, the author insisted that a low-cost ‘do-minimum’ option that ensures the existing transport facility function properly (not worse) by injecting a minimum level of investment needs to be sufficiently considered as a base case. Further, project evaluation based on an implausible baseline case will be biased against ineffective alternatives, making the inefficiency's correction not viable during its expected lifetime (Lee Jr, 2000).

3.2.4 Evaluation Criteria

In contrast, project decision-making criteria upon which projects are approved or rejected are inadequately explored in the current literature (Linovski et al., 2022). Selection criteria are expected to be comprehensive and competent to reflect each option's level of fulfillment of project objectives and needs, including factors in environmental, socioeconomic, political, and financial perspectives (Priemus, 2007). However, the author recognized that the sectoral boundaries among different criteria and the independent evaluation process performed for each criterion hinder alternatives from being compared in an effective and systematic manner. In addition, an imbalanced level of commitment to different criteria may foster biased decision-making, electing one candidate that is superior in a concerning aspect but does not prevail in other aspects. For instance, Priemus (2007) and Eliasson and Fosgerau (2013) observed an emphasis on project up-front capital cost over subsequent operation costs, and Di Ciommo and Shiftan (2017) criticized the insufficient consideration of transport equity. Though multi-criteria analysis covering both quantitative and qualitative interests of various project stakeholders have been called for (Macharis et al., 2009; Macharis and Bernardini, 2015), the principle of pursuing an investment option with a higher return in the transport sector (Short and Kopp, 2005) reinforces the dominant position of cost and quantifiable user benefits in the current evaluation criteria, leaving other criteria existing only in name.

Retrospective project evaluation associates and compares *ex ante* and *ex post* project performance provides valuable insights and lessons learned in managing the aforementioned four concerns. Nevertheless, the mainstream retrospective analysis emphasizes how the actual project payoff differs from the LPA. Concentrating on the final decision made overlooks the impact of early decisions on final project outcomes, shedding little light on what undermines project success (Samset and Volden, 2016; Cantarelli et al., 2022). Although extensive reasons behind worse than expected project performance and corresponding recommendations have been proposed, cost overrun (Flyvbjerg et al., 2004; Odeck, 2004a; Cantarelli et al., 2012; Sebastian, 1990) and demand shortfall (Cruz and Sarmento, 2019; Flyvbjerg et al., 2005) have been continuously observed. As a result, a complete alternative history *ex post* evaluation session investigating the process of judging the robustness and viability of the selected option and involving the rejected alternatives is needed.

3.3 Problems with the Existing Benefit Assessment Method

Under the current practice of transport project benefits evaluation, travel time-based user benefits form the bulk of the direct economic benefits of transport projects (Marleau Donais et al., 2019). Nevertheless, this conventional approach has been questioned for numerous intrinsic flaws.

First, in accordance with numerous retrospective transport project evaluations, the *ex-ante* estimates of project costs and benefits based on this approach have been repeatedly reported to be highly inaccurate (Lundberg et al., 2011; Flyvbjerg et al., 2004; Odeck, 2004a; Andrić et al., 2019; Cantarelli et al., 2012; Park and Papadopoulou, 2012; Sebastian, 1990; Huo et al., 2018; Lee, 2008; Love et al., 2016; Voulgaris, 2019a; Pickrell et al., 1989; Voulgaris, 2019b; Li and Hensher, 2010; Parthasarathi and Levinson, 2010; Welde and Odeck, 2011; Hoque et al., 2022a; Flyvbjerg et al., 2005; Hartgen, 2013; Cruz and Sarmento, 2019; Nicolaisen and Driscoll, 2014). The estimates and verification of project costs are more straightforward and comparable among multiple projects than of economic benefits. The inaccurate estimations of benefits are largely driven by an inaccurate prediction of travel demand, that is traffic flow for road projects and ridership for transit projects. Demand forecasts lay the foundation upon which the evaluation of all types of economic benefits relies. While projecting demand is a complicated mechanism encompassing the aggregate behavior of travelers and commuters (Ceder, 2007), it is even harder to deliver accurate demand forecasts for transit projects than for road projects (Cruz and Sarmento, 2019; Flyvbjerg et al., 2005; Flyvbjerg, 2007, 2009; Voulgaris, 2019a; Pickrell et al., 1989; Bain and Polakovic, 2005; Mackinder and Evans, 1981).

Second, monetizing economic benefits using non-market valuations (shadow price) further erodes the credibility of the estimation results (Ackerman and Heinzerling, 2002). Labeling intangible resources (travel time) and human feelings (level of comfort) with an arbitrary price is recognized as a congenital defect for the traditional BCA. Although the rationale underlying such monetization processes is logical from the traditional rational planning approach, the consideration paid for acquiring those intangible benefits is not credibly quantified because there is no market trading them and no prices are quoted (Ackerman and Heinzerling, 2002). As a result, Ackerman and Heinzerling (2002) insist that the unit dollar value of those benefits is determined under official guidance that is primarily extracted from past experience on comparable projects, but suffers from a lack of attention to project-specific characteristics. For example, when evaluating the Second Avenue Subway, the baseline unit value of travel time savings is set to be equal to the average hourly rate in New York Metropolitan area under FTA 5309 guidance (The Metropolitan Transportation Authority, 1999). However, how travelers value travel time reduction varies with income (Lisco, 1967). The prevailing hourly rate in Manhattan which the Second Avenue Subway serves is higher than the average hourly rate across New York (U.S. Census Bureau, 2017a). The proportion of high-income groups is also higher in Manhattan, so the unit value of travel time assigned to this group of people should also be higher (U.S. Census Bureau, 2017b). Although various methods like considering both stated and revealed preference of value of time have been used to justify the reasonableness of shadow price, arbitrarily pricing unpriced resources is a congenital defect.

Third, both project costs and benefits are calculated by an incremental approach, which essentially recognizes the costs incurred or benefits generated in addition to the baseline 'no-build' case (Florio and Vignetti, 2013; Kelly et al., 2015). As a result, the accuracy of both *ex ante* and *ex post* evaluations are subject to the consistency and appropriateness of the designated counterfactual 'no-build' scenario. Particularly for *ex post* evaluations, whether the counterfactual base scenario remains to be appropriate is constrained by the unpredictability of how the external environment evolves as a result of the project and how the project responds to that evolution. In addition, amid high uncertainty and assumptions inherent in the evaluation process, managing and tracking systematic biases and manipulation in a timely manner are uphill tasks. Retrospective *ex post* evaluations, as one of the primary approaches to this, generally initiate years after project opening considering the difficulties in data collection and ramp-up effects (Flyvbjerg, 2003; Li and Hensher, 2010), imposing a substantial time lag on drawing lessons learned and feeding back to new projects. In addition, to ensure the comparability between *ex ante* and *ex post* analysis, they apply consistent evaluation methods and standards under similar assumptions, which spontaneously discount the effectiveness and quality of the *ex post* verification.

Fourth, determining a feasible 'do-something' project option based on the traditional method has potentially undermined project success from the early planning stage (Mackie and Preston, 1998; Lee Jr, 2000). As one of the earliest key milestones, various candidate project alternatives are analyzed and compared to screen out the ultimate locally preferred alternative. Project alternatives with the same transport mode are differentiated from each other mainly in route alignment. Altering route alignment seems to have subtle impacts on serving capacity, resulting in little difference in usage forecasts. But its impacts on the value of the real estate in the vicinity of key transport nodes can be substantial. However, the current evaluation methods fail to capture the direct land value uplift, negating the potential benefit-generating capacity of candidate alternatives and resulting in unequal or unfair comparisons among them.

Fifth, though the primary contribution of transport infrastructure in various modes may be improving access and equity (Geurs et al., 2016), they differ in benefit-generating mode, the types of benefits, and the scale. The bottom-up evaluation approach applied to aggregate project benefits only considers what can be accurately quantified and reliably measured, overlooking those unquantifiable benefits even if they are important (Nash, 1997; Beria et al., 2012). Uniformly applying the same benefit assessment approach might stifle mode-specific advantages, failing to adequately exploit potential economic benefits that a transport project would generate. Travel time savings benefits seemingly intuitively sketch out how the proposed project would achieve transport-related objectives, which is typically the predominant gains evaluated when assessing the feasibility of transportation investment (Beesley, 1965). However, land use related gains, which would have been supposed to be a key benefit but are perhaps less predictable and measurable (certainly they are not direct outputs of transport models, and are typically outside the domain of transport modelers), are generally swept off in the quantitative BCA analysis and thus fail to contribute during project prioritization and selection (Wang et al., 2019). For example, compared to the residential and commercial properties in remote suburbs, those at the urban core are more expensive and more sensitive to changes in the transit network, enabling a valuation method based on house price appreciation. However, house price uplifts are not one of the critical benefits being independently and directly examined in the traditional travel time savings (TTS) assessment approach, and considering both would risk double-counting the benefit. Moreover, network effects arise and can be recognized when the presence of an additional transport service or facility positively impacts the existing network as a whole (Page and Lopatka, 1999; Liu et al., 2022). Although network effects as a result of improved integration and coverage are always claimed to be important in terms of the ability to offer access benefits (Curtis and Scheurer, 2016), they are imprecisely assessed and implicitly included in the current project appraisal method (Laird et al., 2005). Liu et al. (2022) point out that housing markets are sensitive to public transport network effects, showing higher price increments when positive network externalities take place.

Sixth, in contrast with decisions on house purchases, travel decisions are provisional, changing frequently and dynamically, necessitating fictitious assumptions on factors and events influential in travel behaviors. Real estate purchasing decisions are less frequent and thus more appropriate for evaluating long-term infrastructure investments, which encompass factors directly and indirectly affecting travel behaviors and naturally reflect the weights of each factor based on subjective preferences from individual perceptions. As a result, evaluating transport project benefits based on real estate valuation changes might reduce noise and uncertainty in valuation.

Seventh, many of the large cities across the globe are confronted with the financial stalemate in constructing and operating public transport infrastructure, but the time savings-based benefit evaluation method is challenged in its ability to serve the creation of a seamless and sustainable rotation of capital. Travel time savings are essential gains in users' utility which are monetized through welfare analysis by capturing consumers' surplus informed either by users' stated preference (willingness-to-pay) or wage (Jara-Diaz, 1990). In the absence of tolls or high fares, the demonstrated economic benefits cannot be directly collected and fed into future projects. The conventional funding sources covering the up-front capital expenditures of transport projects originate from tax revenues. Considering the absence of a strong linkage between general tax revenues and allocation as well as the fierce competition for public coffers, transport projects cannot secure funding sources when acute issues in other public services like health and education arise (Ubbels et al., 2001). Special-purpose taxation revenues (such as fuel duty or congestion charges in the US) are partially or entirely earmarked for public transport. In the last decade, the sustainability of the earmarked funding mechanism has been weakened due to the deployment of vehicle electrification, and strong public protest against tax rises (Zhao et al., 2012; Istrate and Levinson, 2011). Farrell (1999) mentioned that particular attention had been drawn to the distribution of earmarked grants. The steep growth of the total costs required by the transport sector are incommensurate with the operational revenues generated by user charges, so that almost all transit systems across the world are drowned in red ink. Since maintaining transit services is considered to be aligned with government objectives (providing access for all users) and to be in the interest of the public, government subsidies have been continuously offered to cover operational deficits (Black, 1995).

3.4 Towards an Access-based Land Value Uplift Benefit Assessment Method

The aforementioned defects in the benefit assessment in the current BCA approach necessitate the search for an alternative benefit assessment method, and among all feasible approaches the access-based land value capture (LVC) has been gradually popularized.

First, this method is rooted in the consensus that the primary motivation of transport development is facilitating access to desired places instead of shortening travel time (Du and Mulley, 2012; Levine et al., 2019; Levinson and Wu, 2020; Sun et al., 2016; Wen et al., 2018; Lin and Hwang, 2004; Riekkinen et al., 2015; Dewees, 1976; Agostini and Palmucci, 2008; Hess and Almeida, 2007; Dubé et al., 2013). Access is an indicator of the level of development of transportation network. The value of access derives from its ability to connect places and people, which depends on the location of people and the directness, speed, and, in the case of transit, frequency of the transport network (Istrate and Levinson, 2011). After decades of research, the definition and calculation method of access (or accessibility) are ample and diversified, but a consensus has been sustained that it measures the ease of reaching (or being reached by) designated opportunities from a particular origin (Hansen, 1959; COTAM, 2020). The rationale behind LVC lies in that the economic value of a transport project's intangible gains, including both travel time savings and comfort, as well as their option value, is largely capitalized by nearby properties' value appreciation, which could be taxed and redistributed to support future projects (Batt, 2001; Mathur, 2014; Medda, 2012). Property owners who enjoy unearned wealth as a result of possessing premises in the vicinity of new transit facilities can relinquish windfall fortune without showing a loss (Smith and Gihring, 2006).

The positive correlation between land value or property price and location advantages (places with high access to manifold opportunities) further reinforces the viability of the access-based method. Hansen (1959) addressed that the possibility of being intensively developed is higher for regions with better access. Wegener (2004) accentuated that the interplay between travel behavior and location choice facilitates that transport planning needs to synchronize with land utilization planning, which lays the foundation for American urban planning in recent decades. Brigham (1965) pointed out that the value of a piece of land is jointly determined by its access, comfort level, geographical features, and other unquantifiable factors. He further specifies that among houses that are in equal proximity to the city center, those with better access are more expensive. For instance, Dubé et al. (2013) found that the new transit service in Montreal's South Shore created location advantages for properties close to transit stations, resulting in value appreciation in those properties.

Second, the measures (accessibility and house price) that the access-based method used are more inclusive and economically informative than those used in the time-saving method. As described previously, accessibility is a comprehensive measure covering concerns on time, distance, and trip purpose (Páez et al., 2012). Horner (2004) deems job accessibility to be a leading factor influencing buyers' residential property choices. Decisions on property choice are generally made after synthesizing people's willingness to pay for numerous activities and rights (Kim and Horner, 2003), so property price is remarkably informative. Concerns about travel time, expenses, and distance for trips have been well encompassed and reflected in the house purchasing decisions (Mohd Thas Thaker and Chandra Sakaran, 2016; Fierro et al., 2009). Apart from that, concerns on qualitative factors, such as natural environment (Hörnsten and Fredman, 2000; Tan, 2012) and the quality of adjacent neighborhoods (Rohe and Stewart, 1996; Parkes et al., 2002; Kim et al., 2005; Caudill et al., 2015), cannot be quantitatively captured by the time-saving method, but can be precisely included in house price and thus grasped by the access-based approach.

Unlike the value of travel time which is arbitrarily and subjectively decided, the market value of real estate can be easily ascertained through online databases. Benefitting from the demand-supply relationship and fierce competition in real estate market, property price is an objective indicator, and the price data is open and transparent (Adair et al., 1996). In addition, house price data can be acquired at low cost and updated whenever it needs. As a result, integrating access measures and land value when studying transport impacts can capture project benefits that have been largely neglected in the travel time-based approach (Mohring, 1961, 1993).

Many researchers have perceived and exemplified the impact of transport infrastructure or policies on housing prices (Sun et al., 2016; Wen et al., 2018; Lin and Hwang, 2004; Riekkinen et al., 2015; Dewees, 1976; Agostini and Palmucci, 2008; Hess and Almeida, 2007; Costa et al., 2021), and some of them have taken this opportunity to approximate property value appreciation and weigh against project cost (Gu and Zheng, 2010). But we notice two limitations.

First, it is observed that the measures of access are inconsistent and confused with the measures of distance. In the existing empirical studies, independent variables representing the effect

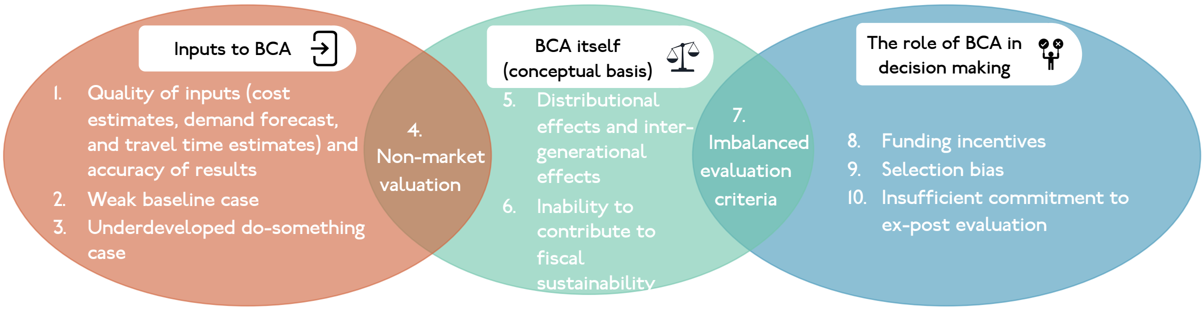


Figure 3.1 A classification of criticisms of quality of inputs to BCA vs. BCA itself vs. the role of BCA in decision-making process

of a transport project are set up and regressed on housing price to judge the magnitude of impact on housing price based on the coefficient output by the regression model. But the accessibility variable is virtually various distances (network distance (Lewis-Workman and Brod, 1997; Dewees, 1976) or straight-line distance (Gu and Zheng, 2010; Hess and Almeida, 2007; Lin and Hwang, 2004; Sun et al., 2016; Riekkinen et al., 2015; Bowes and Ihlanfeldt, 2001; Chen et al., 1998)) to designated destinations which are generally the city center or the closest transit station, which are at best poor surrogates for measures of the actual number of opportunities.

Second, they stop by either observing the tendency as to how housing price has shifted before and after the delivery of a new transport project, or imprecisely estimating property value appreciation by multiplying the total market value of affected properties and the coefficient (Gu and Zheng, 2010). Making improvements on the existing findings by aggregating housing value increment by property type, discounting the total appreciation back to present value, and weighing this value against total project cost would enable the computation of cost-effectiveness measurements like net present value and benefit-cost ratio.

3.5 Conclusion and Discussion

This chapter reflects on the current practice of BCA in the transport sector by synthesizing numerous criticisms and challenges raised and discussed in the current literature. To develop a proper understanding of BCA grounded on the literature, it is critical to distinguish between the criticisms of the quality of inputs to BCA, BCA itself, and the role of BCA in the decision-making process (shown in figure 3.1).

The first category of criticisms centers on various inputs to BCA, including cost estimates and benefit projections (section 3.1) as well as the exploration of project alternative options (section 3.2). Although deficiencies in inputs to BCA are not inherent deficits of BCA itself, they would likely compromise the accuracy and credibility of conclusions drawn upon BCA calculations.

Regarding BCA itself, the choice of discounting method (sections 3.2.3 and 2.4.3) embedded in conventional BCA assumes that the preference for immediate rewards is time-invariant. This underlying assumption is vulnerable in terms of assessing the inter-temporal influence of projects on succeeding generations and social equity. Monetizing the bulk of travel-time-related benefits based on NMV in which parameters are elicited based on past experience and lack project-specific calibrations may misstate project benefits. In addition, grounded on welfare analysis, NMV approaches benefits through users' utility gains, providing limited practical implications on getting through the financial stalemate confronted by public transport infrastructure.

The last category of criticisms points out the limited role of BCA in the wider decision-making process. BCA, due to its quantitative nature, is restricted in embracing wide and balanced evaluation criteria. It mainly assesses the relative desirability of an alternative in terms of economic welfare (section 3.2.4). However, there are indeed numerous factors and considerations (i.e., funding incentives selection preferences, social equity and environmental goals, discussed in section 3.2) involved in the decision-making process, which may divert the final decision away from the best options sorted out by BCA. As such, the choices between candidate alternatives are the responsibility of decision-makers rather than BCA.

The aforementioned defects in the benefit assessment methods in the present BCA process compel the search for an alternative benefit assessment method. The access-based land value capture method is investigated (section 3.4). This method is rooted in the consensus that transport development improves access to desired places and that accessibility gains are capitalized in the value of affected land or property.

Chapter 4

A review of Access-based Land Value Appreciation for Assessing Project Benefits

4.1 Introduction

Transport improvements go far beyond allowing people and vehicles to travel faster. The current practice of planning for, and evaluating, transport places overwhelming weight on the movement function of transport infrastructure, resulting in broad application of the mobility-oriented transport project evaluation framework. Travel time savings (TTS) is generally deemed to be the primary performance metric of mobility benefits. A substantial number of *ex post* project evaluations have empirically demonstrated the weakness of travel-time-based user benefit assessment, with the main critiques centering on:

1. Inability to screen out the best option due to weak baseline cases, underdeveloped 'do-something cases (Mackie and Preston, 1998; Lee Jr, 2000),
2. Inaccuracy in result triggered by deficiencies in inputs to BCA (Pickrell et al., 1989; Flyvbjerg et al., 2004; Odeck, 2004a),
3. Incompleteness in the scope of outcomes (costs and benefits) as a result of imbalanced evaluation and selection criteria as well as limited impacts of BCA on the decision-making processes (Laird et al., 2005),
4. Incredibility in pricing the priceless (i.e. travel time) with Non-Market Valuation (NMV)

(Ackerman and Heinzerling, 2002), and

5. Incompetence in generating funding and sustaining the investment cycle.

As explained in chapter 3, the above critiques can be classified into three categories (as shown by figure 4.1): criticisms of inputs to BCA (critique 2), the conceptual and empirical basis of the BCA framework itself (critiques 1 and 4), and the role of BCA in decision-making processes (critiques 2 and 3).

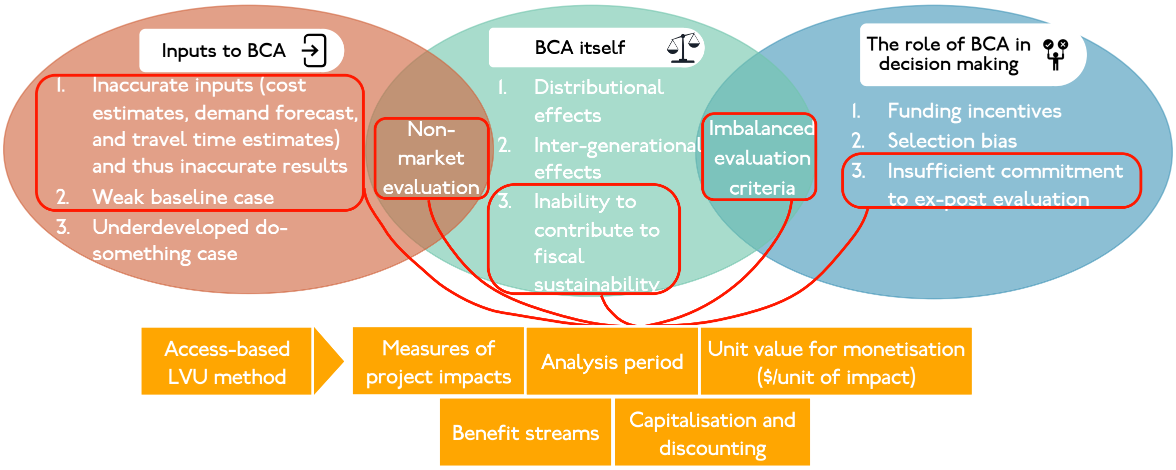


Figure 4.1 Problems that can be mitigated by using Access-based method

In theory, TTS measuring the first-order change in consumer surplus should have already fully captured the impacts associated with a transport intervention. Whereas in practice, there are measurement problems and valuation issues. The poor measurement problems can be ascribed to inaccurate inputs to BCA, which have been observed and reported in numerous literature. The valuation issues are ascribed to the Non-market Valuation. As travel time is not a market good, then whether the unit dollar value of TT saved informed by wages or stated preference method is properly representative becomes controversial. These practical deficiencies facilitate the exploration of an alternative benefit assessment approach.

Instead of saving time, the mission of transport should be about connecting people with all the resources and opportunities they value, where access metrics measuring the ease of reaching those options should have been considered and incorporated in transport planning and evaluation (COTAM, 2020). The *Fundamental Model of Access* (as shown by figure 4.2) (COTAM, 2020) provides a theoretical explanation about the positive feedback loop among transport systems, access, land use, and travel demand activity systems, and financial systems. Transport improvements (like increasing network speed and reducing travel distance) are anticipated to

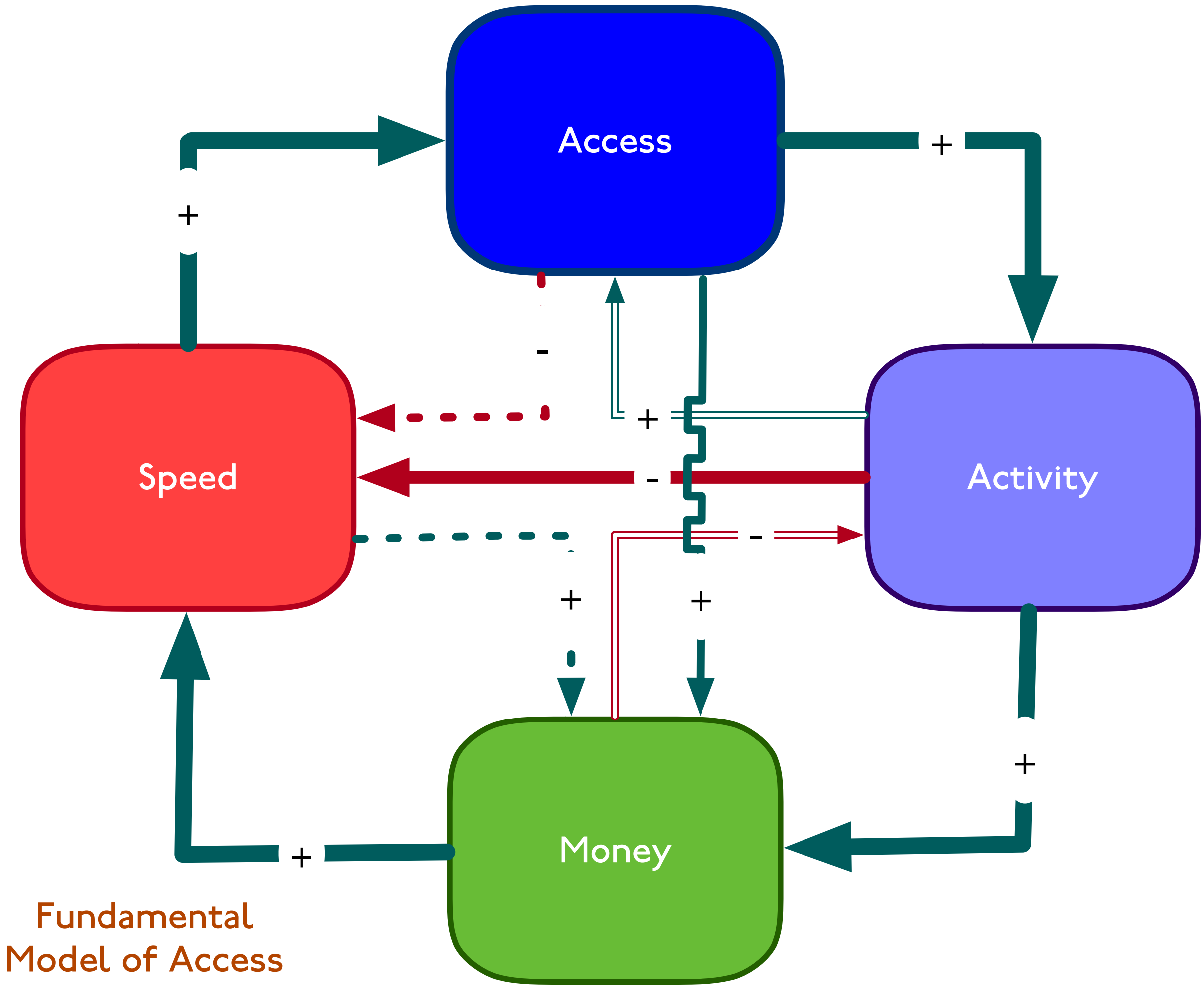


Figure 4.2 Fundamental Model of Access
Source: COTAM (2020)

reduce generalized costs of journeys for land in the precincts, which increases access. The more accessible the land, the more activities will want to occur there, and thereby conferring compact land use in the long term as business activities concentrate and denser housing is constructed. More activity creates better opportunities to maximize profitability by exploiting economies of agglomeration. In this case, the access benefits triggered by locational advantages are capitalized into real estate value. Alonso (1964) and Muth (1969) develop bid-rent theory, an urban economic model where people and companies compete with one another and are willing to pay a premium for the land with better access.

We note the policy significance of that, as it is important not only for assessing benefits more accurately, but that the transport provider can capture some of the land value gains accruing to individuals or businesses to fund or finance transport improvements (Zhao et al., 2012), closing the feedback loop between benefits and project implementation.

The traditional travel-time-based benefit valuation method engages changes in travel time as the key measure of project impacts, which are anticipated to be observed and estimated from project construction and through the life of project operation. The prescribed value of time parameters monetise changes in travel time, where all benefit streams associated with changes in travel time are discounted back to the base year. The key considerations in this benefit valuation system include measurements of project impacts, analysis period (time frame or project stage), the unit dollar value for benefit monetisation, benefit streams, as well as capitalisation and discount rates.

There is a wealth of literature demonstrating the capitalization effect of access benefits induced by transport improvements to property value, some of which are reviewed in this paper. Although the positive correlation between property price and proximity to transport infrastructure has been found, access-based land or real estate value uplift method hasn't yet been widely recognized and employed as an official tool assisting transport evaluation and decision-making. The empirical research design and economic parameters to allow these findings to be directly applied to project evaluation remains incomplete. The objective of the present chapter is to discuss the practical practice and gaps in the access-based land value uplift method based on empirical studies and evidence.

4.2 A comparison of the access-based and TTS-based benefit assessment methods

Before diving into the practical methodology of the access-based benefit assessment method, how it conceptually and empirically differs from the TTS-based method is established in this section.

As visualised in figure 4.3, the comparison is approached from the key considerations underpinning the benefit assessment process. The evaluation process starts by outlining a series of real and plausible candidate project options deemed appropriate to address the identified needs. Generally, a minimum of three options are required: a 'do-nothing' *base case* option, a 'do-minimum' option, and a 'do-something' option.

In the next step of identifying and measuring all the possible impacts of each option on the

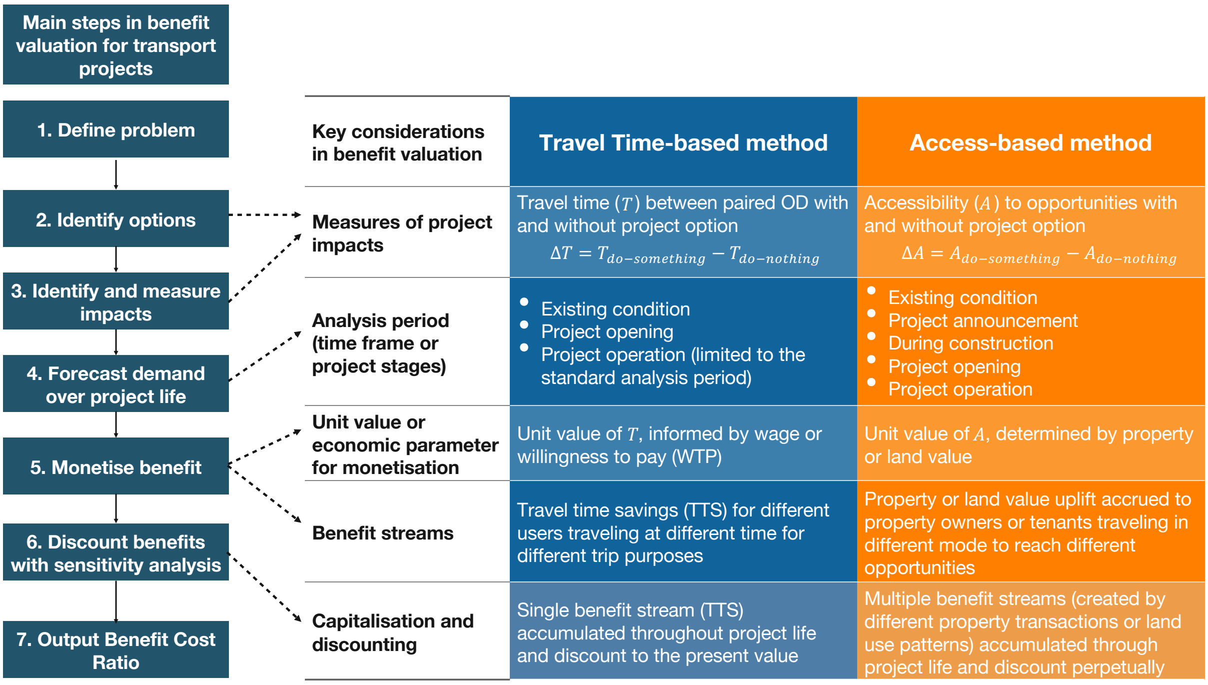


Figure 4.3 A comparison of the access-based and TTS-based benefit evaluation methods

current operation/situation relative to the *base case* scenario, the first key consideration kicks in. The primary measure of project impacts adopted in the travel-time-based benefit assessment method is travel time changes. In the access-based approach, the **choice of measurements of project impacts** is the changes in access (ΔA). Access (or accessibility) measures the ease of reaching (or being reached by) designated opportunities from a particular origin (Hansen, 1959; COTAM, 2020).

Then a question arises whether changes in travel time equals access driven by transport improvements. To address this question, a sample simulation has been undertaken. Assume that there is an origin (point A) and destination (point B) connected by a single road segment with a length of d km. Jobs distribute evenly along the road segment at a density of ρ with an unit of account being the number of jobs per km. A weighted cumulative opportunities (jobs) measure $A_{i,Jobs,T1}$ is adopted as the access measure (shown in equation 4.1).

$$A_{i,Jobs,T1} = \sum_j O_j f(C_{ij}) \tag{4.1}$$

Where:

$A_{i,Jobs,T1}$: the number of jobs that can be reached within 60 minutes (1 hour) from the origin (i, either points A or B).

j: the destination can be reached within 1-hour travel time at a given travel speed.

O_j: the number of opportunities (jobs) accumulated along the route to destination j.

$f(C_{ij})$: impedance function. Among various impedance functions, an exponential impedance function $f(C_{ij}) = e^{\beta C_{ij}}$ is chosen for illustration. The β parameter takes the best model fit value of -0.054, which was reported by Wu et al. (2021) and Feldman et al. (2012) (cited in COTAM (2020)).

Given the baseline vehicle speed of V_0 km/h, the baseline $A_{Jobs,T1,0}$ is calculated by the jobs that can be reached within 1-hour driving multiplied by the integral from 0 to 1 of the impedance function, which is shown in equation 4.3. At this speed, the average travel time (T_0) is calculated as equation 4.2.

$$T_0 = \frac{d}{V_0} \tag{4.2}$$

$$A_{i,Jobs,T1,n} = V_0 \times 1 \times \rho \times \int_0^1 exp^{\beta C_{ij}}\, dCij \tag{4.3}$$

Assume that a transport intervention that could increase travel speed from V_0 to V_n is under investigation. To simplify this proof-of-concept simulation, it is assumed that the transport intervention only affects travel speed and hence has impacts on both travel time and access to jobs. As shown in equations 4.4 and 4.5, when travel speed increases to V_n, the travel time taken to travel between A and B as well as the access to jobs at speed V_n become T_n and $A_{i,Jobs,T1,n}$, respectively.

$$T_n = \frac{d}{V_n} \tag{4.4}$$

$$A_{i,Jobs,T1,n} = V_n \times 1 \times \rho \times \int_0^1 exp^{\beta C_{ij}}\, dCij \tag{4.5}$$

Relative to the base case, changes in travel time (ΔT) and access to jobs ($\Delta A_{i,Jobs,T1}$) are calculated as equations 4.6 and 4.7, respectively.

$$\Delta T = \frac{T_n}{T_0} - 1 \tag{4.6}$$

$$\Delta A_{i,Jobs,T1} = \frac{A_{i,Jobs,T1,n}}{A_{i,Jobs,T1,0}} - 1 \tag{4.7}$$

Substituting equations 4.2 and 4.4 into equation 4.6 as well as equations 4.3 and 4.5 into equation 4.7 respectively, after simplification, changes in travel time (ΔT) and access to jobs ($\Delta A_{i,Jobs,T1}$) can be written as:

$$\Delta T = \frac{V_0}{V_n} - 1 \tag{4.8}$$

$$\Delta A_{i,Jobs,T1} = \frac{V_n}{V_0} - 1 \tag{4.9}$$

Equation 4.8 shows that given a constant distance, changes in travel time are a function of travel speed, which is expected to be a negative value lying within the range of 0 and -1. Equation 4.9 demonstrates that changes in access to jobs are a function of travel speed regardless of the choice of impedance functions, which is expected to be a positive value lying within the range of 0 and positive infinity.

To numerically illustrate the above process, the distance between points A and B is assumed to be 100 km, job density ρ equals 50 $jobs/km$, and the base case speed V_0 is 10 km/h. When travel speed increases from 10 km/h to 50 km/h, how travel time (ΔT) and access to jobs within 1-hour travel ($\Delta A_{i,Jobs,T1}$) change relative to the baseline case are visualised in figure 4.4. It should be noted that the change rate of travel time, which should have been negative values, takes an absolute value form to enable a direct comparison against the change rate of access to jobs.

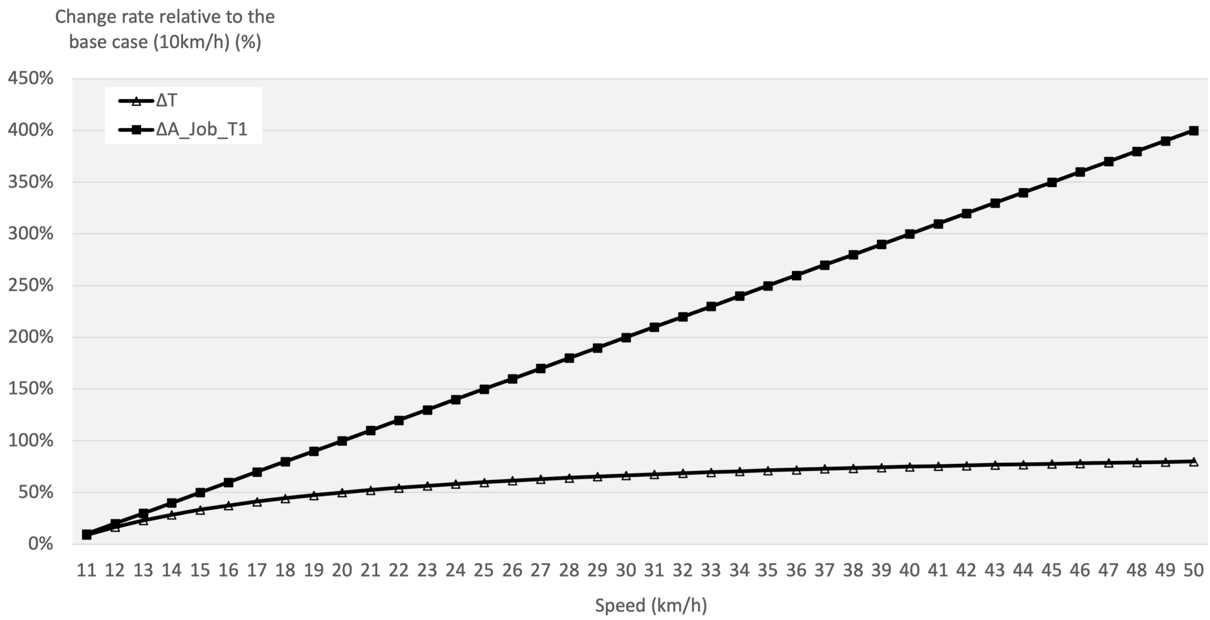


Figure 4.4 The change rate of vehicle travel time ($|\Delta T|$) and access to jobs within 1 hour by vehicle ($\Delta A_{i,Jobs,T1}$) (Detailed results are available in Appendix A.4)

The range of absolute value of ΔT lies between 9.1% and 80%, indicating that travel time can be shortened by as much as 80% relative to the base case. Whereas the value of $\Delta A_{i,Jobs,T1}$ falls into a much wider range (10% to 400%). This means that when speed reaches 50 km/h, the corresponding $A_{Jobs,T1}$ is 4 times higher than that in the base case. The slope of the line denoting the change rate of access to jobs ($\Delta A_{i,Jobs,T1}$) is much sharper than that for the (absolute) change rate of travel time (ΔT), meaning that access to jobs changes faster than travel time given the same changes in traveling speed.

Even if through some magical technology, the cost of travel on the segment were zero, travel time savings is capped at the total base travel time. However, the amount of additional access is limited only by the job density.

These results refute the hypothesis that changes in travel time equal changes in access given the same transport intervention.

The next step in benefit assessment is estimating future demand for the prospective project, which closely links to the scale of the expected benefits of each option. In this step, the analysis period needs to account for all time periods over the expected project life, leading to the second key consideration about **time frame or project stage**. The analysis period in the TTS-based method typically comprises three phases: the status quo, initial opening, and subsequent operation. The project announcement and construction phases are normally excluded. The access-based method could uncover the impacts accumulated during these two phases by disentangling changes in the land (or property) value from the perspective of owners (or tenants).

In benefit monetization (step 5), project-specific impacts identified in previous steps are monetized via multiplying the unit dollar value by the total number of users that are impacted. The amount a user is likely to pay for (or against) the gain (or loss) is the **unit value for monetization**. Non-market valuation (NMV) is the key tool of eliciting the unit dollar of travel time saved, which is informed by wages or user's willingness to pay collected from stated preference surveys. In the access-based method, the price elasticity of access is determined by real estate value, which can be dynamically updated by the latest property transactions. These elasticity parameters can be cross-validated and calibrated by employing different econometric models and controlling for any perceived influential factors.

The last step before outputting the benefit-cost ratio is summing up all types of benefit streams, discounting to the present value, and testing sensitivity using different hurdle rates and duration (expected economic life). Travel time savings form the bulk of benefit streams under the TTS-based method. The access-based method captures benefit streams derived from real estate transactions about multiple land use types, which is also affected by the type of transactions – sales and rental – with different time features. The hurdle rate refers to the minimum expected rate of return at which the project remains break-even, which generally acts as a discount factor when computing the present value of future benefit streams generated by the study transport project.

4.3 Methodology and Data

4.3.1 Data Collection Methodology

The data used in this study primarily comprise the methods and empirical results of peer-reviewed journal articles and research reports which are collected in accordance with the search processes shown in figure 4.5.

To acquire a pool of empirical research that is relevant to the studied issue, two groups of search terms were identified to enable combinations of keywords when searching in different

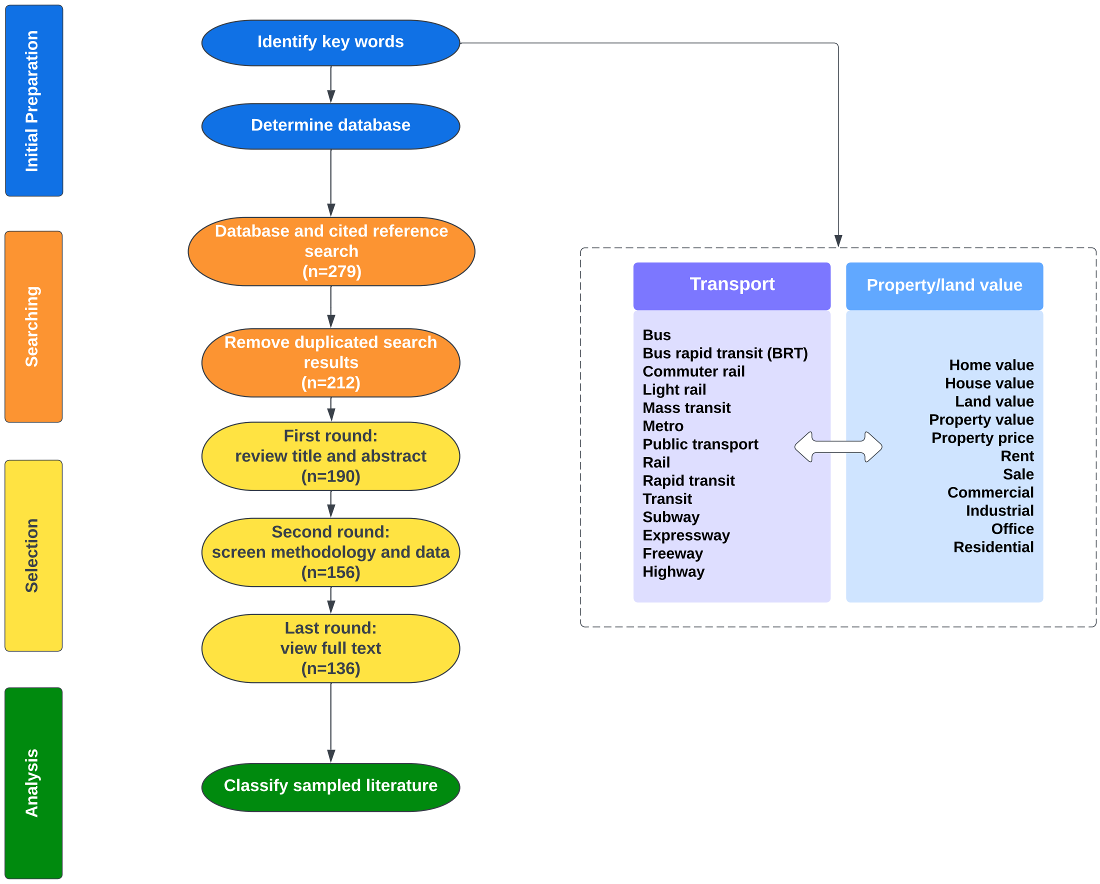


Figure 4.5 Literature Collection Methodology and Keywords Used in Literature Search

database. The first group of keywords covers different modes of transport facilities or services, which describe public transport and road transport. The second group of keywords targets at capturing considerations in housing or land valuation, including pointer words about property values and types.

Google Scholar was used for the literature search, as it returns far more related results than any library database. The settings of Google Scholar are specified as: 1) 'since 2000 ' for time range; 2) 'sort by relevance ' for result sorting; and 3) 'any type ' for source type. The time range is restricted to 'since 2000 ' to avoid incorporating early studies which may significantly differ from recent studies in study design, methodology, and data. Acknowledging that Google Scholar has limited capacity in exclusively returning peer-reviewed scholarly results, we paid particular attention to control for the quality of results, ensuring only those from peer-reviewed academic sources are included in the study.

The literature selection processes experienced several rounds of screening, finally forming a sample of 136 empirical studies.

4.3.2 Analytical Method

Grounded on the empirical studies collected, the feasibility of the access-based method is then examined by disentangling its capabilities of handling those key considerations described in figure 4.3.

Regarding the first key consideration - **choice of measurements of project impacts**, ample empirical evidence has corroborated that change in access with and without a project (ΔA) has been captured and capitalized in real estate value. However diverse access indicators have been observed, and each study uses its own metrics, making direct comparability difficult. So the sampled literature is then classified by the access measures used and the extent to which they precisely capture the changes of impact in the 'do-something' case relative to the baseline case.

In terms of the second key consideration - **time frame or project stage**, real estate data across different project stages, starting from project announcement, throughout project construction, and sustaining after project completion, can be used to capture changes in property value. As a result, particular attention has been paid to the temporal structure of study design in literature classification.

With respect to the third consideration - **unit value for monetization**, the sampled literature is stratified in accordance with the model specification and variables considered to gain a thorough understanding of the extrapolation of the price elasticity of access parameters.

Regarding to the last two key considerations, the sampled literature is then examined in terms of real estate types and transaction types to investigate the potential benefit streams that can be consolidated using the access-based method.

4.4 Key Observations about the Practice and Gaps based on the Current Literature

Figure 4.6 visualizes the geographical distribution of the sampled studies. The sampled literature comes from 34 countries across the globe, and no relevant empirical studies about Africa have been observed in the last two decades. The United States (US) and China rank the top two counties with 36 and 30 studies respectively, followed by Australia with 10, South

Korea with 8, and Canada with 6. The rapid growth of public transport system construction in developing countries fosters research on the interplay between transport infrastructure and the local real estate market. It is noted that more than one empirical study has occurred in Colombia (4), Thailand (3), and Malaysia (2).

Table 4.1 Number of Studies Observed in Each Transport Mode

		Transport Project Mode					
		BRT	Bus	Highway	Light Rail	Metro/Subway	Other Rail
Design 1	A[1]		2		1	1	
	C[2]						
	O[3]	10		8	8	14	11
Design 2	A&C				4	1	
	A&O						
	C&O	1		3	8	14	1
	All stage	5		1	5	2	
Design 3	A&C				1		
	A&O			1	1		1
	C&O	2		1	5	7	
	All stage	2	1	3	7	3	1
	Total	20	3	17	40	42	14

[1] Announcement stage
[2] Construction stage
[3] Operation stage

Among all the public transport projects investigated, light rail and metro or subway occupy the predominant proportion, followed by Bus Rapid Transit (BRT) (table 4.1. Public transport has been increasingly recognized as an effective measure to revitalize and strengthen urban development and alleviate various problems caused by automobile-oriented transport. The construction of modern fixed-guideway transit facilities have been extensively accelerated in the last a few decade, but the exorbitant construction and maintenance costs restrict them to replace conventional buses which are still the mainstay transit mode in most countries, especially in developing countries. For example, urban subway systems were opened in 36 cities in mainland China, while more than 300 cities primarily relied on traditional bus systems to serve residents' daily commuting needs (Yang et al., 2020). Accordingly, investigating the impact of access gains induced by enhanced conventional bus services on real estate market is not outmoded. The impact of highway infrastructure, although receiving less attention than transit infrastructure, is far more than satisfying people's travel demand. The heavy dependence of commercial and industrial development on the road network confers that the capitalization effect of highway infrastructure penetrates all types of land use in the real estate market. The impact of active transport investment has received little attention Mogush et al. (2016).

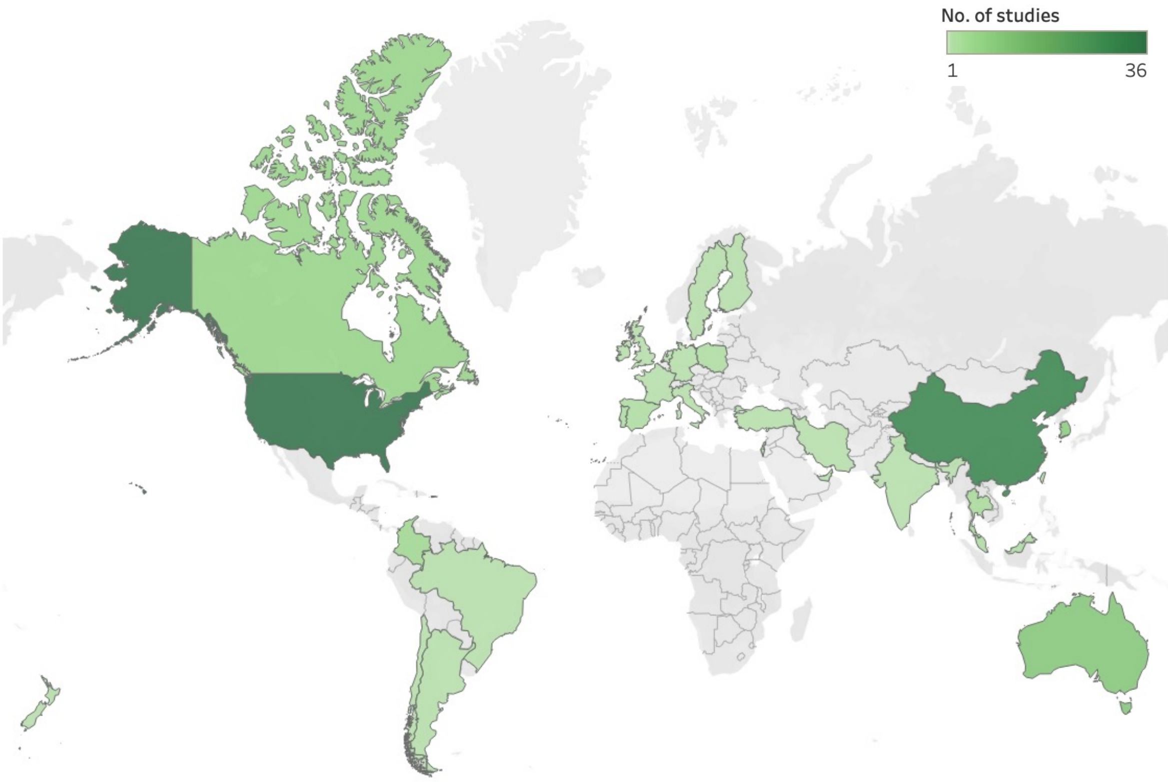


Figure 4.6 The Number of Empirical Studies by Country

4.4.1 Measurements of Project Impacts and Time Frame

The major challenge in evaluating the effect of transport intervention on real estate prices is the consequence of the confounding impact of other externalities happening in the study region and varying over time, thus resulting in specification problems in model design. This problem can be alleviated by customizing temporal and locational considerations in study design. The three general types of study design observed in the existing literature are listed as follows, which can be written as equation 4.10:

1. Covering properties in the expansive areas potentially impacted by the project or even the entire Corridor and only observing the period after project opening;
2. Comparing the price of properties in the expansive areas potentially impacted by the project or even the entire corridor before and after the project, including a temporal indicator (T_i); and

3. Comparing the price of properties in treatment and control areas before and after the project, including both a temporal and a spatial indicator (L_i);

$$P_i = f(\mathbf{A_i}, T_i, L_i) \tag{4.10}$$

where:

P_i is the price of parcel i,

$\mathbf{A_i}$ denotes a series of independent variables indicating the access of parcel i,

T_i is a temporal indicator variable assigned with a value of 1 if the price of parcel i is measured after a transport intervention (only in Study Design 2 and 3),

L_i is a locational indicator variable assigned with a value of 1 if parcel i locates in the treatment area, (only in Study Design 3)

Almost half of the sampled studies adopted the first type of design and aim to capture the general effects of transport facilities on property price without considering any changes in locational factors due to the studied transport project, thus is the least appropriate to quantify project-specific incremental impacts. Specifically, a positive correlation between property price and proximity to public transport stations is found, but the real estate price premium directly attributable to spatial advantages caused by the studied project cannot be accurately estimated. These studies are unable to distinguish between historic access benefits embedded in the price and the value of new access resulting from infrastructure investments. The value of new access may be lower than a unit of historic access if diminishing returns to access exist.

However, transport projects experience several stages, starting from project conceptualization, the official announcement, construction, opening, and post-opening. Changes in real estate property values happen in well advance of the opening of the transport facility as participants from both the demand and supply side in the real estate market initiate speculation on the prospective gains, capitalizing on expected future property uplift.

The second study design considers temporal effects (γT_i) and formulates a simple comparison about the price of properties located next to the studied transport project before and after transport investment, which has been taken by roughly 30% of sampled studies. In this case, it is expected that observations on the same study object (property) are available across many years. Mohammad et al. (2013) pointed out that panel data may outperform cross-sectional and time-series datasets in terms of the ability to calibrate for impacts caused by omitted or unobserved time-invariant factors. The starting point of the study time window to observe real estate price changes should be carefully decided to capture access benefits capitalized in prices as much as possible. However, it is observed that all the research using this design compare price changes between the construction and operation stages, but that fewer than half extend the observation time window to time stages before construction.

A strong precondition underlying the before and after comparison is that the properties covered remain comparable regardless of the intervention, which somehow overlooks the fact that real estate price changes are triggered by joint impacts, including the intervention and other extraneous factors (Salon et al., 2014). Appropriately isolating the differential impacts of the project on the base scenario and project scenario is crucial because it influences the attribution of incremental economic benefits to the studied project option.

In the last type of design which was embraced by fewer than a quarter of the sampled studies, two groups of properties are considered, one group from the control area without major transport improvements and the other group from the treatment area with access benefits induced by the transport project. This quasi-experimental design, with the presence of (θL_i) in equation 4.10, gauges the impact of the transport intervention on real estate prices by contrasting the average price change in unaffected regions over time against that in the affected regions over time, which is also known as a Difference-In-Difference (DID) method.

In terms of the establishment of the evaluation baseline, choosing control (untreated) regions that are comparable to treatment regions is particularly important to observe the actual impact of transport-related externalities in real estate prices over time. Some studies collect data about properties located in the entire affected transport corridor and define dwellings located within a pre-defined distance radius, such as a 1-kilometer radius adopted by Agostini and Palmucci (2008) and an 800-meter distance by Filippova and Sheng (2020), as the treatment group and the remaining as the control group. It is presumed that the causal relationship between transport infrastructure and property prices wears off after a specific point, though that assumes at least some of the result.

Propensity score matching (PSM) is a widely utilized alternative to decide the treatment and control groups, which could handle the issue caused by the high dimensionality of property attributes. PSM methods choose control groups by pairing each (or a group of) treatment parcel with a (or a group of) control parcel of similar observable attributes, where the level of similarity (propensity score) is computed with a logistic regression model (Dehejia and Wahba, 2002). The authors insist that comparing the values of properties with identical (or similar) propensity scores but distinct locational attributes forms a less biased evaluation of the intervention impact.

4.4.2 Unit Value for Monetization

The valuation and monetization of benefits require a set of economic parameters or unit monetary values that are fairly representative, standardized in the unit of account, and periodically justifiable. Those economic values of benefits are essentially capitalized in property price or land value, which could be evaluated using the hedonic pricing model.

In hedonic theory, the differentiated good – e.g. the house – is decomposed to a bundle of commodities and characteristics that differ between specific goods (houses). The hedonic pricing model is a regression model fitted to identify the statistical relationship between property price and the set of attributes affecting it (Lancaster, 1966; Rosen, 1974; Sheppard, 1999). As shown by figure 4.7, the slope of the line showing the cumulative number of studies adopting the hedonic model gets steeper since 2009, indicating its wide use in this specific research topic. The coefficient output by a hedonic model reveals the economic value of each non-monetary characteristic of a property from the lens of property value and thus can be incorporated into benefit assessment, such as the access benefits provided by transport infrastructure. Aside from the study design described in the previous section, the validity and robustness of economic parameters estimated by hedonic models largely depend on model specification, that are the variables engaged in explaining property price.

The prices of parcels are likely to be affected by other parcels that are spatially clustered together, suggesting that property prices are not spatially independent. Concerns about spatial autocorrelation arise when a standard linear least squares method is coupled with the hedonic pricing model because of the violation of the default assumption about homoscedasticity and no autocorrelation. As observed in figure 4.6, a tendency towards using more advanced spatial hedonic models employing multilevel, spatial lag/error, and geographically weighted modeling techniques have been observed. Multilevel models enable to distinguish the differences at the parcel level and community level by outputting different error terms. A spatial lag method attempts to directly frame the spatial autocorrelation in modeling process by accounting for spatial weights and the level of spatial dependency. The residual error term in a spatial error model is decomposed into two components: an evenly distributed and spatially independent part and a spatial component. A tendency towards embracing more advanced modeling techniques, as indicated by the upward slope of the cumulative number of observations on spatial lag/error and DID model, can be observed from figure 4.7.

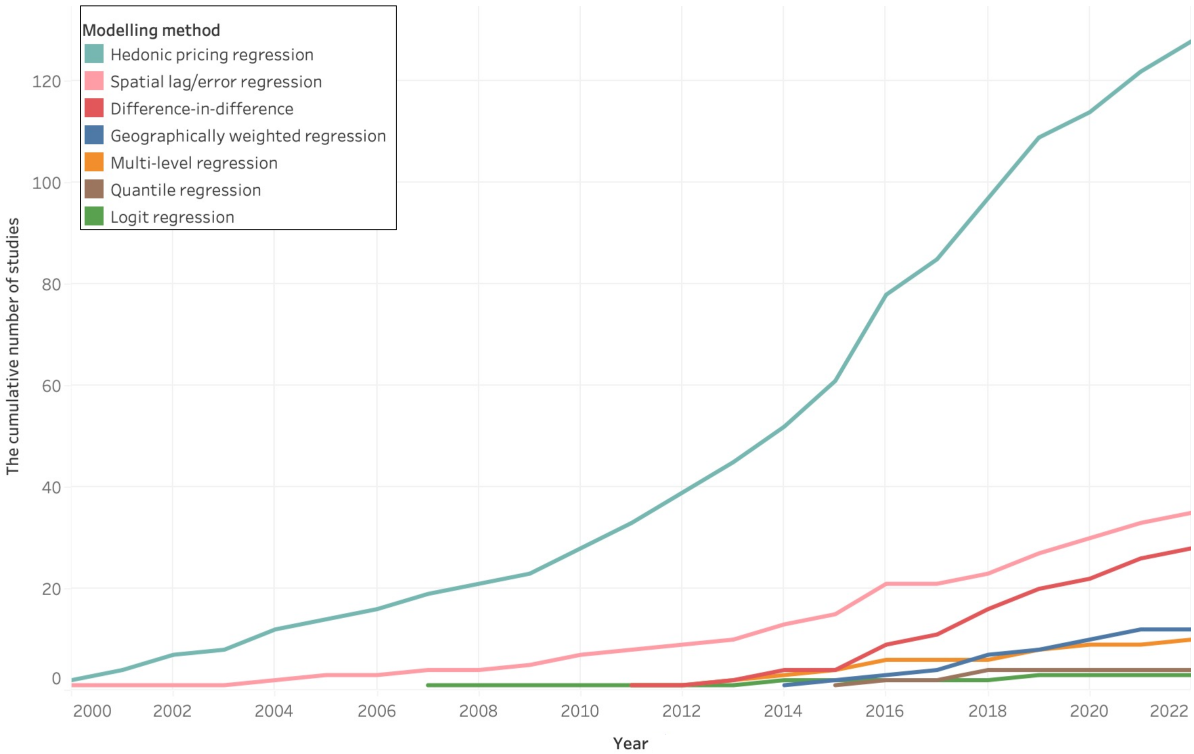


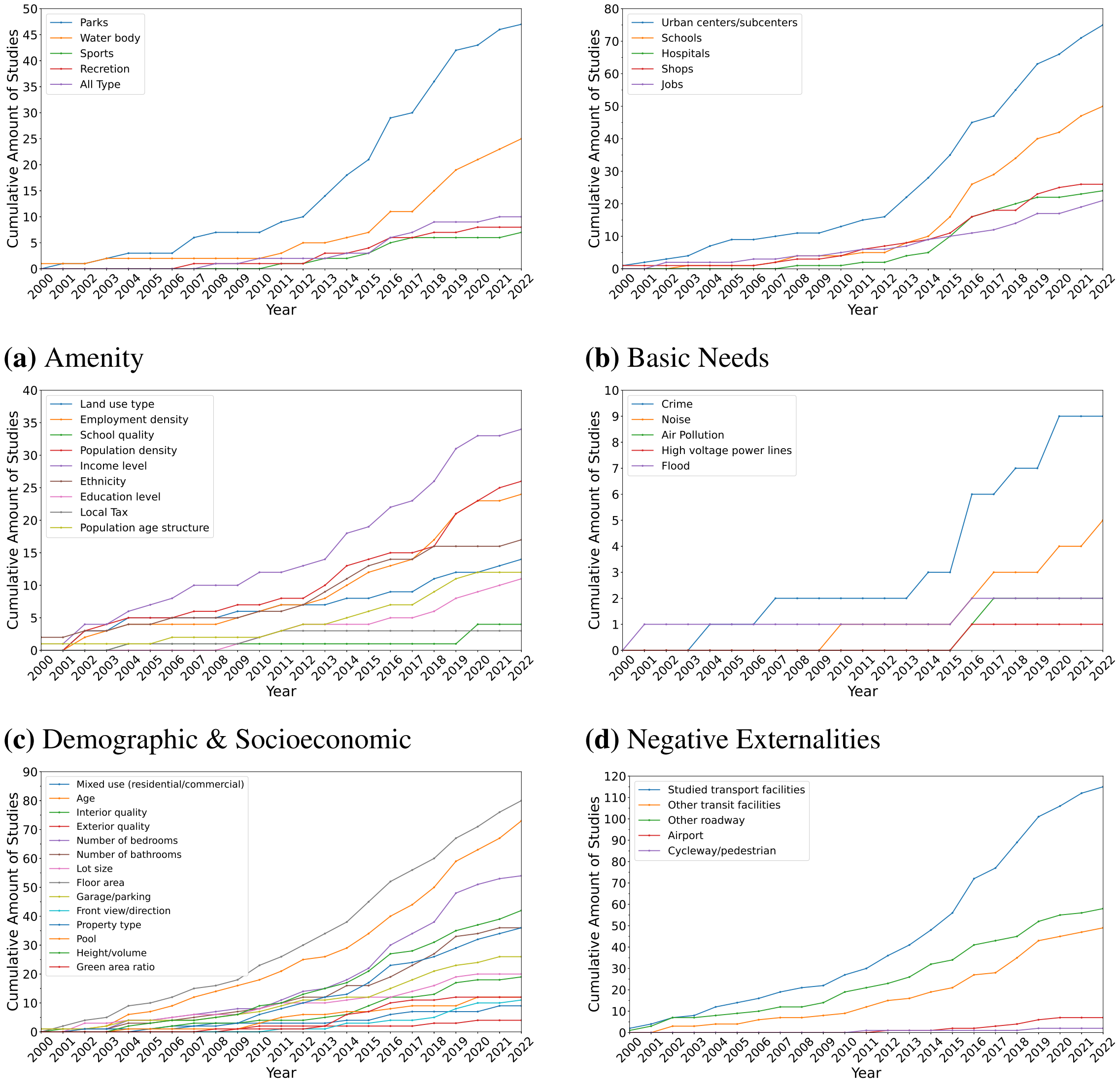
Figure 4.7 Cumulative Number of Studies by Modelling Method 2000-2022

Hedonic Pricing Model Specification

From a pool of candidate properties available in the market, the property meeting the buyer's budget requirement and meanwhile to the largest degree satisfying his (or her) needs is most likely to be chosen. Figure 4.8 summarizes the cumulative number of attributes incorporated in modeling, which are stratified into six major categories. Among all factors affecting the value of land, the geographical location determining the access of the land to surrounding opportunities is the most important one (Alonso, 1964; Mills, 1967). Distance gradients for the price of properties have been recognized by Muth (1969) and Mills (1967) in the model of urban land use and spatial distribution, where housing prices are expected to drop with the distance from the urban core.

As shown by sub-figure 4.8f in figure 4.8, the access to transport services (access to a station or interchange, e.g.) is used as an indicator of locational advantage. It is also the most frequently used variable in hedonic pricing model, as indicated by the highest cumulative number of observations shown by the y-axis. It is noted that more than half of the sampled studies did not consider access to competing transport modes (alternative transit facilities or roadways other than the studied one), overlooking the fact that access gains offered by other modes are also capitalized into real estate values (Damm et al., 1980). In addition, although cycle paths and walkways may be constructed jointly with transit projects to solve the first/last mile problem and support the access to public transport services, it is observed that active transport modes are sparsely accounted for by the current empirical literature.

The proximity to transport services is essentially a surrogate measure of access to people's needs because the purpose of going to a train station or highway is to reach the ultimate destinations. So another set of variables – the proximity to places or opportunities that fulfill people's basic needs (figure 4.8b) and amenity (4.8a) needs – is incorporated to further identify properties' locational advantages. One typical measure of the locational attribute is the distance to the central business district (CBD) in a monocentric city or the closest subcenter in a polycentric city (figure 4.8b), as a proxy of a property's position advantage relative to the whole urban area. The spatially centralized opportunities and activities available at the urban center allow distance to CBD to be a synthetic access measure (Heikkila et al., 1989). Further, access to parks and water bodies, ranked the top two attributes in the amenity category, could reveal people's willingness-to-pay for positive environmental externalities. Goodman (1978) and Linneman (1980) empirically found that neighborhood attributes are important factors affecting properties' value, which can be broadly categorized as demographic, socio-economic (figure 4.8c, and negative externalities (figure 4.8d). Income level appears to be the most common metric involved to address concerns about neighborhood quality, followed by employment density, population density, and ethnicity. Ethnicity is an intriguing factor involving a bundle of traits (such as language and religion) shared by a community. For example, Daniels (1975) tested if nonwhites tend to pay a premium to locate in a white community (Daniels, 1975). Concerns about negative externalities are rarely encompassed in modeling. In comparison to other negative impacts, crime continuously attracts attention because public transit may facilitate various



(a) Amenity

(b) Basic Needs

(c) Demographic & Socioeconomic

(d) Negative Externalities

(e) Structural

(f) Locational

Figure 4.8 Cumulative Number of Attributes by Category

crimes (Brantingham et al., 1991).

Property-specific characteristics (figure 4.8e) cover structural attributes (e.g. floor area size and the number of bedrooms) and availability of supporting facilities (like parking spaces). Garage is a frequently considered factor in housing purchase decisions. A property with an independent parking space or garage provides easier access to a weather-protected car, guaranteeing a space for a car in neighborhoods where on-street parking is competitive, and allowing the driver to remain dry or warm when the weather is adverse.

Basically, all the factors affecting site selection stem from people's concerns about access. In this case, all the variables incorporated in the hedonic model can be translated to access metrics.

$$P_i = f(\mathbf{A_{B,i}}, \mathbf{A_{N,i}}, \mathbf{A_{H,i}}, \mathbf{A_{D,i}}, ..., \mathbf{S}, \mathbf{Y}) \tag{4.11}$$

P_i is the price of property i

$A_{B,i}$ is access to the locational characteristics of property i with respect to basic living needs (e.g. access to jobs, shops, education, etc.)

$A_{N,i}$ is access to the quality of the surrounding neighborhood of property i,

$A_{H,i}$ is access to the interior and exterior structural attributes of property i,

$A_{D,i}$ is access to social groups or communities with specific qualities i,

S is the control variable for spatial effects not otherwise captured

Y is the control variable for temporal effects

However, it is observed that the sampled studies generally did not incorporate all aforementioned variables. The choice of explanatory variables has great influences on the model's goodness-of-fit which indicates its ability to explain the movement in housing prices. Omitting key variables could discount the accuracy and reliability of economic parameters, resulting in misvaluation of the consumers' marginal revealed willingness to pay (Wooldridge, 2015).

Measures of Access to Opportunities

Being close to desired opportunities and away from undesired ones provides intangible gains, which are of great value but do not come with a market price. The way the access attributes are defined and measured has great impacts on the unit monetary value output by the hedonic regression model. It is observed from the literature that different types of operational measures of access have been engaged, these include:

1. **Euclidean distance** measures the straight-line length between two points, providing a straightforward indication of physical distance, which is the most frequently used method.

2. **Buffer ring** is a measure based on Euclidean distance. It classifies whether a feature of concern falls in a pre-determined distance buffer and generally sets as a dummy variable.

3. **Network distance** is the distance between origins and destinations when traveling along the existing transport network such as road or transit network.

4. **Travel time** is the duration of time spent traveling between origins and destinations in a specified transport mode. E.g. the auto travel time spends arriving at the closest motorway entry point, or the shortest time spends traveling to the closest employment hub by bus.

5. **Primal access** (shown in Equation 4.12) measures the number of opportunities (O_j) that can be reached within a specified cost function ($f(C_{ij})$), which is also called 'opportunity-denominated' access.

The generalised function for primal access can be written generally as (Levinson and Wu, 2020):

$$\mathbf{A_i} = \sum_{j=1}^{J} g(\mathbf{O_j})\, f(\mathbf{C_{ij}}) \tag{4.12}$$

Roughly two-thirds of studies used Euclidean distance, followed by distance buffer ring observed in 55%, network distance in 23%, primal access in 17%, and travel time in 12.5% of sampled studies, respectively. In comparison to network distance and travel time, Euclidean distance provides the least information. It neglects the fact that people travel along a transport network where the actual travel distance differs significantly from the straight-line distance, which can be measured by network circuity (Levinson and El-Geneidy, 2009). Aside from that, Euclidean distance is a mode-insensitive measure. For example, the Euclidean distance between a property and the town center is a constant value, which fails to reflect the speed or convenience provided by different transport modes. Given such, this measure can hardly capture the real contribution of improvements in the transport network to reduce spatial separation. Network distance provides a more realistic proxy of the movement trajectory between an origin and a destination. But travel choices are affected by confounding factors where distance has limited capacity to explain people's behavior. Zahavi and Talvitie (1980) pointed out that travel time and money costs display great influence on travel behavior. In this case, both measured and reported travel times are used to represent travel experiences.

However, access measures are expected to consist of two fundamental factors: the cost incurred to overcome the spatial impedance to reach the opportunity and the quality or number of opportunities (Páez et al., 2012). The first three measures only cover the first component but omit the second one, thereby classified as 'impedance' instead of 'access'. As shown by equation 4.12 primal access comprises two parts, the number of opportunities available at place j and an impedance function $f(C_{ij})$ accounting for factors (distance, travel time or money costs) that hinder travel from i to j (COTAM, 2020). With respect to the consideration of travel impedance, many types of impedance functions are available. For instance, in a cumulative opportunity measure, the cost of travel C_{ij} is accounted for in dichotomous form (see Equation 4.13), where a value of 1 is assigned if travel time by a specific mode (e.g. bus) is shorter than some specified threshold (e.g. 30 mins) and 0 otherwise.

$$f(C_{ij}) = 1 \text{ if } C_{ij} \leq t, \text{ else } f(C_{ij}) = 0 \tag{4.13}$$

The gravity-based cumulative opportunity measure considers that the value of an opportunity wears off with the increase in travel cost. The impedance function $f(C_{ij})$, in this case, can take on the form of a negative exponential.

4.4.3 Benefit Evaluation and Monetization

Land-use Type and Transaction Type

It is observed in figure 4.9 that over 86% of empirical studies on capitalization effects paid attention to residential properties, less than one-fifth targeted commercial properties (including office), and roughly 6% of studies involved but were not dedicated to industrial properties. In the real estate market, residential property transactions are more active and frequent than transactions about other kinds of land uses, providing a huge volume of consistent and acquirable data for statistical analysis. Residential sales data appears to be more often used than rental data, where the difficulty in obtaining the latter restrains the exploration of rental premiums. A property is deemed as a necessary good from the perspective of the rental tenant, whereas a speculator purchases a house for potential capital gains induced by transit-oriented development in the future. Assessing changes in rental income reveals the willingness-to-pay of people who actually benefit from enhanced transit access (Wang et al., 2016).

Although it is reported that rental price increment is higher in the commercial rental market than in the residential market (Mohammad et al., 2013; Debrezion et al., 2007), commercial properties received less attention. The feasibility and practicability of capturing land value uplift in the commercial real estate market may discourage the exploration of commercial properties in this topic. For example, joint development land value capture strategies have been successfully applied in Hong Kong. The local transit agency collaborates with property developers to jointly develop the land awarded by the local government at cheap prices, and then value uplift in all types of property as a result of transit-oriented development is ploughed back by claiming a fraction of capital gains from property-related transactions, which is subsequently redistributed to future transit development (Mathur, 2019). The replicability of this strategy is heavily subject to local policy and legislation, which is popular in Asian countries but sparsely observed in western countries (Istrate and Levinson, 2011).

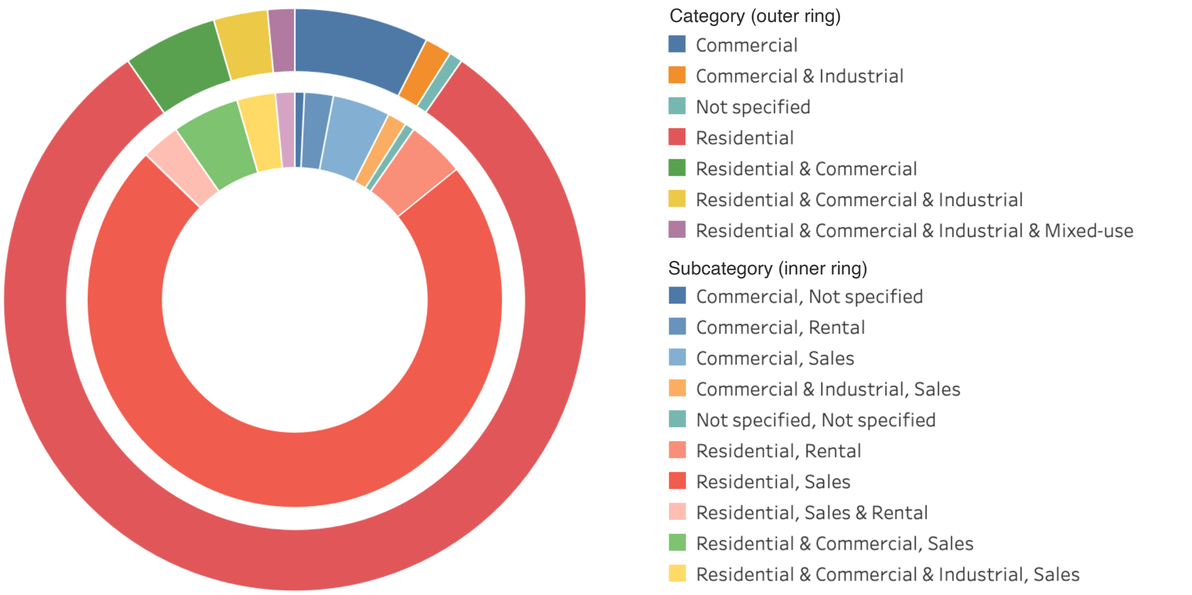


Figure 4.9 The Proportion of Real Estate Sub-market and the Proportion of Rental vs. Sales in Each Sub-market

In addition, taking commercial gentrification induced by public infrastructure, particularly public transport facilities, into account in project benefit evaluation is vital. Commercial gentrification refers to the upgrading of various local businesses by displacing the original inferior local stores (Lin and Yang, 2019). The positive externalities resultant from commercial gentrification are typically value appreciation in commercial properties, but there are also negative externalities like depriving original shoppers' source of income when they are forced to relocate elsewhere (Lim et al., 2013). The justifiability of transport project benefit assessment would be heavily discounted if the downsides of commercial gentrification are not properly accounted for by carefully overseeing the affected commercial property market.

Industrial land use received the least attention. Industrial site selection relies more heavily on port and aviation infrastructure. Consider that the current study restricts its research scope to the roadway and public transport infrastructure, limiting the number of observations about the capitalization effects of industrial properties.

Housing Price

The raw value of the dependent variable includes the price per property or per standardized areal unit (e.g. m^2 or feet^2) and the differences between the price before and after the transport intervention (typically in a repeated-sales approach). In the first form, the inclusion of absolute prices is intended to disentangle how each independent vector can explain the housing prices. Whereas using the differenced values for the same sets of properties assists to attribute the changes in property prices to all the independent variables considered. It should be noted that in the latter form, the raw values of the independent variables are generally in absolute values form instead of differenced values form, which is not a first-differenced method.

The functional form of the dependent variable, either in an absolute value form or a log-transformed ratio-scale form, would vary the interpretation of the coefficients. For example, in a semi-log model, if the number of jobs reachable within a 30-minute time threshold by bus is accommodated as a continuous variable (the unit of account is no. of jobs), a positive coefficient of 0.00002 can be explained as the property is expected to appreciate by 0.2% when the number of jobs increases by 1000.

The diverse measures of housing prices, including asking prices, sales prices, and assessment values, have pros and cons when engaged in the hedonic pricing model (Henneberry, 1998). Asking prices (or listing prices) are the prices quoted by sellers when properties are listed for sale, which represent a starting point of subsequent price bargain and thus is likely to differ from the ultimate sales price. A property's sales price is the price at which the property transaction is finally settled, which is a better indicator of the real market valuation of the property than a listing price (Debrezion et al., 2007). Although asking prices have been criticized for the divergence with sales prices (Cheshire and Sheppard, 1989) and the low likelihood of being adjusted to reflect negative factors like overhead high-tension wires (Sims and Dent, 2005), they are argued to be plausible alternatives to sales prices when the availability of the latter is limited (Du and Mulley, 2007). Han and Strange (2016) find that the proportion of property transactions closed at listing prices is nontrivially relative to those settled higher or lower than listing prices and that asking prices affect and navigate home buyers' behavior. In addition, the representativeness of the asking price varies upon the bargaining power in the local housing market. For instance, the bargaining power of purchasers is weak in the real estate market in Beijing (Zhang and Wang, 2013) and Guangzhou (Salon et al., 2014), resulting in a high likelihood of closing a deal at the asking price offered by the seller. Some markets like Australia use an auction and don't have 'asking prices' as such, though there may be a reservation price.

4.5 Concluding Remarks

The traditional travel-time-based user benefit assessment method has been repeatedly questioned for numerous flaws that are mainly related to measurement problems and valuation issues. Using the access-based method potentially outsources these issues to the real estate market, as the unit dollar value of access changes is informed by property/land value uplift. Land or property are market goods, although the real estate market is not a perfectly competitive market either. WEBs (as an externality) are increasingly accepted and evaluated in addition to TTS to capture the benefits end up in productivity and land market, reflecting the importance of benefits accrued to non-users.

This chapter disentangles the obstacles hindering a general access-based land or property value uplift method by systematically reviewing methodological design, the access metrics of transport improvements, and the target real estate sub-markets or land use types upon which access benefits are quantified.

First, it is observed that the US and China rank as the top two countries in terms of the total number of empirical studies published in this research field, and that the rapid growth of public transport system construction in developing countries should encourage research on the interplay between transport infrastructure and the local real estate market. In addition, among all the transport projects investigated, light rail, metro or subway, and BRT occupy the largest share, whereas conventional bus services, as well as roads and highways and active transport facilities received less attention despite their wide use.

Second, in terms of study design, almost half of the sampled studies just investigated the general effects of transport facilities on property price without considering any changes in locational factors due to the studied transport project, which is considered least appropriate to capture project-specific incremental impacts. For studies that considered temporal effects, the observation time window is rarely extended to time stages before construction, overlooking the fact that changes in real estate property values may happen well in advance of the opening of the transport facility as participants from both the demand and supply side in the real estate market anticipate the prospective gain. Considering that real estate prices change are triggered by joint impacts, including the studied transport intervention and other extraneous factors, choosing control regions that are comparable to treatment regions is important to isolate the differential impacts of the project on the base scenario and project scenario. However, it is pretty common to distinguish treatment and control regions by a pre-defined distance radius, which assumes the causal relationship between transport infrastructure and property prices wears off after a specific point and fails to handle the inherent high dimensionality of property attributes.

Third, although the hedonic pricing model remains the most popular model for identifying the statistical relationship between property price and the set of attributes affecting it, some studies have embraced more advanced modeling techniques such as spatial lag/error and DID model to control for bias caused by spatial dependence have been observed.

Fourth, with respect to model specification, the locational features of a property, which are indicated by proximity to transport services, amenities, and places fulfilling people's basic needs are the most frequently used variables in the hedonic pricing model to capture access benefits. Euclidean distance and distance buffer ring are the most widely used operational measures of access, measures which are mode-insensitive and neglect the fact that people travel along a transport network. Access measures are expected to consist of two fundamental factors (Wu and Levinson, 2020): the cost incurred to overcome the spatial impedance to reach the opportunity and the quality or number of opportunities. In this case, primal access measures covering the number of opportunities available at a destination and an impedance function accounting for factors (distance, travel time, or money costs) that hinder travel should be employed.

Last, over 86% of empirical studies on capitalization effects paid attention to residential properties, less than one-fifth targeted commercial properties, and roughly 6% of studies considered, but were not dedicated to, industrial properties. Property sales data appear to be more frequently applied than rental transaction data. Further, it is observed that asking prices, sales prices, and assessment values have all been used as measures of housing prices. This bias towards residential land uses in the literature presents a significant research gap that should be addressed.

There are several challenges confronted by the new method. First, adopting appropriate access measures (not distance measures) which can cover all factors (i.e., quality of transport service, quantity and quality of destinations, etc.) potentially affecting travel demand is the precondition. Access measures have not been widely applied as a transport system performance metric. So introducing access as a standardized performance measure (COTAM, 2020), establishing uniform guidance and precise metrics on access measures, and considering it as a criterion in transport investment decisions can promote the development and recognition of the access-based benefit assessment approach.

Second, land value is driven by numerous interconnected factors. Disentangling the specific proportion of land value uplift associated with accessibility improvements triggered by a transport intervention from other concurrent factors can be challenging. It is noteworthy that the hedonic pricing model, although acting as a fundamental approach to decomposing land value, is essentially a partial equilibrium model projecting land value changes within the designated study area. It is limited in terms of distinguishing the 'transferring' parts from the 'net growth' part in observed land value uplift under a general equilibrium condition.

Last, evaluating land value and changes in land value might suffer potential measurement and valuation issues. For instance, land value evaluation is subject to the availability, reliability, promptness, and quality of land value data. The lack of sound historical land value data which assists in establishing causal relationships may further complicate the land value uplift decomposition processes.

Chapter 5

Benefit-Cost Analysis in Developing Countries

5.1 Introduction

As demonstrated by ample literature regarding the *ex post* analysis for transport projects in the developed world, measuring the extent to which the results of Benefit-Cost Analysis (BCA) are consistent before and after project completion delivers important value for future project evaluation and monitoring. However, limited attention has been paid to the BCA applied to transport projects in developing countries and its accuracy. In addition, a few questions about the fundamentals of evaluation methodology, including the determination of the shadow price, the choice of discount rate, and the identification of counterfactual ‘no-build’ or ‘do-minimum’ base case upon which incremental costs and benefits are assessed, have been repeatedly raised and discussed. A discussion about how developing countries address those problems during project evaluation and how the current practice might be optimized is needed.

This chapter supplements the current literature by expanding the focus on *ex post* BCA of transport projects in the developing world. It does so by focusing on roadway projects funded by the Asian Development Bank (ADB), which possess both *ex ante* and *ex post* BCA that were prepared in a somewhat similar way, and answering the following questions.

1. Which BCA primary elements (cost or benefit items) are most vulnerable to errors?
2. How much do those BCA primary elements and other project-specific characteristics con-

tribute to the inaccuracy of the performance indicators output by BCA?

3. What is ADB's current practice in terms of the social discount rate, shadow price, and counterfactual base case?

5.2 Data

To avoid the heterogeneity caused by different modes of transport projects, this study targets 59 roadways funded by the Asian Development Bank (ADB) and erected in developing countries in Asia and Oceania. Those roads were approved between 1998-2010, constructed between 2004-2018, and evaluated between 2004-2020. The 59 projects are documented in 'ADB's Success Rates Database 2010-2018', which is a dataset produced by ADB and ADB Independent Evaluation Department (IED). The original dataset includes 72 roadway projects, but we finally retained 59 projects (82%) for *ex post* cost analysis and 23 projects for *ex post* economic analysis (32%). The selection criteria include:

1. Keep complete record of *ex ante* and *ex post* project cost breakdown
2. Disclose both *ex ante* and *ex post* project Economic Internal Rate of Return (EIRR).
3. Disclose detailed net benefit streams throughout the anticipated project life.
4. Contain reliable record of historical national economic indices like the Consumer Price Index and exchange rate to USD.

Among the 23 projects, it is worth noting that the base year chosen to calculate NPV is inconsistent. On the one hand, among different projects, the construction beginning year, project opening year, or even a few years post to project opening were observed to be used as the base year. On the other hand, for the same project, the selected base year changed between *ex ante* and *ex post* evaluation stages. Since the choice of the base year has a great influence on the final NPV, we designated the construction beginning year as the base year and recalculated the NPV for all 23 projects.

According to Asian Development Bank (2016a), ADB provides various public sector financial assistance, including loans (Ordinary Capital Resource (OCR) Loan), grants (Asian Development Fund) and technical assistance for its Developing Member Countries (DMCs) to support regional development and economic growth. From the perspective of ADB, sovereign credit rating and the level of per capita income are fundamental factors affecting the type of financial support granted. Roadway projects sampled by this study were those granted the OCR loan.

For each completed sovereign operation project in which the ADB invests in part or in full, ADB requires a two-step *ex post* evaluation process. First, it mandates a self-assessment under the supervision of ADB's regional department, producing the project completion report (PCR) (Asian Development Bank, 2016a). A PCR provides the results of an assessment of the performance of a project through four critical dimensions: relevance, effectiveness, efficiency, and sustainability (Asian Development Bank, 2016b).

- **Relevance** delves into the level of strategic alignments between the intended project and the sovereign's development priorities, the conformity of the expected project outcomes by ADB's rules and strategies, and the fitness of the project design for delivering the expected outcomes.

- **Effectiveness** assesses the extent to which the expected project outputs, represented by the project baselines and planned targets, are substantially realized when the project is completed and detects the existence of unexpected outcomes that corrode the project's value.

- **Efficiency** focuses on how successfully the resources are utilized to deliver the planned outcomes, which is central to our concerns. It is measured by EIRR, NPV, or BCR, which are recalculated and compared against the *ex ante* ones to decide if society will benefit from the net economic return generated by the project. ADB highlights that if the methods of recalculating EIRR in PCR differ substantially from that applied in *ex ante* stages, such as the alteration to underlying assumptions, parameters, discount rates, and the expected project lifespan, further clarification is warranted. For the projects sampled in this paper, we only noticed minor differences between the expected project lifespan stated in *ex ante* and *ex post* evaluation stages, but no explanations were attached. And some of the benefits which had been identified in project appraisal were eliminated in PCR. For those benefits and costs identified and extant in both stages, we did not observe any further clarification on substantial changes in the calculation methods, parameters, and assumptions.

- **Sustainability** considers the chance that project outcomes and outputs will persist over the project's foreseeable lifespan, which covers financial (the income-generating ability against the upfront capital costs), institutional, and environmental sustainability aspects.

ADB stipulates that a PCR is expected to circulate across the ADB's board and be available on the website within 1-2 years of project completion (the official closure of the project loan account).

Second, this PCR will be subsequently assessed and justified by ADB's IED Asian Development Bank (2016a). The IED, which does not participate in the preparation of PCR conducts an evaluation as either: a Project Validation Report (PVR) or a Project Performance Evaluation Report (PPER) Those two forms of independent evaluation differ in the breadth and depth of assessment, reflected by the duration of the assessment, the manner of evidence collection, and the evidence and analytical resources relied on. Asian Development Bank (2019) specifies that PVR is a quick desk review type of assessment which generally takes 2-3 weeks and relies heavily on information reported in previous documentation like PCR. Given the rapidity of the PVR, roughly 80% of completed projects are independently assessed this way. The PPER is a field-based sophisticated assessment which typically consumes 3 months or so to prepare and adopt field visits, surveys, and interviews to collect information and examine the validity of the PCR. Considering such a heavy investment of staffing and time, about 20% of completed projects go through PPER. Given the limited information available in the initially extracted dataset, we scoured PCRs for all 59 projects (and PPERS and PVRS where available) to collect additional information.

Although we tried the best we could to collect all available information about those projects in the developing countries, the lack of national open data portals recording the actual traffic states and overhead costs post to project opening restricts independent cross-validations and the traceability of the actual usage of those public facilities in the following years. It is noteworthy that in comparison to the retrospective project analysis in developed countries where the risks of projects being distorted by vested interests and potential political biases are more effectively identified, disclosed, and hedged by using transparent and objective actual operation data, relying solely on the *ex post* project analysis produced by ADB is somewhat uncertain.

5.3 Methodology

As a measure of the inconsistency of BCA results between *ex ante* and *ex post* project stage, an error is defined as the numerical discrepancy between the two stages. Various costs, economic benefits, and expected performance indicators output (mainly NPV and EIRR) are subject to the assessment of errors. We proposed four dimensions from which the errors can be assessed.

First, *frequency of error* is defined as the frequency of observed discrepancy between *ex ante* and *ex post* BCA. It is computed by the number of projects reporting discrepancy divided by the total number of projects collected. This dimension identifies the likelihood that each element of BCA is vulnerable to inaccurate estimation. Second, *magnitude of error* describes the magnitude to which the *ex post* results deviate from the corresponding *ex ante* estimation. It is measured with two patterns: errors in absolute value (E_{abs}) and errors in percent form (E_{per}). The former is calculated by equation 5.1, meaning that the absolute error of project i equals its observed value in *ex post* stage (O_i) minus its forecast value in *ex ante* stage (F_i). And the arithmetic mean ($\overline{E_{abs}}$) is calculated by the summation of E_{abs_i} over the total number of projects (n). As shown by equation 5.2, E_{per_i} is calculated by the Mean Absolute Percent Error, and the arithmetic mean $\overline{E_{per_i}}$ is dividing the summation of E_{per_i} by the total number of projects (n). This dimension provides summary statistics showing the severity of estimation inaccuracy, and its result will be used in the following dimensions.

$$E_{abs_i} = |O_i - F_i| \quad \text{and} \quad \overline{E_{abs}} = \frac{1}{n}\sum_{i}^{n} E_{abs_i} \tag{5.1}$$

$$E_{per_i} = \frac{O_i - F_i}{F_i} \quad \text{and} \quad \overline{E_{per}} = \frac{1}{n}\sum_{i}^{n} E_{per_i} \tag{5.2}$$

Third, *correlations of error* aims at capturing and quantifying the statistical interaction among project characteristics, changes of economic condition, and the results output by BCA. Multivariate linear regression is engaged in this dimension, and variables fed into regression analysis are shown as per table 5.1. Fourth, *tendency of error* identifies if certain types of errors present a temporal or regional tendency. It is measured primarily by engaging continuous time variable Y2000 (variable 9) and interaction terms (variable 11) in table 5.1 via regression analysis.

Table 5.1 Overview of Variables in Regression Analysis

ID	Name	Type[1]	Description	Differs in *ex-ante* and *ex post*?
1	ADB Funding %	C	The proportion of funding disbursed by ADB in total project costs	✓
2	Implementation Period	C	The number of years between the start and end of project construction	
3	Initial Construction	D	1 for a new construction project, otherwise 0	
4	Subsequent Construction	D	1 for a project that aims to retrofit, rehabilitate, widen or extend the existing roads, otherwise 0	
5	Access Road	D	1 for an access road, otherwise 0	
6	Limited-Access Road	D	1 for a limited-access road, otherwise 0	
7	Access and Limited-Access Road	D	1 for a project consisting of both access and limited-access roads, otherwise 0	
8	Length	C	The centerline lengthy (kilometer) of a road.	
9	Y2000	C	The number of years between a project's opening year and the base year 2000.	
10	Project Life	C	The proposed project life of a road.	✓
11	Location · Length	IT	An interaction term combining a road's geographic location and its length (Locations include South Asia, East Asia, Central West Asia, Oceania, and Southeast Asia (base group))	✓
12	PVC	C	The accumulated present value of the total costs for a project, including capital costs and maintenance & operation costs	✓
13	PVB	C	The accumulated present value of the total benefits for a project, including VOC savings, TTS, and other benefits	✓
14	NPV	C	The difference between a project's PVC and PVB.	✓
15	EIRR	C	The discount rate at which a project is break even.	✓
16	ΔCPI	C	The variation of local CPI during the period of project construction.	

[1] C refers to a continuous variable, D refers to an indicator variable, and IT refers to an interaction term.

5.4 ADB Results

5.4.1 Frequency of Error

Results for the first assessment dimension on initial project construction cost and economic analysis are shown in tables 5.2 and 5.3 respectively. In table 5.2, project contingency, cost of civil works and land acquisition cost rank at the top three in terms of the likelihood of suffering from *ex ante* underestimation. Project contingency, occupying about 10% of total costs, is reserved to cover costs incurred due to any unforeseeable events. Its 0.05% weight at *ex post* stage shows that it almost has been used up during project implementation. This is also confirmed by the fact that 98.08% projects have an ending balance of contingency lower than the beginning balance. As the largest single cost component, the cost of civil work accounts for 70.74% (*ex ante*) and 83.35% (*ex post*) of the total initial project cost. We see that roughly 88% (52 out of 59 projects) of projects ended up with a higher-than-expected civil work cost. However, only three-fifths of the 59 projects experienced total project cost overrun, implying that the contingency reserve effectively functioned as a buffer and mitigated the risk of cost overrun. Although land acquisition cost comprises a small share of the total cost, there is 56% projects (23 out of the 41 projects that incurred this cost) exceed initial expectation.

Table 5.2 Frequency of Errors in Initial Project Construction Cost

	n[1]			*ex ante* Stage		*ex post* Stage	
	Total	F<O[2]	F>O	W%[3]	Std[4]	W%	Std
Civil Works	59	52	7	70.74%	10.37	83.35%	9.88
Land Acquisition	41	23	18	3.02%	4.44	3.58%	5.80
Equipment	47	13	34	2.51%	4.57	1.51%	3.26
Consulting Service	54	30	24	4.46%	4.36	4.50%	4.50
Project Management	32	14	18	1.26%	2.18	1.16%	2.45
Interest Expense	54	17	37	4.07%	2.78	3.41%	3.75
Contingency	52	51	1	10.58%	5.60	0.05%	0.35
Other Costs	39	15	24	3.36%	4.61	2.45%	4.12
Total Cost	59	36	23	100%		100%	

[1] n stands for the number of projects.
[2] F refers to the forecast value at *ex ante* stage, O refers to the observed value at *ex post* stage.
[3] $W\%$ represents the average weight of the cost item out of the total cost.
[4] Std denotes the standard deviation of $W\%$.

As shown in table 5.3, the number of projects disclosing detailed *ex ante* and *ex post* economic analysis is less than that providing detailed cost breakdown. A total of 47 projects reported *ex ante* and *ex post* EIRR, while only 23 road projects disclosed detailed economic analysis. For those 23 projects, 18 of them underestimated the present value of cost in *ex ante* analysis. Although capital cost occupies the largest weight in terms of the total cost, the likelihood of underestimating capital cost and operation & maintenance cost is roughly equal. We saw that 13 projects had underestimated the total present value of future economic benefits. Among the three types of benefit, Vehicle Operating Costs (VOC) savings shares the largest portion of total benefit and is almost equally likely to be over- and underestimated. The portion occupied by Travel Time Savings (TTS) is much lower than by VOC, and 90% of those projects (19 out of 21) reported underestimation of TTS in *ex ante* stage. As for economic effectiveness measures, 53.19% projects (25 of 47 projects) underestimated EIRR and 12 projects (52.17% of 23 projects) underestimated NPV.

Table 5.3 Frequency of Errors in Project Economic Analysis

	n			*ex ante* Stage		*ex post* Stage	
	Total	F<O	F>O	W%	Std	W%	Std
Capital Cost	23	16	7	95.63%	4.08	98.01%	17.61
O&M Cost	22	14	8	4.37%	4.08	1.99%	17.61
Total PVC	23	18	5	100%		100%	
Vehicle Operating Cost Saving	23	11	12	73.59%	21.22	68.57%	16.22
Travel Time Saving	21	19	2	15.09%	20.10	25.83%	13.85
Other Benefits	16	7	9	11.32%	12.27	5.60%	7.31
Total PVB	23	13	10	100%		100%	
EIRR	47	25	22				
NPV	23	12	11				

5.4.2 Magnitude of Error

As shown by table 5.5, the average overrun of the total cost for 59 projects is 10.71%, equivalent to USD 71.4 million. One may question whether project costs exceeded because of project scope expansion. Table 5.4 shows that on average only 95.33% of the originally planned projects were actually delivered.

The largest percent cost overrun is identified in civil works, followed by land acquisition cost and consulting services cost. In terms of cost underrun which is indicated by a negative E_{per}, project contingency has a mean percent error of 99.69%, again indicating that almost all

Table 5.4 Project Completion Percent

Roads	n	Average Project Completion % [1]	Std
Access road [2]	16	98.15%	26.46
Limited-access road [3]	16	92.93%	14.87
Limited-access road and Access road	27	95.07%	22.77
Initial Construction	28	98.20%	19.45
Rehabilitation	31	93.62%	23.14
Total	59	95.33%	21.78

[1] The project completion rate is calculated by the actual road length completed at the time of *ex post* evaluation divided by its planned length.
[2] Access roads refer to roadways other than limited access roads.
[3] Limited-access roads refer to motorways which can only be accessed from authorized entrances.

contingency reserves have been used up during project implementation. The '–' presented in the penultimate column in table 5.5 can be interpreted as either a zero ending balance or a cost item that hasn't incurred.

Table 5.5 Magnitude of Errors in Initial Project Construction Cost

	E_{abs} (in \$mil)[1]	Std	Lower[2]	Upper[3]	$E_{per}(\%)$[4]	Std	Lower	Upper
Civil works	97.35	199.13	-70.30	1238.90	31.16%	32.22	-38.80%	132.91%
Land Acquisition	14.23	45.08	-25.60	258.20	25.13%	99.26	-[5]	378.18%
Equipment	-3.39	11.96	-73.50	15.90	3.50%	247.24	-	1605.00%
Consulting Service	0.45	8.05	-40.30	29.00	15.69%	74.79	-	453.13%
Project Management	0.03	3.90	-20.92	12.89	-0.08%	85.82	-	304.00%
Interest Expense	6.11	35.62	-49.51	179.80	-14.00%	80.56	-	471.92%
Contingency	-41.15	56.10	-260.60	0.00	-99.69%	2.22	-	-84.00%
Other Cost	-2.24	8.85	-42.72	13.80	2.39%	112.51	-	422.22%
Total Cost	71.40	194.84	-142.81	1025.60	10.71%	26.24	-46.15%	99.26%

[1] E_{abs} expressed in \$US million and calculated as per equation 5.1.
[2] Lower means the lower value for E_{abs} or E_{per}.
[3] Upper means the highest value for E_{abs} or E_{per}.
[4] E_{per} as per equation 5.2.
[5] '–' shows that the end balance of the cost item is zero.

In terms of the assessment of economic analysis (as shown by table 5.6), the volatility of the overall results is far larger than the previous table 5.5. A smaller sample size including only 23 projects may help explain this. In terms of total PVC, capital costs were underestimated by 45.74%, and regular maintenance & operating costs are 47.90% higher than planned. As for economic benefits, VOC savings were underestimated by 10.42% on average, but the average underestimation of TTS and other benefits are as large as 1313% and 249% respectively. This is because for many projects, TTS and other benefits were either not considered at all or not fully accounted for (eg. only consider TTS savings for freight transport but not for passenger transport) as potential project benefits at the planning stage, but were re-considered at *ex post* stage. The – presented in the penultimate column (in table 5.6) for other benefits shows that they have not been recognized as expected, at least not under the same category as planned, in the *ex post* evaluation stage. Subject to data unavailability, other benefits, such as savings on traffic crashes, poverty reduction, and the boost to agriculture production via improved market access, are occasionally reflected as an added proportion to VOC savings or TTS, indicating variation of the types of benefit considered in *ex ante* and *ex post* evaluation. Since the underestimation of economic benefit is too small to offset the underestimation of project cost, the overall EIRR is overestimated by 5.4%.

Table 5.6 Magnitude of Errors in Project Economic Analysis

	E_{abs} (in \$mil)[1]	Std	Lower	Upper	E_{per}(%)	Std	Lower	Upper
Capital Cost	95.69	196.41	-169.39	764.68	45.74%	1.32	-75.30%	630.16%
O&M Cost	6.87	33.37	-37.40	131.84	47.90%	2.06	-471.74%	445.01%
Total PVC	102.55	196.76	-199.13	727.28	45.32%	1.31	-86.11%	623.19%
VOC Savings	-102.11	272.06	-774.38	408.41	10.42%	0.66	-78.51%	185.18%
TTS	115.23	261.06	-93.50	1079.04	1313.06%	51.90	-65.28%	23926.08%
Other Benefits	-36.92	99.08	-233.59	240.87	249.48%	11.43	-	4523.26%
Total PVB	-23.79	318.69	-1022.54	482.51	28.49%	0.74	-71.10%	232.68%
EIRR (N=47)	-0.02	0.06	-0.18	0.08	-5.40%	0.28	-65.32%	50.20%
NPV (N=23)	-126.35	339.47	-1406.54	175.61	45.66%	1.71	-197.41%	553.70%

[1] E_{abs} expressed in \$US million except for EIRR, which is in %.

5.4.3 Correlation and Tendency of Errors

Models 1 & 2 in table 5.7 summarise the regression results of total project cost and multiple independent variables. First, the amount of funding injected by ADB and the project's total length show statistically significant impacts on total project cost. Projects with heavier capital investment are expected to deliver longer roads. Notably, the length variable appears to be a more statistically significant estimator for project costs in the *ex ante* stages than in the *ex post* stage. As a key driver of project variable costs, length turned out to be less important than had been stated in the planning stage, implying the existence of other influential fixed cost drivers independent of length which our model has not captured. The negative coefficient of ADB funding % indicates that the project earmarks from ADB may be limited, resulting in a relatively smaller proportion of ADB's funds for more expensive projects. Then, initial construction is more expensive than subsequent construction. Compared to projects containing both limited access and access roads, constructing either road type appears to be cheaper. This is plausible since projects containing both road types are likely to be larger. Moreover, our sample shows no statistically significant correlation between total project cost and local inflation. Suggested by the adjusted R^2 and the significance level for each statistically significant variable, model 1 outperforms model 2 in terms of the overall model fitness. The variables identified and included in our models are reliable when projecting total project costs in the planning stages, but factors or uncertainties not captured by our model influence the actual out-turn cost in reality.

Models 3 & 4 describe the regression results of percent cost overrun (E_{per}) and multiple independent variables. First, cost overrun is independent of project size (represented by total cost), but it is positively correlated with the project implementation period. Limited access roads have cost overruns greater than projects containing limited access and access roads. For the latter, the limited access road component generally consumes the majority of the project cost. As a result, when project budgets fall short, construction of the access road component may be postponed to ensure the completion of the limited access road. In other words, the budget for access roads functions as an extra funding reserve for the limited access road. In addition, the correlation between cost overruns and road length planned at *ex ante* stage shows geographic differences. In contrast with extending 10 km of road in Southeast Asia, doing it in East Asia would induce an extra 0.7% of percent cost overrun.

Models 5 & 6 in table 5.7 show the regression result between project EIRR and multiple independent variables. First, project EIRR negatively correlates with the total project cost in both *ex ante* and *ex post*. Then the EIRR for initial construction is lower than that for subsequent construction. The EIRR for an access road is higher than a project containing both limited access road and access road components. Again, geographic differences are observed. EIRRs delivered by projects in South Asia and Central West Asia are higher than that of projects in Southeast Asia. Constructing 10 km of roads in South Asia and Central West Asia is expected to deliver EIRRs higher than in Southeast Asia by 0.02% and 0.03%, Nevertheless, things go awry in Oceania, given that EIRR would reduce by 0.25%. The implication of this observation is limited since the sample size of Oceania's projects is small (N=2). The independent variable Y2000 shows no statistical significance in all models, indicating that year of construction does not seem to be a factor (after controlling for general inflation).

Table 5.7 Linear Regression Models Addressing the Correlation between Project-specific Features and Key Performance Indicators

Dependent Variables	Project Cost *ex ante*	Project Cost *ex post*	E_{per}		EIRR *ex ante*	EIRR *ex post*	*ex post* NPV	
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Constant	919.18 **[3]	843.40 .	-0.23	-0.20	0.21 **	0.23 **	1,670.83 **	208.97 *
ex ante Total Cost			6.64E-05		-3.98E-05 .			
ex post Total Cost				1.07E-04		-4.31E-05 *		
ex post PVC[1]							-0.05	
ex post PVB[2]								0.18
Implementation Period	-3.61	32.30	0.04 .	0.04 .	7.97E-03	0.01	-108.15 *	-110.21 **
Y2000	-1.96	-3.37	2.14E-03	3.99E-03	-1.49E-03	-1.62E-03	-9.68	-5.43
ex ante ADB Funding %	-774.53 **		-0.05		-0.12 *			
ex post ADB Funding %		-781.49 **		-0.19		-0.03	-451.59	-112.09
Initial Construction	316.11 **	385.17 *	-0.08	-0.11	-0.05 *	-0.06 *		
Access Road	-363.51 **	-322.35 .	0.04	0.09	0.14 ***	0.04	-381.52	-300.32
Limited Access Road	-126.06	-231.45	0.15 .	0.16 *	0.03	-3.81E-03	2.81	48.34
ex ante Length	0.20 ***							
ex post Length		0.10 *					1.50 ***	1.18 **
ΔCPI	-194.77	-309.50						
ex post Project Life							-33.14	-25.79
ex ante East Asia · Length			7.03E-04 .		-7.35E-06			
ex ante South Asia · Length			-3.21E-05		2.05E-04 *			
ex ante Central West Asia · Length			-5.22E-04 *		3.37E-04 *			
ex ante Oceania · Length			3.00E-03		-2.55E-03 ***			
ex post South Asia · Length				5.79E-04		4.42E-06		
ex post East Asia · Length				-2.28E-05		7.42E-05		
ex post Central West Asia · Length				-4.74E-04		1.52E-05		
ex post Oceania · Length				2.45E-03		-1.70E-03 **		
N	59	59	59	59	47	47	23	23
Adj. R^2	0.58	0.50	0.26	0.30	0.55	0.42	0.31	0.41
P-value	6.98E-09	5.51E-07	6.70E-03	2.40E-03	1.53E-05	8.34E-04	0.038	0.011

[1] *ex post* PVC is the reevaluated present value of project cost, including capital costs and routine operation & maintenance costs.
[2] *ex post* PVB is the reevaluated present value of project benefits, including VOC savings, TTS and other benefits.
[3] ., *, **, *** indicate significance at the 90%, 95%, 99% and 99.9% level, respectively.

Models 7 & 8 illustrate the correlation between *ex post* NPV and project features. As suggested by the negative coefficients for the independent variable implementation period, a longer implementation period severely diminishes the project's value. Longer roads are anticipated to generate higher NPV.

5.5 Discussion

This section first discusses three methodological issues associated with BCA for Asian Development Bank projects and then qualitatively reviews the causes of the discrepancies between expected and actual project performances.

5.5.1 The Choice of Social Discount Rate

Weighing the upfront investment against the future social well-being is critical when engaging BCA to evaluate the worthiness of a public project. The accuracy and credibility of the evaluation results are largely determined by the appropriateness of the social discount rate (SDR) used. Applying a high SDR eliminates many projects which are less economically desirable in the near future but may generate large inter-generational benefits in the distant future. In contrast, adopting a low SDR would expose the lenders to excessive risks and reduce their expected return on investment.

In line with the approach prescribed by other multilateral development organizations specializing in supporting countries in under-developed regions, ADB follows a weighted average approach when determining the SDR, reconciling the opportunity cost of public funding in private investment or private consumption (Asian Development Bank, 2013). ADB adopts a uniform Social Discount Rate (SDR) of 12% in both *ex ante* analysis and *ex post* evaluation when calculating NPV, which ensures the comparability of BCA results in both stages (Asian Development Bank, 2016b). This SDR is also regarded as the benchmark EIRR guiding project selection. ADB states that in *ex ante* stage, projects with an EIRR of higher than 12% or lower than 10% will be accepted or rejected respectively. For projects with an EIRR between 10% to 12%, decisions are made depending on the existence of provable extra economic benefits. In *ex post* evaluation, the recalculated project EIRR is compared with this SDR, which is a key determinant judging the efficiency of project implementation. Although a range of 10% to 12%

has been designated, ADB encourages discretion in project SDR based on factors including geographical region, industry section, economic condition and project-specific features.

This 12% SDR appointed by ADB is far higher than that adopted by the European Union Commission, which is 5%, and than that used by other developed countries like Canada (10%), France (4%), Italy (5%), New Zealand (10%) and the UK (3.5%). The differences in the applied SDRs among different regions across the world reflect different marginal opportunity costs of public capital and projects' impact on inter-generational equity. Overall, the opportunity cost of public capital in less developed countries is higher than that in developing countries, leading to a higher SDR in the former. This can be explained by concerns that scarce resources and funding, less sophisticated financial systems, and high market volatility in developing countries require extra rate of return to attract limited transnational capital. Asian Development Bank (2013) put forward that a reassessment of the suitability of the age-old 10-12% SDR is needed. In 2017, ADB decided to replace the old 12% SDR with a new 9% SDR (Asian Development Bank, 2017). This replacement took into account the growing income levels in ADB member developing countries, lower transnational loan costs than in the past decades, and ADB's increasing emphasis on environmental projects that typically have a long-run impact over the distant future. All the projects discussed in this chapter uniformly applied a 12% SDR without any discretion, which ensures the comparability between *ex ante* and *ex post* evaluation.

However, whether this is the appropriate value, or if it is too high – leading to underinvestment in infrastructure – or too low – leading to overinvestment – needs to be addressed. Figure 5.1 visualizes *ex ante* (as per the y-axis) and *ex post* (as per the x-axis) project BCR. The size of each circle indicates the percentage of ADB funding out of the total project cost, and the color represents project NPV (in US$ Million). Basically, both forecast and actual BCRs are above 1, indicating accumulated present value of benefits exceeds that of costs. In addition, informed by the eight circles distributing to the right of the average *ex post* BCR reference line, the proportion of ADB's disbursement is higher for projects with smaller NPV since the six circles in light blue are bigger than the two circles in dark blue. This observation does not suggest a negative causal relationship between *ex post* project NPV and ADB funding proportion but means that ADB is likely to be the major or even exclusive investor for projects of relatively small funding scale.

Figure 5.2 illustrates the distribution of *ex ante* (as per the vertical axis) and *ex post* (as per the horizontal axis) project EIRRs for 47 road projects. Each circle filled in different color

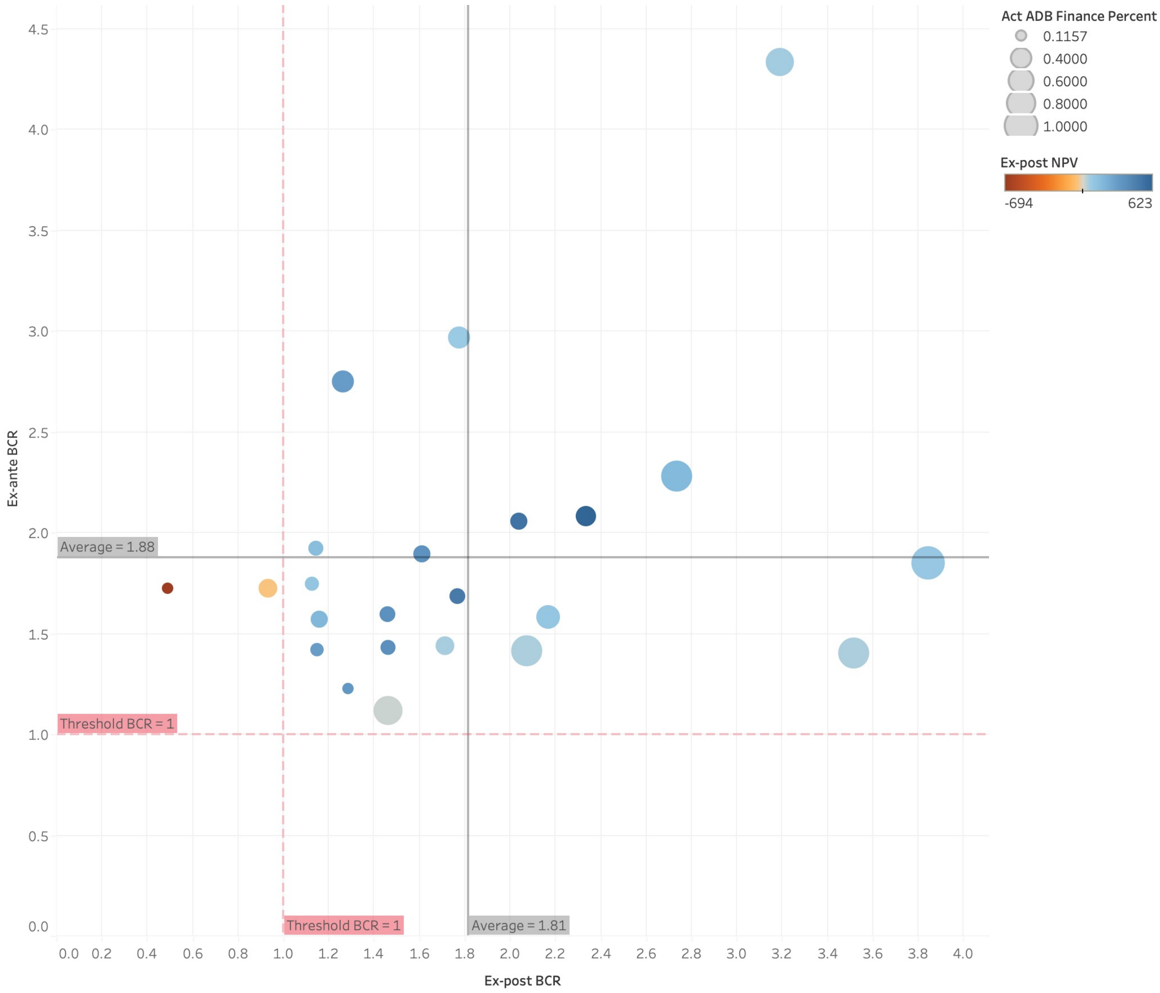


Figure 5.1 Distribution of Asian Development Bank Road Projects' BCR (N=23)

represents a road project, with the size of the circle conveying the same information as figure 5.1. Given the 12% threshold EIRR stipulated by ADB, only one project falls below this line in *ex ante* evaluation stage, and two projects failed to achieve an *ex post* EIRR exceeding this line. The average *ex ante* and *ex post* EIRR are 20.41% and 19.5% respectively, which are far higher than the 12% threshold.

In conclusion, the project outcomes informed by both BCRs and EIRRs demonstrate that ADB's practice conforms to or even exceeds the decision rules. The rigorous compliance secures return on investment to a large extent, where almost all projects generate BCR higher than 1 and EIRR higher than 12%. As a result, the adopted 12% discount rate at planning and post evaluation maintains the effectiveness of ADB's investment but at the same time indicates excessive risk aversion and consequent under-investment, as it is the portfolio of projects which should exceed a Benefit/Cost Ratio of 1, not every single project, and clearly they do so by a large margin. To avoid nearly every project falling below the threshold implies many projects especially those aiming to relieve regional poverty, were not funded.

Figure 5.2 Distribution of Asian Development Bank Road Projects' EIRR (N=46)

5.5.2 The Application of Non-Market Valuations

The monetary evaluation of transport projects' TTS benefits relies heavily on Non-Market Valuations (NMV). As non-marketable intangible benefits, TTS benefits are neither tradable nor priced by the market. In this case, the shadow price is defined as the estimated unit price used to monetize TTS. In contrast to TTS benefits, VOC reductions can be gauged by considering factors like the price of tires and auto parts, depreciation expense, and fuel price, which are available with the market price. As a result, the risk caused by imprecise shadow prices is negligible when evaluating VOC reductions.

Given that only by using fair and realistic shadow prices can project benefits be accurately and credibly measured, our discussion about shadow prices centers on two issues: 1) how shadow prices are determined and 2) whether shadow prices are properly adjusted. For the first issue, OECD countries generally consider revealed and stated preference of value of time for given origin-destination trips (Asian Development Bank, 2013). But it is much more difficult to acquire precise information in developing countries. According to ADB, journey time is evaluated separately for trips during working and non-working hours. For the former, ADB uses working wage as the fundamental element of shadow price, adds the overhead cost of employment like pension and holiday costs if applicable, and adjusts the ultimate shadow price with the shadow wage conversion factor. For the latter, non-working time value is proportionate to local household income, especially when TTS only accounts for minor weight in terms of total project benefit.

However, engaging the user benefit assessment approach as the core benefit assessment method might largely overlook the wider benefits realized beyond the direct usage of the transport infrastructure. Because benefits accrued not only when people and goods can travel around faster (mobility) but also when reaching the destinations gains greater values (Levinson and King, 2019). Accessibility measures the ease of arriving at valuable destinations (COTAM, 2020; Hansen, 1959). The changes in land or real estate values resulting from the changes in accessibility are reflected by fluctuation in their market prices and hence provide an alternative path to assessing project benefits. The shadow price is largely determined by users' willingness to pay for transport, reflecting the perceived value of provisional travel decisions. Decisions regarding residential and commercial locations convey aggregate information and thus are more appropriate for evaluating both direct user benefits as well as indirect user and non-user benefits.

Furthermore, since project benefit evaluation covers multiple years after project delivery, shadow price is expected to be adjusted for changes in users' perception of time value which varies with productivity and income. The valuation accuracy is subject to the accuracy of the base shadow price and the expected growth rate. An accessibility-based evaluation method, in contrast, is superior to the traditional NMV method due to the existence of the housing market and the availability to predict and verify the growth rate in a more credible manner. It is vital to notice that adding the NMV and accessibility-based methods leads to double counting. They are two distinct methods operating independently, but a comparison of their results may provide some practical insights.

For the second issue, the adjustment of shadow price is classified into adjustment to currency price and adjustment to variations in macroeconomic conditions. Both local price and world price are accepted in *ex ante* analysis. The distinction induced by using either local price or world price is pertinent whenever there is a disparity between those two types of prices. ADB measures and reports such a price disparity using the Standard Conversion Factor (SCF) and its inverse, the Shadow Exchange Rate Factor (SERF). Moreover, the assumptions based on which EIRR is calculated do not vary with change in price numeraire, thereby ensuring that the same EIRR is acquired using either price numeraire. Variations in the macroeconomic environment influence the users' perception of the value of time. Thus for developing countries with less stable economic environments, the adoption of two different sets of conversion factors in *ex ante* and *ex post* stage is justifiable.

5.5.3 The Counterfactual Base Case

Project cost and benefits under various (at least one) 'build' options are weighed against the corresponding 'no-build' or 'do-minimum' option, and the incremental approach captures the differences between them. The 'no-build', as the name suggests, refers to a counterfactual circumstance where the prospective project does not exist. Given that the incremental approach is adopted in *ex ante* and *ex post* BCA, identifying proper counterfactual scenarios is required in both stages.

First, the consistency of the counterfactual scenario used in the two stages is of great concern. If the assessment of incremental cost and benefits hinges on distinct base scenarios, the output performance measurements are incomparable, thus negating the reliability of the conclusions on the accuracy of BCA. Considering the heterogeneity of projects conducted in different sectors and countries, ADB does not provide standardized guidance for determining the reference scenario, and project teams are encouraged to determine it at their discretion. After scrutinizing the Project Completion Reports (where the *ex post* and *ex ante* economic benefits are reported), we did not discover any further specification about the choice of counterfactual case, presuming that no substantial amendments have been made on the initial choice. Although occasionally *ex ante* economic analyses were updated after the formal decision had been made, the *ex post* analyses are performed with respect to the updated *ex ante* version.

The second concern lies in the appropriateness of the counterfactual scenario used in both stages, particularly in the *ex post* stage. ADB states that the 'no-build' base scenario may not necessarily be the current situation when preparing *ex ante* BCA. The extent to which the traffic facility is used currently (for projects aiming at replacing, rehabilitating, and modifying existing traffic facilities) and will be used in the foreseeable future in the absence of the envisaged action would form the reference base case. Routine maintenance costs in keeping reasonable road services are crucial when projecting cost streams for the 'no-build' base case. In *ex ante* stage, the rationale of this setting is conceivable since the continuation and expansion of the actual demand observed in the absence of the future project are reasonable in contexts with growing demand. However, whether it remains to be an appropriate base case in the *ex post* stage is constrained by the unpredictability of how the external environment evolves as a result of the project and how the project responds to that evolution (Florio and Vignetti, 2013). To solve this problem, an observation period that is long enough to figure out how demand and supply, price, macroeconomic conditions, and demographic features actually evolve is essential to ensure a practical simulation of the potential evolution across decades after project completion in *ex ante* stage. The current practice in ADB where a PCR covers an actual observation time window of 1-2 years post to the project opening may be insufficient.

5.5.4 Causes of The Discrepancies in Project Performances

As informed by the results in section 5.4.2, the cost overrun of civil works ranks at the top in terms of both frequency and magnitude.

First, the unforeseeable price escalation of road construction materials, crude oil, and utility is a common cause of civil works cost overrun. The situation might worsen when the developed country mainly relies on importing those construction materials and its domestic currency depreciate during project implementation. Further, experiencing high inflation during project implementation is also thought to increase civil costs, although we did not find statistical evidence for this hypothesis.

For instance, the civil work cost of Zamiin-Uud road in Mongolia was 2.5 times higher than that stated at appraisal (US$ 50.06 million in appraisal and US$ 135.93 million at completion) (Asian Development Bank, 2015b). During the road construction process, the CPI of Mongolia rose from 100 in 2010 to 153.7 in 2014 (World Bank, 2020).

Second, partial or complete changes to the initial road design are likely to lift the cost of civil works. However, rather than technical design defects, the less regulated driving environment and illegal driving behaviors take some blame for the changes in project scope (Asian Development Bank, 2015a).

Third, less than satisfactory performance of civil work contractors (both domestic and international contractors), like inefficient workers and material mobilization at the inception of project construction, being less proactive and responsive to project scope alteration, and withdrawing from the project in the middle of implementation, delays the overall project progress and incurs extra expenses. Park and Papadopoulou (2012) stated that granting civil work contracts to the lowest bidder runs high risks of over-budget, although we did not observe that the lowest bidder was regarded as a risk factor in the projects covered by our study.

Last, since many of those projects have road rehabilitation components, worse than expected road conditions (after project approval) caused by environmental factors (faster than expected road erosion or collapse caused by spring thaw) or socioeconomic factors (social instability) require additional investments to secure the successful completion of projects.

After civil works, land acquisition and resettlement rank next in terms of vulnerability to overspending. For road projects in urban areas, the expansion of the area of permanent land acquisition, the increases in the number of buildings to be demolished, the increased number of residents to be re-accommodated and compensated, as well as the increased compensation rates introduced by new government policies have been documented as causes of excessive costs. For instance, the Third Ring Road project in Xian, China, which links four major districts and two commercial zones in central Xian, incurred a land acquisition and resettlement cost of 3 billion in CNY, which doubled the budgeted amount (Asian Development Bank, 2011). For roads passing through arable fields where local resistance to road construction is strong, extra compensation is required for residents.

A common way of managing successful project delivery within budgets is reallocating the costs on less essential project components like the construction of local roads or the improvement to cross-border facilitation (many road projects have cross-border components) to the project components with higher priority like the construction of expressways, resulting in an average project construction costs overrun of 10.71%.

In terms of project benefits, an underestimation of both VOC and TTS is highlighted in section 5.4.2.

First, traffic demand has grown rapidly. The improved level of service and the shorter journey times, which are directly related to the project roads, facilitate growth. Such growth might be motivated by factors like the additional economic activities induced by the improved road networks. For example, a boom in contract farming in the vicinity of project roads in

Laos (The Lao People's Democratic Republic) was identified when the project was about to complete, which turned out to facilitate the local farms to grow corn and other crops, followed by a sustainable increase in the export of those crops by using the project cross-border roads (Asian Development Bank, 2015a). In contrast, some projects identified no generated traffic at the inception of project operation because either the data were unavailable or the increase in traffic demand was thought to be driven by exogenous factors and thus accounted as normal traffic. Second, the rise in the costs considered when projecting VOC, including producer price, labor costs, fuel costs, tire costs, and other costs, results in higher *ex post* VOC savings. Third, the actual growth rate of GDP per capita is higher than what was anticipated at the *ex ante* appraisal stage. GDP per capita is a crucial proxy used to predict the growth rate of traffic demand, unit travel time cost, and other unit prices used to project benefits.

5.6 Conclusion

This chapter covers 59 roadway projects funded by Asian Development Bank (ADB). By scouring Project Completion Reports for all 59 projects to collect project information, the accuracy of BCA results is assessed through four dimensions: the frequency of error, the magnitude of error, the correlation of error, and the tendency of error.

First, under an average project completion rate of 95.33%, we observed that the average construction cost overrun for 59 roadway projects is 10.71%, equivalent to USD 71.4 million. The cost of civil works and land acquisition rank at the top in terms of the likelihood and magnitude of suffering from *ex ante* underestimation. A 10% project contingency reserve was almost used up during construction and effectively functioned as a buffer mitigating the risk of cost overrun.

Second, grounded on 23 projects disclosing detailed economic analysis, we discovered a systematic tendency of understating both the present value of costs (18 out of 23 projects) and the present value of benefits (13 out of 23 projects) in *ex ante* BCA. As the two major components constituting transport project benefits, VOC savings and TTS are prone to be understated.

Third, more than half of projects (25 out of 47) underestimated EIRR, and about 52.17% of them (12 out of 23) understated NPV. Nevertheless, the underestimation of economic benefits is too small to counterbalance the underestimation of costs, resulting in an overall project EIRR is

5.4% lower than the initial expectation. The vast majority of projects still have an *ex post* BCR above 1, suggesting under-investment or too strict a threshold for project funding.

Fourth, the two most statistically significant factors affecting total project cost are the proportion of funding injected by ADB and project length, and the direction of their correlations with project cost is opposite. Road type and project implementation period show significant impacts on percent cost error. A longer implementation period implies a higher percent error, and limited access roads generate cost overrun greater than roads containing limited access and access roads. Furthermore, the percent cost error shows clear geographical differences where projects in East Asia have a cost overrun greater than those in Southeast Asia.

Last, project type and construction sequence appear to be statistically significant estimators for project EIRR. In terms of geographic location, constructing 10 km of road in South Asia or Central West Asia is expected to deliver EIRR higher than in Southeast Asia.

Further, ADB's choice of three key BCA elements: social discount rate, shadow price, and counterfactual base scenarios were discussed. First, applying a uniform 12% social discount rate in both *ex ante* and *ex post* stage ensures the accuracy and comparability of BCA results. The high discount rate (relative to the developed countries) successfully secures the overall return on investment but indicates an excessive risk aversion and consequent under-investment by rejecting projects which would have produced an *ex post* BCR of 1. Second, the shadow price adopted when calculating TTS is determined fairly and adjusted realistically, thereby reinforcing the accuracy and credibility of BCA results. Whereas the NMV-based user benefit assessment approach might largely overlook the wider economic benefits realized beyond the direct usage of the transport infrastructure. In regard to the last question, we recommend that ADB either extend the observation period after the project opening or prepare for subsequent *ex post* evaluation. This recommendation helps ascertain how demand and supply, price, macroeconomic conditions, and demographic features actually evolve in *ex post* stage and thus ensures practical simulation of the potential evolution of project benefits and costs for decades after project completion in the *ex ante* project evaluation stage.

The causes of cost overruns include unforeseeable price escalation of construction materials, partial or complete changes to the initial road design due to the less regulated driving environment or illegal driving behaviors, less satisfactory performances of civil work contractors, and worse than expected road conditions. The causes of benefits underestimations are the general growth of traffic demands, a higher-than-expected growth rate of GDP per capita, as well as the rise in the Product Producer Index, labor costs, and other costs used to project VOC benefits. However, the discussions on those causes are qualitative. A systematic comparison with statistical evidence is required to explore further the differences between the causes of cost overruns (and the underestimation of benefits) in developed and developing countries. Besides, an in-depth analysis of the accuracy of traffic demand forecasts is helpful in explaining the reasons behind the underestimation of the benefits of road projects in developing countries.

Chapter 6

The Overlooked Transport Planning Process: What Happens before Project Execution

6.1 Introduction

In the process of transport project planning and appraisal, many efforts have been devoted to the conceptualization, design, evaluation, and selection of the best 'do-something' or 'build' alternative, which is more commonly referred to as the Locally Preferred Alternative (LPA). However, mainstream *post hoc* project assessments are generally performed based on comparing the actual performance against what was stated in the LPA (Flyvbjerg et al., 2003), overlooking that in principle the decision-making procedure of large transport projects iterates until the LPA is decided. Concentrating on the final transport investment decision made overlooks the impact of early evaluation on project outcomes, drawing limited lessons learned on what actually undermines project success (Samset and Volden, 2016; Cantarelli et al., 2022).

Previous studies have raised several concerns regarding the appraisal process before the final action strategy. In the US, the intergovernmental project appraisal and funding process impels local project initiators to prefer capital-intensive projects to modest-cost projects because financial risks are jointly or even mostly shared by higher-level authorities and ultimately transferred to taxpayers (Weiner, 2013; Lee Jr, 2000).

The selection bias towards a favored course of action stems from project initiation and is reinforced with escalating resources devoted throughout the entire planning phase (Cantarelli et al., 2022, 2012). Although other competing alternatives may be proposed halfway through, decision makers are likely to incline to the original preferred option even when additional resources may be required (Priemus, 2007; Brockner, 1992).

The core analytical tool - Benefit-Cost Analysis (BCA) - engaged in project appraisal and prioritization has been criticized as unreliable and misleading and has been labeled as a deceptive tool driving projects away from success (Flyvbjerg, 2009). Particularly, if BCA inadequately exploits and differentiates potential values credited to each option (Quade, 1981; Pickrell, 1992), or if it is imprecise to control forecast mistakes within an acceptable margin relative to the differences among the performances of competing options (Pickrell, 1992), decision makers guided by BCA would opt for disqualified alternatives.

Typically project alternatives' analysis is expected to encompass all reasonable courses of action and aid in the formal decision-making on selecting the preferred action strategy that is anticipated to best fulfill the identified transport problems in the studied corridor. Those analyses are refined several times along the project planning cycle and preserve valuable records for the entire project-specific decision flow, and the mission of them does not terminate with project completion and closure.

The primary objective of this chapter is to prepare a complete 'alternative history' *ex post* evaluation and investigate the process of judging the robustness and viability of the selected option considering the competing alternatives that were ultimately discarded. Based on 43 light rail segments and lines opened between 1991-2018 in the US, the stated research objective is approached by addressing the following subsequent questions:

1. What alternatives were considered and assessed to support the identification of the locally preferred light rail alternative?

2. Did the Locally Preferred Alternative (LPA) outperform the other candidate alternatives in the light of the demonstrated cost-effectiveness?

6.2 Project Data and NEPA Project Planning Process

Considering the diversity of public transit modes and the distinct mechanisms for benefits projection for each mode, we targeted light rail projects to ensure homogeneity and comparability. Initially, a list of LRTs were found based on the 'Predicted Versus Actual Impacts of Capital Investment Grants Projects' prepared by the US Federal Transit Administration (FTA) and 'the Public Transportation Ridership Report' released by the American Public Transportation Association (APTA). As listed in table A.1 and A.2 (in appendix A.1, a total of 43 light rail projects or segments were finally selected subject to the following selection criteria:

1. Both the Draft Environmental Impact Statement (EIS) and the Final EIS are publicly-available;
2. At least two EIS alternatives (including a baseline option and an action option) were prepared and analyzed; and
3. Cost estimates and ridership forecasts were clearly stated in both DEIS and FEIS.

Three different levels of environmental review and planning procedures with which any proposed actions or projects should comply were introduced and enforced by the US National Environmental Policy Act (NEPA) (Eccleston, 2008). The first level is called *Categorical Exclusion* (CATX), which is the quickest streamlining process. A new initiative is identified to be categorically excludable once it is agreed not to cause significant impact, and thereby free from the preparation of an Environmental Assessment or an Environmental Impact Statement (EIS). The next level of action calls for the preparation of an Environmental Assessment (EA), which is less resource-incentive and time-consuming than an EIS. If the EA qualifies the new initiative as a *Finding Of No Significant Impact* (FONSI), or if the impact is potentially significant but can be mitigated to an acceptable level, the agency is allowed to implement the proposed project without preparing an EIS.

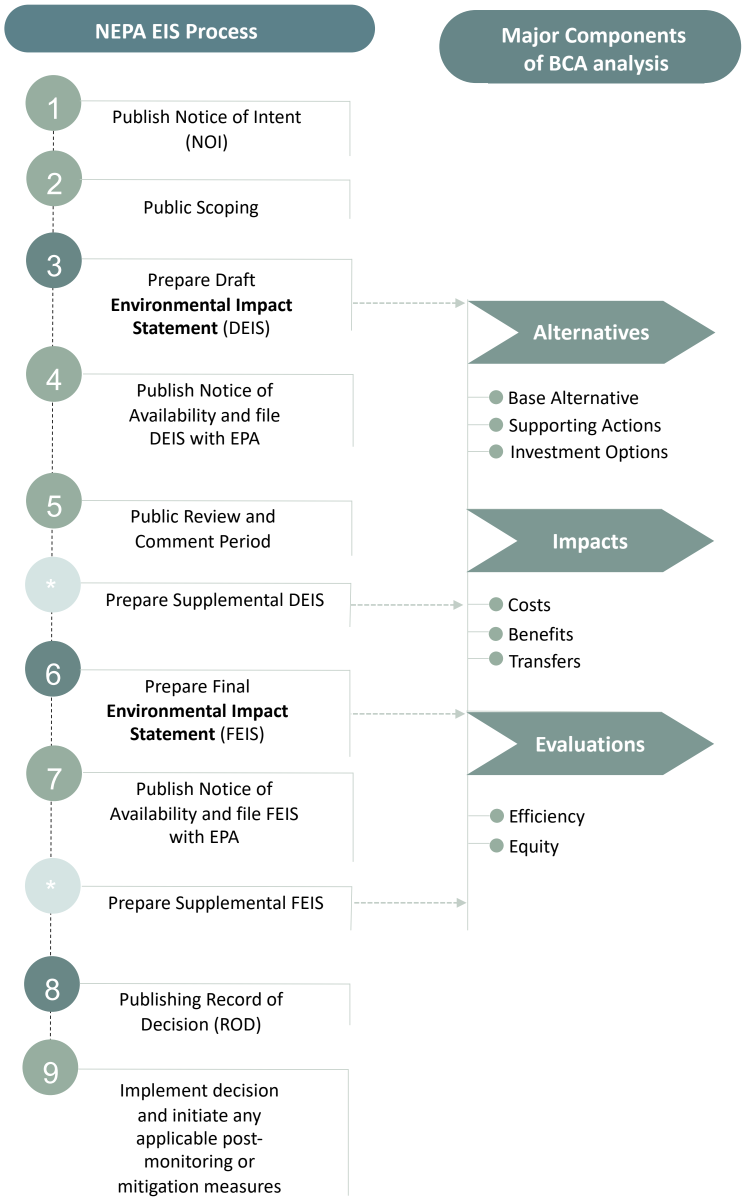


Figure 6.1 The NEPA EIS Process and the Major Components of Benefit-Cost Analysis (BCA)
Source: Modified based on Eccleston (2008) and Lee Jr (2000)

The last level requires the preparation of a full EIS for new major federal projects that are not recognized as a FONSI or a CATX, aiming to identify possible significant impacts and devise alternatives to manage such impacts. A full EIS is typically produced by a group of experts with multidisciplinary backgrounds, has 200 to more than 2000 pages in length, consumes 1-5 years, and costs between US$250,000 and $2,000,000 (Eccleston, 2008). EISs are chosen to be the primary source of project information.

Figure 6.1 visualizes the key steps for producing an EIS. In this process, a draft EIS (DEIS) is first completed, made available for public review, and open for public comments, followed by the preparation and completion of a final EIS, which incorporates public comments. A Supplementary EIS is only required when new substantial impacts that were not identified in the previous EIS are detected, when the size and scope of the project are altered, when a long period of time has passed since the issuance of the FEIS to capture changes in the surrounding environment during that period, or when the proposed alternatives in an EIS are regarded to be unable to cope with the identified impacts and new options are in request. One of the most important objectives for the EIS is determining the LPA. To accomplish this objective, a series of alternatives that are deemed appropriate and feasible are documented and analyzed in DEIS by engaging BCA, which lays the foundation upon which the LPA can be established in the following FEIS. There might have been numerous alternatives in different modes or with different route alignments considered in planning stages prior to DEIS which are excluded from in-depth analysis in DEIS because of reasons like poor appropriateness to the strategic development of the target transport corridor or being inferior to the alternatives listed in DEIS. EISs have been criticized from many perspectives, such as discounted practicality caused by outsourcing EIS to external consultants, inadequate due diligence to project-specific contexts, or delay in project progress considering the long preparation time (Wright et al., 2013), yet they are still the most comprehensive documents offering insights into project planning and decision-making. As a result, compared to other documents produced in even earlier planning stages, EISs are more qualified to be the primary source of alternatives information.

6.3 Methodologies

Project Alternatives For each project, we scoured both its DEIS and FEIS and recorded the number and types of alternatives considered. During this process, we paid particular attention to how baseline alternatives were scoped and defined, aiming to disentangle whether the baseline options upon which 'build' options were evaluated were devised in a consistent and comparable pattern.

Alternatives' Cost-Effectiveness Initially, we attempted to apply Benefit/Cost Ratio (BCR)-a performance indicator directly output by BCA - as the primary measure of comparing cost-effectiveness among alternatives. But we found that although the rationale of BCA is observed to be widely applied in evaluating project alternatives (like the 'build' alternative's incremental cost and patronage forecast relative to the baseline case), the BCR is unavailable in most projects' EIS.

Then, Cost Effectiveness Index (CEI) comparing the total expense of each alternative to its economic benefits is another quantitative approach to assessing the cost-effectiveness of different alternatives. CEI was mandated by the Urban Mass Transportation Act (UMTA) since 1984 (Smerk, 1985). For each alternative, CEI is calculated as per equation 6.1 (Ryan, 1990), which can be interpreted as an alternative's cost per new rider or trip relative to the TSM alternative. The decision rule behind CEI is that it prefers projects that produce the greatest benefits per dollar invested, aligning with our objective of revealing the ranking of alternatives in accordance with cost-effectiveness.

$$UMTA\ CEI = \frac{(\Delta Ann.\ Cap.C + \Delta Ann.\ O\&MC - \Delta Ann.\ TTS - (\Delta Ann.\ Rev.\ Ctrb))}{\Delta Ann.\ TransitTrips/Riders} \tag{6.1}$$

where:

- $\Delta Ann.\ Cap.C$ = incremental annualized capital costs relative to the TSM alternative
- $\Delta Ann.\ O\&MC$ = incremental annualized Operating and Maintenance costs relative to the TSM alternative
- $\Delta Ann.\ TTS$ = incremental monetized Travel Time Savings for **existing** riders served under the TSM alternative
- $\Delta Ann.\ Rev.\ Ctrb$ = annual transit revenue contributions, which is not considered in most projects (Since fares are a transfer from a social welfare perspective, this should be excluded.)
- $Ann.\ TransitRiders$ = annual transit riders in addition to those expected under the TSM alternative

However, several flaws in the CEI approach are noted. First, CEI is a relative measure, based upon the calculated changes in cost per new transit rider compared to the base alternative (Zimmerman, 1989). The baseline option commonly refers to a 'do-minimum' case instead of the ‘no-build’ case. A ‘do-minimum’ case covers the minimum efforts required to address the identified transport problems, which is unique in every project. As a result, CEIs for all the alternatives devised for one project are incomparable to that reported for another project, disabling the formulation of a systematic comparison across all the sampled projects. Second, the Federal Transit Administration, successor to UMTA, did not establish a rigid standard for CEI at the federal level. The calculation of CEI requires many assumptions and parameters, including but not limited to the expected economic life of material cost components (like rolling stock and heavy construction machines) and a discount rate at which the total up-front capital costs are converted into equivalent annual costs. These assumptions have changed many times since UMTA first enforced CEI. It is hard to reconcile the assumptions and parameters adopted by projects evaluated in different years and reproduce results to enable a consistent comparison. Last, we noticed that the application of CEI has gradually discarded or transformed from producing quantitative results to providing qualitative rankings in the last three decades. In this case, CEI results are only available for projects planned before 2000 or so. For these reasons, CEI is rejected.

Last, the Ridership to Cost Ratio (RCR), which is analogous to the BCR, is proposed to contrast the unit cost at which the proposed transit alternative can serve one additional transit patron. As per equation 6.2, the denominator is the estimated capital cost, and the numerator is the estimated incremental systemwide ridership.

Incremental transit ridership is the number of additional passengers (relative to the ‘no-build’ baseline or TSM where available) by different modes of access (walk, auto and bus) in the entire studied corridor, which consists of both new riders and existing riders. Although it is a less precise measure to reflect project-specific impacts on transit ridership, more exact estimates such as average daily station-level boardings are mostly unavailable at the DEIS stage. Capital cost encompasses all capital costs incurred for each alternative, allowing horizontal comparison between different alternatives for the same project. Particular cost items like rolling-stock procurement costs are not excluded because cost breakdowns are not available for every project.

The majority of user benefits involved in BCR calculation stem from the expected and actual usage of the proposed services, primarily measured by ridership in transit projects. Compared to BCR, RCR peels off the impact of various assumptions and manipulation underlying the monetization processes of the user benefits. For instance, the assumed unit economic value multiplied by Travel Time Savings (TTS) per trip varies across states and years, which might interfere in comparing the cost-effectiveness of different projects. Whereas RCR directly considers the number of users, reflecting the proposed project's actual usage. It enables fair and straightforward comparisons among different projects without causing controversies in the absence of considerations of benefits monetization.

However, the scale of project capital costs and the envisioned serving capacity differ substantially across transit projects. A direct comparison of RCR among projects can barely return informative results. As a result, ρ measuring how RCR of the LPA differs from that of other alternatives are introduced.

Considering that when a 'do-minimum' baseline scenario like TSM appears in alternative analysis, it may beat the second-best alternative in most cases and produce the highest RCR taking advantage of its low-cost trait. So 2 ρ are proposed, with $\rho_{TSM/LPA}$ weighing up TSM and the LPA (as per equation 6.3) and $\rho_{2nd/LPA}$ comparing the second-best 'do-something' alternative against the LPA (as per equation 6.4).

$$RCR = \frac{Incremental\ Transit\ Ridership}{Capital\ Cost} \tag{6.2}$$

$$\rho_{TSM/LPA} = \frac{TSM's\ RCR}{DEIS\text{-}LPA's\ RCR} \tag{6.3}$$

$$\rho_{2nd/LPA} = \frac{2nd\ Best\ Alternatives\ RCR}{DEIS\text{-}LPA's\ RCR} \tag{6.4}$$

The decision rules for ρ are straightforward. For instance, if $\rho_{2nd/LPA}$ is greater than 1, the second-best alternative outperforms the LPA because of the higher RCR generated by the former, indicating better cost-effectiveness. In contrast, $\rho_{2nd/LPA}$ would be smaller than 1 when the second best alternative reports a RCR lower than the LPA. Both ρs smaller than 1 for a project mean that the LPA economically outperforms all the alternatives that were considered and rejected.

In addition, the level of dispersion of the cost and ridership estimates of different alternatives proposed for the same project is measured by Cost Ratio (C) and Ridership Ratio (R) respectively. As indicated by equation 6.5, the cost ratio of project j is computed by summing up how the expected investment scale of the i^{th} alternative differs from the selected LPA and divided by the number of rejected 'do-something' alternatives proposed for project j, which is denoted by $(I_j - 1)$. $\overline{C}$ reflects the average dispersion of cost estimates for a total of J studied projects.

The same interpretation applies to R_j and $\overline{R}$.

$$C_j = \sum_{i=1}^{I_j} \frac{c_{i,j}}{c_{LPA_j}} \cdot (I_j - 1)^{-1} \qquad \overline{C} = \sum_{j=1}^{J} C_j \cdot J^{-1} \tag{6.5}$$

$$R_j = \sum_{i=1}^{I_j} \frac{r_{i,j}}{r_{LPA_j}} \cdot (I_j - 1)^{-1} \qquad \overline{R} = \sum_{j=1}^{J} R_j \cdot J^{-1} \tag{6.6}$$

6.4 Results

6.4.1 Project Alternatives

The Setting of the Baseline Case The first step to understand alternative analysis is revealing how the baseline case is scoped. By scouring the EISs of the sampled light rails, we found that generally two baseline cases are defined. The first one is the 'no-build' alternative, which acts as the baseline scenario upon which other action alternatives are evaluated and compared. It represents the future traffic conditions in the affected corridor after considering the long-run strategic development plan, but in the absence of the prospective project.

The 'no-build' case comprises two major parts: the existing traffic conditions, including the current road and transit network operating at the present level; and the planned and approved future improvements (other than the project discussed in the EIS) to cope with increased demand resulting from demographic growth and land use changes, comprising the augmentation of road and transit networks (e.g. extended roads or alignments, widened road lanes, and extra intermodal transport facility), improved transport accessibility (e.g. more transit stops), and operation and maintenance (periodic services at minor costs). No new transit services or capital improvements are introduced unless they are approved and funded initiatives. The estimated capital cost for the 'no-build' case is zero because all the capital outlay as a result of the envisaged improvements is irrelevant to the project discussed in the EIS.

The other base case is a 'do-minimum' option, which is also named the Transportation System Management (TSM)/ Transportation Demand Management (TDM) option. It is a low (to medium) capital cost approach for addressing the need for transit improvements in the study corridor. Except for the components covered by the 'no-build' option, the TSM alternative involves extra transit services and facilities, testing if those economical actions are capable of satisfying future transport demand and delivering benefits being sought by a 'do something' alternative. The common actions considered in a TSM are: enhanced bus services (shorter bus headway, skip-stop or express bus services, additional bus fleet or fleet modernization, additional bus stops, and procurement of clean buses for environmental concerns), additional bus services (e.g. a new busway/shuttle bus connecting employment hubs and central business districts), and improved passenger amenities and accessibility. The incremental capital cost of the TSM option is estimated relative to the zero capital cost of the 'no-build' option, which is generally designated to be the baseline for evaluating the cost-effectiveness of all build alternatives.

It is noteworthy that occasionally the TSM option may not be evaluated as an EIS alternative, which either has been eliminated in earlier planning phases (like the Major Investment Study (MIS)) due to the inability to fulfill project purposes, or has been considered as a less capital-intensive measure addressing regional transport issues and embedded in short-term transport strategies.

The Number and Types of Alternatives As shown by table 9.1 in the appendix, the average number of alternatives considered is 5.51 (standard deviation = 3.39), including the 'no-build' and 'do-minimum' baseline alternatives where existing. The minimum number of alternatives is 2, meaning that only a 'no-build' option and a 'build' option were evaluated in the EIS. The maximum number is 16. It is observed that the number of alternatives considered in DEIS has gradually reduced across the last three decades, indicating the identified transport problems are prone to be approached from confined terms of references, at least in the preparation of DEIS (see figure 6.2).

The two basic factors differentiating build alternatives are transit mode and route alignment. Based on the projects reviewed by this paper, we classify projects in table 6.1. When only one build alternative with a specified transit mode and one route option was considered for a project, the project was classified into group A. We observed that roughly 30% of the sampled projects fall into group A, indicating no competing alternative was carefully considered in the DEIS stage. Although some of these projects mentioned that different modes had been studied in Major Investment Study (MIS), a planning document generally produced before DEIS, we did not find the MIS they mentioned via searching publicly-available sources.

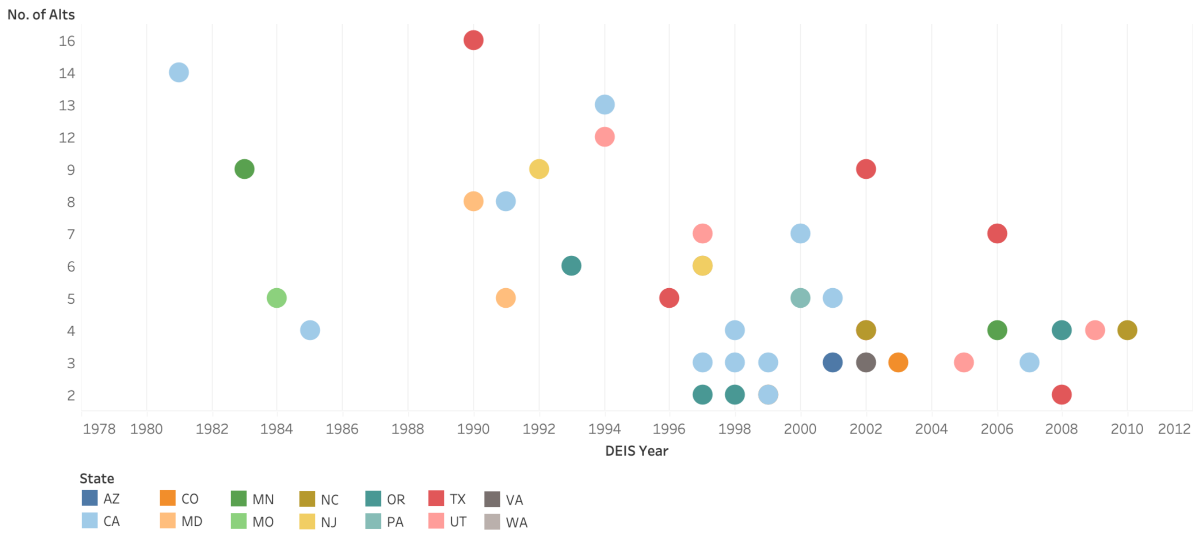


Figure 6.2 The Number of Alternatives (*I*) Considered in DEIS Created in Different Years

When multiple alternatives were considered, and the mode for all build alternatives was the same, the project was assigned to group B. In this case, the alternatives differ in the overall route alignment or in the alignment of a few crucial parts (like in the vicinity of a historical property), which is essentially one alternative mode with a few route options. Group B encompasses more than one-third of the projects. Whether alternatives proposed by using this method are justifiable and comparable especially when the magnitude of capital costs shows little difference is questioned by Lee Jr (2000), who pointed out that alternatives are expected to be examined against other alternatives with similar investment scale, not against many alternative route options for the same mode.

Group C includes projects with multiple build alternatives with distinct modes and routes. If more than one route was proposed for the same mode, the project is categorized as group C. In this case, diversified build options are able to be further explored and brought into public involvement which initiates after the release of DEIS. Whereas only 20% of projects indeed underwent such a process.

Last, for projects in group B with phasing and C with phasing, the full-length alternative with a determined mode and route was phased, with one minimum operable segment being delivered in the first phase and the remaining in later stages. In the strict sense, this is not a way of proposing an independent project alternative but a method of phasing the considerable up-front costs required by a project. In most cases, phasing was proposed when the full-length preferred alternative confronting funding shortage to avoid the project from being indefinitely deferred or even discarded.

In addition, it is noted that for the alternatives in the same mode but differing in route alignment, cost estimates and demand forecasting may yield nearly the same quantitative results because partial or trivial differences in route options cannot be distinguished by the forecasting procedures and models. Or alternatively, alternatives with different route options are reported with the same base estimates (quantitative), and qualitative discussions are added to explain expected differences where necessary.

Table 6.1 Number of Projects Observed in Each Classification Group

Group	No. of Build Alternatives	Mode	Route	Observed Number
A	1	-	-	13
B	>1	Same	Different	14
B with phasing	>1	Same	Different	5
C	>1	Different	Different	10
C with phasing	>1	Different	Different	1

Mode of Alternatives We observed that various transit modes were considered and declined in the EIS planning stage, meaning that the alternatives shortlisted in EIS have already been filtered and refined. So there is a caveat here that MIS or other planning documents recording decisions in earlier planning stages might be helpful to acquire a full list of transit modes that have ever been considered. We primarily depend on the EIS because of the availability of extensive and complete information about alternatives' design and evaluation, which might be absent from earlier planning documents.

- **Bus Rapid Transit (BRT)** mode includes bus-based transit services operating on road lanes dedicated to buses (semi-exclusive right-of-way), reducing conflicts with automobiles without compromising transit mobility and travel time reliability. BRT is superior to conventional buses in capacity, travel time, and reliability. Compared to light rail, BRT is generally cheaper in construction costs and enjoys higher flexibility. However, the BRT option is disfavored when competing against rail options purportedly because of the lower-than-desired peak hour level of service at crucial route segments, limited attainment of transit-supportive development and multi-functionalizing land-use in transit station precincts, and lower community support.

- **BRT Convertible (BRT Cvt.)**, considered in two projects in Houston, differs from BRT in that the former operates on a full-distance fixed guideway structure embedding LRT tracks. It was envisaged that after years of operation of BRT Cvt. mode, the actual ridership may hit a predetermined threshold capacity, and land use may change. Then the infrastructure of BRT Cvt. could be upgraded to light rail tracks at minimum costs and efforts, and light rail vehicle fleets would ultimately replace buses. The long-term capital outlay of BRT Cvt. ranges between full-build LRT and full-build BRT, and its up-front capital costs are lower than the other two modes. However, it was finally rejected and replaced by the full-build LRT alternative on the ground that LRT has a forecast ridership three-quarters higher than BRT Cvt. and needs minimum relocation.

- **Conventional bus (sometimes coupled with a High-Occupancy Vehicle Lane)** appeared and was compared to the locally preferred light rail mode in every project because it was the existing transit mode operating in the study corridor before introducing any new transit services. Although it is featured for low capital outlay, bus mode is typically rejected due to arguments about its limited ability to shorten travel time and accommodate the growing demand for transit service, the lack of connectivity to intermodal transport centers and facilities (such as airports and regional passenger transfer hubs), as well as being less environmental friendly and less sustainable (the assumption being that conventional diesel-powered bus induces high emission compared with electrically-powered rail modes).

- **Commuter rail** is proposed as an economic alternative choice when sharing existing railroad (with a freight rail track) is possible and viable, which incurs no extra cost for acquiring separated right-of-way and constructing rail tracks. However, its superiority of cost reduction would be substantially weakened when track sharing is insecure. Other claimed reasons for rejecting commuter rail include: limited space to construct additional commuter rail tracks and stations given the existing right-of-way (indicating acquiring new right-of-way is compulsory), using the existing ready-to-use rail tracks fails to stimulate the local economic development (because the tracks are away from major business districts), without priority over freight rail (because commuter rail may not own track), and potential safety concerns underlying track-sharing.

- **Light rail** is the preferred mode for all studied projects. The shortcomings of this mode were widely discussed, including high up-front cost, long-term intrusion on local traffic conditions and business during implementation, lower capacity and speed relative to other rail-based options, and lower flexibility in service and route adjustment compared to the bus-based option. Constructing light rail was strongly supported because it coordinates with regional land use plans and urban renewal strategies, improving transport system integrity at costs lower than heavy rail. In addition, in comparison to the bus, light rail is asserted to be eco-friendly, provides comfortable transit trip experiences, and gains strong community support.

- **Monorail and automated people movers** generally occupy a dedicated guideway with grade-separated alignment, allowing for fully automated driverless services and avoiding conflicts with vehicular traffic and street transit. However, they are assumed incapable of accommodating large numbers of riders given smaller carriages (smaller capacity) and lower speeds. The grade-separated (generally elevated) operation structure is visually intrusive. It also strikingly lifts the construction cost and lowers the overall cost-effectiveness. Although driverless services remove labor costs, the elevated structure brings about safety concerns, particularly when considering the high population and business density in the urban area they operate.

6.4.2 Alternatives' Cost-Effectiveness

Distinguishing the relative cost-effectiveness of the LPA helps explain the opportunity costs of discarding the second-best alternatives. As shown by figure 6.3, we analyzed and compared the economic advantage of the LPA against the TSM baseline option and the second-best alternative for 35 out of 43 projects (6 projects were excluded because only a 'no-build' and a 'build' options were considered, and 2 projects were excluded because of missing ridership forecasts). First, the average $\rho_{TSM/LPA}$ equals 9.16 (median = 7.02), representing that, on average, the 'do-minimum' option generates a ridership-to-cost ratio (RCR) nine times higher than the LPA. Baltimore Washington International Airport Extension has the highest $\rho_{TSM/LPA}$ of 38.69, followed by Baltimore Hunt Valley Extension of 32.08, and Minneapolis Central Corridor Light Rail of 27.52. The C of TSM to LPA equals 0.03 for the three projects, contributing to the high

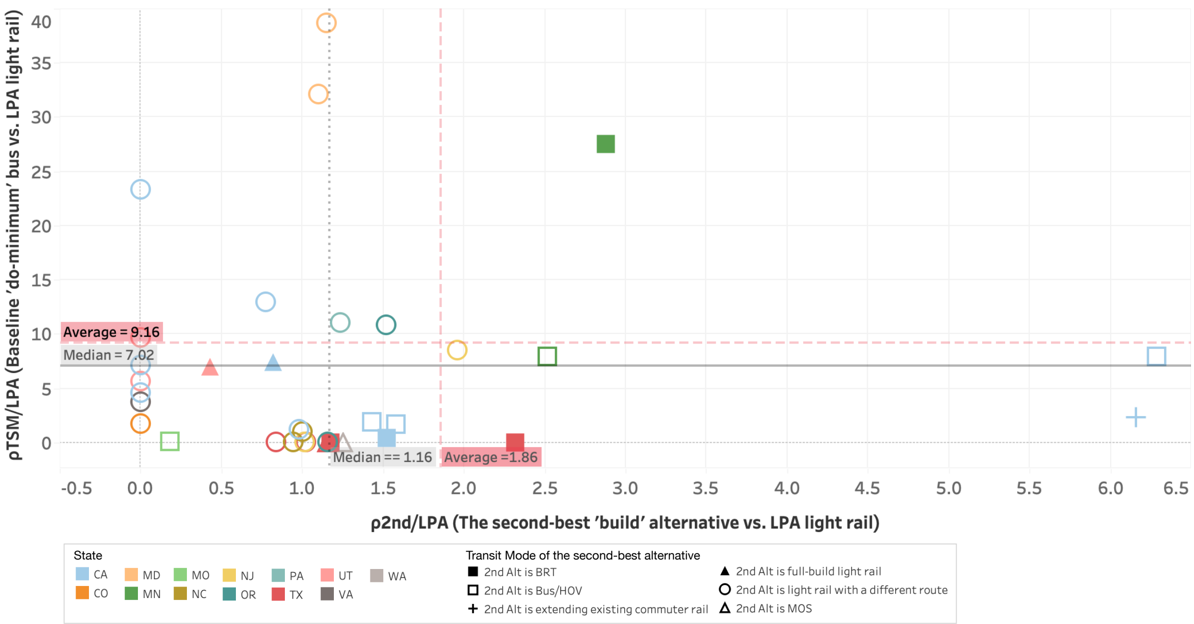


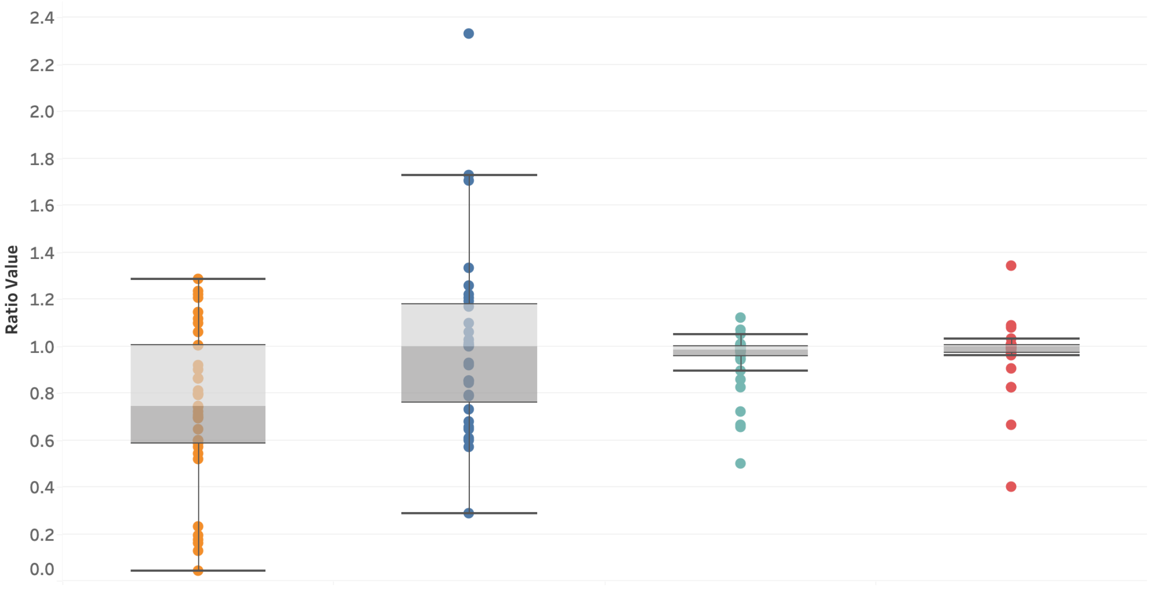
Figure 6.3 The Distribution of $\rho_{TSM/LPA}$ and $\rho_{2nd/LPA}$ for 35 out of 43 Light Rail projects (A value above 1 means the alternative has a higher (better) RCR than the LPA.)

$\rho_{TSM/LPA}$. Overall, this observation seems plausible in the sense that low cost is the core trait of the 'do-minimum' baseline option.

Second, the average $\rho_{2nd/LPA}$ is 1.86 (median = 1.16), indicating that the average ridership to cost ratio produced by the second-best 'build' alternative is 51% higher than that of the LPA. From the perspective of economic return on investment, about 60% of studied projects (20 out of 33) rejected the second-best alternative option which would have significantly outperformed the LPA. Further, whenever a BRT or an enhanced bus with a High-Occupancy Vehicle (HOV) lane was proposed (8 projects out of the 35 projects mapped in figure 6.3) as a competing alternative, its RCR was always much better than that of the LPA light rail option.

Third, average $\rho_{2nd/LPA}$ is smaller than $\rho_{TSM/LPA}$, showing that the economic feasibility of discarded 'build' options are closer to the LPA. This justifies the viability of separating TSM from the second-best 'build' when comparing the relative cost-effectiveness. However, transit modes considered in the 'build' option are mainly fixed-guideway facilities, while traditional bus mode is representative of the TSM option. It is worth questioning why the economic course of action (TSM) which could have served the potential demand for public transport at much lower costs was always renounced.

In addition, to clarify whether the potential values credited to each candidate option differ significantly, we also investigated the distribution of C (Cost Ratio) and R (Ridership Ratio)



	C including TSM	C excluding TSM	R including TSM	R excluding TSM
Observation No.	37	30	35	28
$\overline{C}$	0.739	1.002		
$\overline{R}$			0.945	0.967

Figure 6.4 The Distribution of Cost Ratio (C) and Ridership Ratio (R) of Studied Light Rail Projects/segments (A value above 1 means the alternative has a cost (or ridership) estimate higher than the LPA)

of all studied projects (see figure 6.4). The average C ($\overline{C}$) after excluding TSM equals 1.002 (median = 1), meaning that the average cost estimate for rejected build alternatives is 0.2% higher than the expected average cost for the LPA. The average R ($\overline{R}$) excluding TSM is 0.967 (median = 1), showing that the LPA is expected to serve 3.7% more transit riders than the rejected build options.

First, both findings demonstrate that cost and ridership estimates for different build alternatives of the same project are almost identical. For more than three-quarters of studied projects (projects classified into group A, B, and B with phasing as per table 6.1) alternative analyses were committed to one particular mode. We observe that ridership forecast models are incapable of distinguishing these kinds of differences. The concerns raised by Pickrell (1992) and Quade (1981) regarding whether the assessment methods and models engaged are incapable of differentiating alternatives are corroborated.

Second, the international evidence on average cost overrun and demand forecast error for transport projects is 34% (Odeck, 2019) and 6% (Hoque et al., 2022b) respectively. For US capital intensive transit projects (various transit modes) with New Starts funding grants reported in 2003 and 2007, the average cost error relative to DEIS estimate is 20.9% (Federal Transit Administration Office of Planning and Environment U.S. Department of Transportation, 2003) and 40.2% (Federal Transit Administration Office of Planning and Environment U.S. Department of Transportation, 2008), and the average demand forecast error is 65% (Federal Transit Administration Office of Planning and Environment U.S. Department of Transportation, 2003)and -38.9% (Federal Transit Administration Office of Planning and Environment U.S. Department of Transportation, 2008) respectively. The magnitude of forecast errors is substantially more than the average differences in competing alternatives' forecast capital cost and patronage, verifying that the project quantitative alternative appraisal process, as engaged by the studied projects, is incapable of effectively assisting decision-makers in justifying choices.

It may also be that the models reflect that the tested alternatives have only trivial differences in cost or ridership, so the decisions should be made on grounds beyond traditional ridership and cost metrics, or a broader set of more differentiated alternatives considered.

6.5 Discussion and Conclusion

In this chapter, a complete 'alternative history' is conducted for 43 light rail segments and lines in the US. First, it is observed that two baseline alternatives - a 'no-project' case and a 'minimum-effort' case - were scoped from a set of 43 projects. The 'no-build' case comprises two major parts: the existing traffic conditions plus the planned and approved future improvements in the studied corridor (other than the project discussed in the EIS). The other base case is a 'do-minimum' TSM/TDM option. It is a low (to medium) capital cost approach for addressing the need for transit improvements in the study corridor, which is generally in bus mode. Except for the components covered by the 'no-build' option, this alternative involves extra transit services and facilities, examining if those economic actions can satisfy future transport demand and deliver benefits sought by a 'do something' alternative. Separating the 'do-nothing' option from the 'do-minimum' option and appointing the latter as the baseline for evaluating other 'do-something' alternatives (Zimmerman, 1989) secures the realism of the appraisal of alternatives (Mackie and Preston, 1998).

Second, the number of alternatives considered ranges between 2 to 17 and has gradually declined since the 1980s, indicating the identified transport problems are prone to be approached from confined terms of references, at least at the time when DEIS formally records the decision-making. Although various modes were considered when collectively reviewing the projects sampled in this study, the maximum number of alternative modes considered at the project level is 3. Moreover, most projects only compared the preferred LRT mode against the traditional bus mode in TSM base option.

Third, in the evaluation of build alternatives, over two-thirds of projects only examined the preferred LRT mode with different routes. We conclude that the primary factor differentiating build alternatives is route alignment. Nevertheless, it is regularly observed that ridership estimates for alternatives with different routes show narrow differences, casting doubt on whether the existing user benefit assessment framework is capable of fully exploiting potential values credited to each alternative option (Quade, 1981).

Last, the 'do-minimum' option generates an RCR nine times higher than the LPA, and the average RCR produced by the second-best alternative is 86% higher than that of the LPA. Whenever a BRT or a Bus/HOV lane alternative was considered, it generated a RCR surpassing the LPA LRT option.

Those findings have several implications for policymakers and researchers in the transit sector. First, it was corroborated that LRT is chosen over the bus in most cases when they are proposed together, attesting to concerns about the existence of selection bias and discrimination in early-stage appraisal and decision-making (Priemus, 2007; Hensher, 2016; Cantarelli et al., 2022). Second, the limited modal diversity observed in the alternatives' analyses at EIS stages raised the concern that some worthwhile alternatives might be undermined in the planning stages. Third, evaluating candidate alternatives that primarily differ in route alignment using the existing quantitative criteria (costs and ridership) is hard to fully address the relative advantages of alternatives. The underdeveloped 'do-something' options raise concerns regarding the quality and reliability of the inputs to BCA, which turns to affect the ultimate recommendation framed based on BCA results.

Fourth, in many cases, it was found that the LPA was not the best 'do-something' alternative in terms of the demonstrated cost-effectiveness, indicating potential opportunity costs of rejecting more economical courses of action which could have likely managed prospective demand at much lower costs, and thus would have enabled more projects to be built and more people to have been served.

Last, the findings that alternatives with a higher rate of return were generally declined implies that BCA and its results seem to have limited contribution to *ex ante* transport investment decision-making.

However, it should be noted that one cannot deny the usefulness of BCA grounded on these findings. BCA as a quantitative investment assurance tool assesses the relative desirability of an alternative from the economic welfare perspective. Considerations of numerous other factors (i.e., social equity and environmental goals) involved in the decision-making process could divert the final decision away from the best options sorted out by BCA.

6.6 Limitation and future research opportunities

Although viewing the validity of the current transit project planning process and the quality of its outcomes (the LPA) through the lens of RCR ensures comparability across projects and simplifies the evaluation process, the method is far from perfect.

On the benefit side, ridership is a simplified proxy of total project benefits. It omits some wider socio-economic and environmental impacts, such as social equity, emission reduction, integration with future land-use planning, as well as impacts on cost-of-living. In addition, RCR is not able to reflect on how a transit project or segment influences the overall transport network in the geographic area and the transit riders it serves. For instance, extending rail services may impact the existing bus services, and there might be issues with forcing existing transit patrons to switch from bus to rail.

On the cost side, the up-front capital costs, as the surrogate of total project costs, exclude the ongoing operating and maintenance costs as well as subsequent capital costs, drawing a limited picture as to how the LPA gains an overall cost advantage over the competing alternatives. In comparison with LRT, buses have lower capacity and hence require more vehicles and more drivers to carry an equivalent number of transit users, which is likely to result in higher labor costs (an increase of transit agency's operation costs) to handle future increments of patronage demand. In addition, bus fleets need to be maintained and replaced more regularly than LRT rolling stock.

Future studies could extend the study scope by incorporating subsequent capital costs, operating and maintenance costs, and other overhead costs into the analysis. Apart from that, looking at whether the conclusion would be affected by taking a range of the wider and non-ridership benefits into account is another potential direction for future studies. In addition, digging into projects in which bus alternatives beat rail alternatives, as opposed to the scope of this study, would provide insightful findings for project alternatives evaluation.

Chapter 7

Alternatives' Evaluation and Ranking Criteria

7.1 Introduction

When carrying out a Benefit/Cost Analysis (BCA), the criteria upon which the merits of alternatives are evaluated and compared serve as the foundation for subsequent decision-making, which are expected to be comprehensive and capable of reflecting each option's level of fulfillment of project objectives and needs.

Due to the quantitative nature of BCA, the relative goodness of each alternative is examined through the lens of reliably recognizable and quantitatively measurable characteristics (costs and benefits). The direct performance indicators output by BCA, such as the Benefit/Cost Ratio (BCR) or Net Present Value (NPV), convey the resulting information to decision makers. In this case, project cost (primarily capital cost) and benefits (reflected by ridership) dominate the alternative screening process, limiting the participation of other unquantifiable features in decision-making.

Imbalanced emphasis and commitment to alternatives' selection criteria have been repeatedly observed and discussed (Priemus, 2007; Eliasson and Fosgerau, 2013; Di Ciommo and Shiftan, 2017), which may result in a preferred alternative that is superior in a few aspects but does not prevail in others. Motivated by this concern, this chapter looks into the criteria upon which the soundness and robustness of each alternative were gauged and the best project alternative was selected. This chapter addresses the following questions based on the same series of projects described and used in chapter 6.

1. What were the alternatives' justification criteria?

2. Does the degree of emphasis on each criterion differ across time?

7.2 Methodology

Qualitative content analysis is performed to leverage the qualitative resources collected. The qualitative materials include a total of 86 Environmental Impact Statements (EISs) that were prepared for 43 US light rail projects (each project has a draft and a final EIS). The EISs were downloaded as .pdf files from Google Books, and handled by using Adobe Acrobat Professional to ensure the documents' editability and searchability. Then the qualitative data analysis software - NVIVO (version 20.5.0) is used as the primary tool to perform content analysis for all the EISs collected.

General word frequency queries and target keyword search were engaged to identify the criteria considered in the alternative analysis and to detect if any temporal and regional tendency or any differences between draft EIS and final EIS exists. By running general word frequency queries (including stemmed words) for all the EISs in full text, the 1000 most frequently appearing words are filtered out (shown in table A.5 in appendix A.3), excluding the common stopwords in English(US). In the domain of natural language processing, stopwords refer to the words that are frequently used but don't convey important information (Fox, 1989; Raulji and Saini, 2016). The list of stopwords we used can be found in table A.4 in appendix A.2.

Grounded on these 1000 words, the main criteria and sub-criteria are preliminarily identified based on subjective and logical judgment and then ranked as per the corresponding occurrence frequency. Then, target search queries (encompass exact match and stemmed words) were performed for all the keywords selected from the previous step. And the related contexts where the keywords (criteria) appear most frequently were assessed by reviewing and analyzing word trees to finally determine the alternatives' evaluation criteria.

7.3 Results

7.3.1 Alternatives' Evaluation and Ranking Criteria

To reveal what criteria were considered when approving or rejecting project alternatives, we conducted general word frequency queries and target keyword search for all the EISs collected, resulting in 6 major criteria and 15 sub-criteria shown by figure 7.1. And the constitution and measures considered under each major criterion are further explored and expounded as displayed by figure 7.2. The following sub-sections are organized in descending order in accordance with the total word frequency.

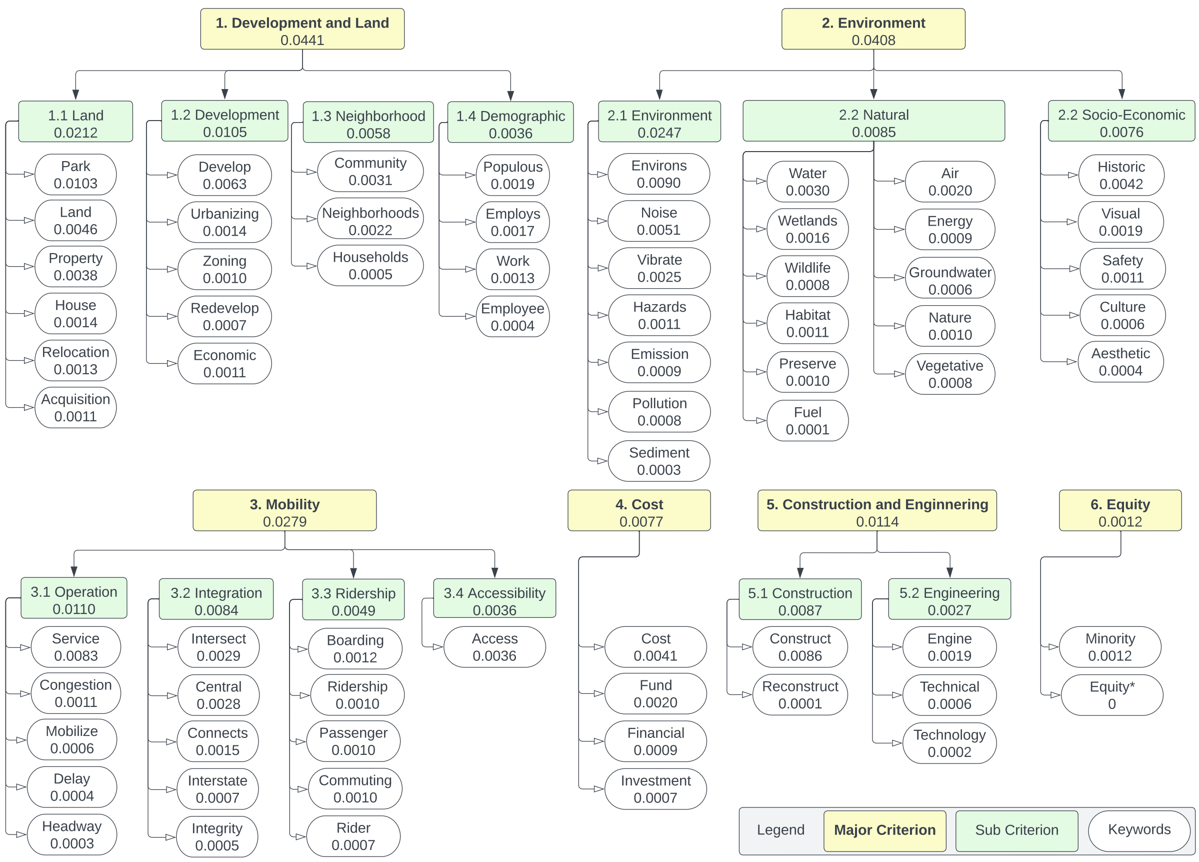


Figure 7.1 General Word Frequency Search Results

1.* Equity did not appear in the 1000 most frequently appearing words.
2. The fraction under each word shows the appearance frequency (the weighted percentage out of total word counts) of the word.
3. The appearance frequency of each major criterion is calculated by the summation of the frequency of the sub-criteria.
4. The appearance frequency of each sub-criterion is calculated by the summation of the frequency of the corresponding keywords.

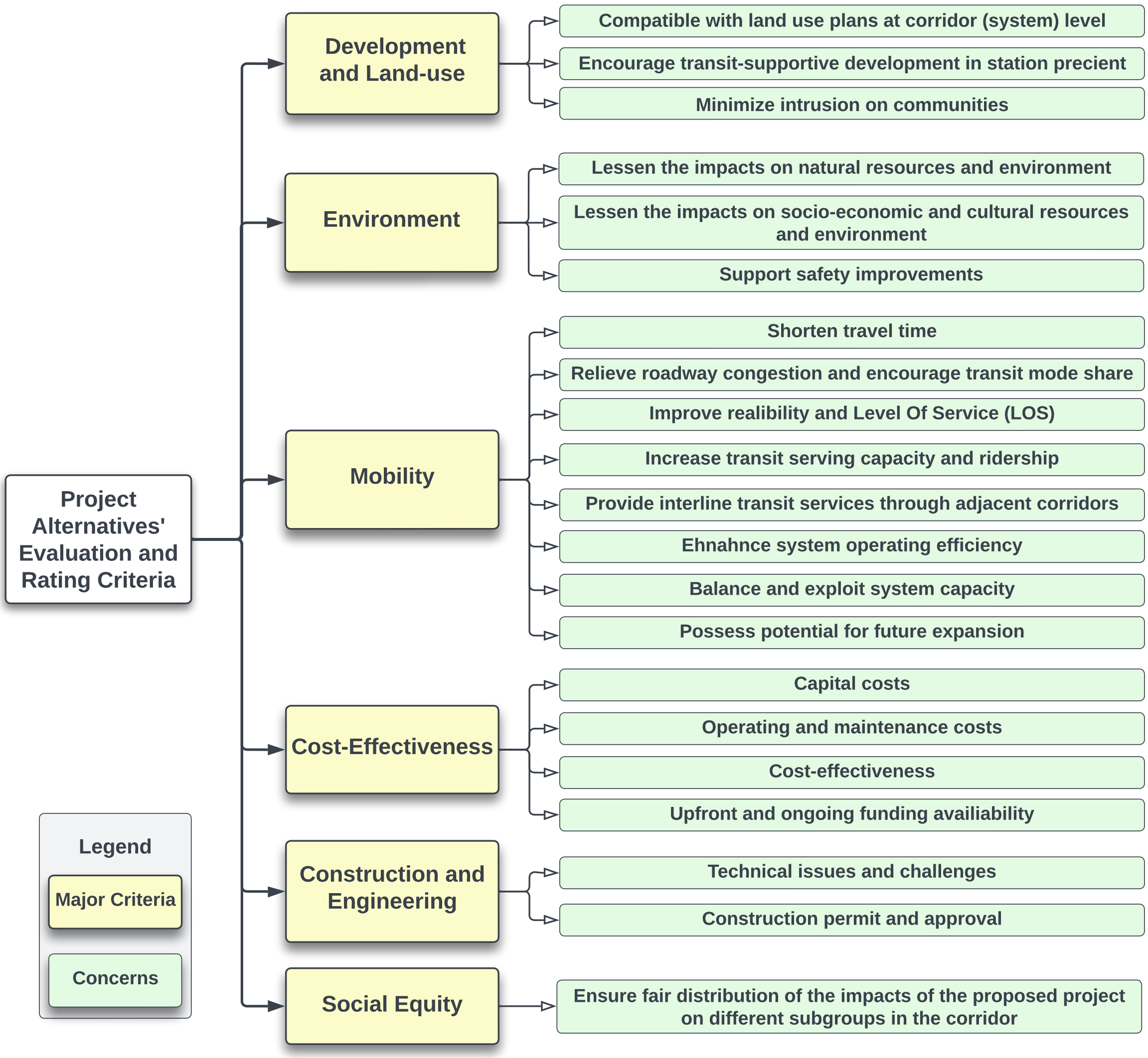


Figure 7.2 The Evaluation and Rating Criteria for Project Alternatives

Development and Land

Development and land, incorporating its sub-criteria and the corresponding keywords, accounts for 4.567% word coverage out of the total word count of approximately 7.9 million and ranks first.

As always highlighted in the objective statement in an EIS, the best alternative is anticipated to be strategically aligned with and supportive of future regional (or corridor level) land use plans, encourage transit-supportive development in station precincts, as well as minimize displacement as a result of the proposed project.

First, the introduction of new transit infrastructure is claimed to be a turning point of regional land uses, informed by the keywords classified into *land* and *development* sub-categories. It has been observed that most regions considered introducing new transit facilities intended to transform new development from continuing the trend of land use being low-density development in outlying zones to building compact and high-density development in the urban core. Relocating and concentrating commercial and production activities along the corridor (where the new transit lines serve) facilitates efficient integration of land use and transport and creates economies of agglomeration sourced from the booming of diversified business activity and enhanced productivity. Relative to the transit modes with exclusive right-of-ways, conventional buses sharing rights-of-way with cars have limited capacity to achieve those benefits:

> "*Objective A- Support investments in infrastructure, business, and community that sustain the heart of the region.*
>
> ...
>
> The Baseline Alternative is consistent with previous roadway and bus transportation investments, and operations could be within the Twin Cities Metropolitan Council responsibility. However, no direct transit-related benefits to previous development investment or developable and redevelopable land would be realized. Overall, the Baseline Alternative "does not support" the objective.
>
> ...
>
> The University Avenue LRT Alternative would have highly compatible elements with current and future transit investments, including shared facilities and the operating agency. The alternative would serve previous development investments, and is in close proximity to developable and redevelopable land. The University Avenue LRT Alternative "strongly supports" the objective. (The United States Department of Transportation Federal Transit Administration, Ramsey County Regional Railroad Authority, and Metropolitan Council, 2006)"

Second, based on the keywords under *neighborhood* and *demographic* subcategories, prospective transport interventions are envisioned to enhance regional-wide development. Albeit the construction of transport projects inevitably results in involuntary resettlement and physical displacement of people, firms, and utilities because fixed-guideway transit modes require exclusive rights-of-way, intensifying transit-supportive development and multi-functionalizing land-use in transit station precincts, like establishing a combination of office buildings, residences, recreational facilities, active transport infrastructure, and shopping centers, could materialize the development potential triggered by transit stations and exploit place-making benefits. However, traditional bus stations are claimed to have less potential and attraction for focusing development and expansion:

> "*Objective B - Promote a reliable transit system that allows an efficient, effective land use development pattern in major activity centers which minimizes parking demand, facilitates the highest and best use of adjacent properties, and gives employers confidence that employees can travel to and from work.*
>
> ...
>
> The Baseline Alternative ... is consistent with current land use patterns, but would not enhance service to planned developments and land use patterns. It would not enhance service to major travel markets or planned developments. ... Major employment centers would not receive the enhanced service provided by either build alternative, ... Overall, the Baseline Alternative "does not support"the objective.
>
> ...
>
> The University Avenue LRT Alternative would provide direct service to all four major travel markets. The alternative would penetrate the two downtowns, both the west and east banks of the University of Minnesota campus, and the Midway area. ... The proposed LRT stations are in close proximity to each of the noted development projects, and the stations would provide transit service for both business patrons and residents. Further, the stations would provide the potential for additional growth of the planned developments. ... The LRT alternative uses proven technology and is highly consistent with land use patterns and service to major travel markets. The alternative is in close proximity to planned development and serves a higher number of employees than the BRT Alternative. ... Overall, the University Avenue LRT Alternative "strongly supports" the objective. (The United States Department of Transportation Federal Transit Administration, Ramsey County Regional Railroad Authority, and Metropolitan Council, 2006)"

As shown by figure 7.3b, the average word coverage of development and land has increased rapidly since 1996, demonstrating an increasing degree of emphasis on this major criterion in transport planning and appraisal. This shift of focus is largely attributed to the popularity of the concept of Transit-Oriented Development (TOD). In comparison to other states, Minnesota (MN) shows the highest average word coverage rate, followed by Virginia and Arizona.

Environmental

The word coverage rate of this major criterion is 4.08%, which ranks second among all the six major criteria. As one of the three sub-criteria under *environmental*, 'environment' shows a frequency of 2.47%, which has the single highest frequency among all sub-criteria across different major criteria.

In this criterion, the impacts of implementing and operating each project alternative are assessed from three broad categories:

1. The impacts on natural resources and environment (natural reserve, wildlife, wetlands, energy use, and water resources), informed by keywords under both natural and environment sub-categories;
2. The impacts on non-natural resources and environment (socio-economic environment, cultural environment, parkland, air quality, noise, and vibration), informed by keywords under all three sub-categories; and
3. The contribution to safety improvements, informed by keywords under environment and socio-economic sub-categories.

In some cases, the first criterion displayed in figure 7.2 - land use and economic development - are classified into socio-economic environmental impacts.

Special analytical techniques like contingent evaluation might be able to precisely assess environmental impacts and report in monetary terms, but the EISs we collected and reviewed were generally produced in the absence of project-specific quantitative environmental analysis. The only quantitatively acquirable environmental consequences directly linked with human well-being, safety, air quality, and energy consumption rest on the changes in Vehicle Miles Travelled (VMT). Build options considering bus mode generally result in minor impacts on the natural environment and resources. Nevertheless, the overreliance on road traffic leads to higher VMT, and the usage of nonrenewable energy engenders more greenhouse gas emissions. Fixed guideway transit modes are claimed to be more capable than buses of realizing positive environmental benefits. As for the negative impacts on the environment associated with infrastructure construction, it is alleged that the consequences are extensively analyzed and that the corresponding treatment measures are in place to tackle or minimize those impacts.

> "The pollution emissions associated with the alternatives are determined by their effect on motor vehicle traffic. Depending on the change in total vehicle-miles traveled, the alternatives would have varying degrees of impact on local and regional air quality conditions. ... All alternatives would reduce air pollution levels relative to the Baseline alternative. LRT-High UPRR Option D would result in the greatest reduction of air pollution in terms of pounds of emissions per day. The lowest reduction would be for the TSM-Low alternative. There is no significant difference in the reduction of emissions associated with either the LRT alternatives along the Old SPRR or UPRR alignments. ... The pollution emissions resulting from generating electricity to power the LRT system would probably be negligible to the Sacramento region. (The United States Department of Transportation Federal Transit Administration and Sacramento Regional Transit District, 1994) "

The sharp upward slope of the green line in figure 7.3b indicates that the *environment* criterion has received intensive attention since 1990. Various negative environmental consequences since the proliferation of private vehicles in the 1920s have facilitated transport planning to shift from automobile-centered to transit-centered, which could be a possible explanation for this phenomenon. But the high word coverage rate also implies that the evaluation of alternatives' environmental impacts remains in a qualitative and descriptive manner.

Mobility

With a total word count of 2.79%, the major criterion *mobility* ranked third. Mobility to a large extent covers and compares project alternatives' ability to address the fundamental transport needs and issues in the study corridor, although it actually can be decomposed into several aspects with distinct focuses.

First, as corroborated by the keywords classified into integration and accessibility subcategories, mobility advantages are closely related to the improvement on network integration and accessibility. The betterment of intermodal connections at transit center (or stations) and accessibility to critical destinations directly contribute to travel time savings - the single largest user benefits under the current mobility-based user benefit assessment scheme. Transit-dependent commuters are prone to value out-of-vehicle time (like dwelling and transfer time) more than on-board time. To reduce people's access time to bus stops, bus routes have high circuity, and bus stops are frequent, inducing longer in-vehicle and out-of-vehicle commuting time. When operated this way, bus mode has limited ability to reduce travel time. The strengthened intermodal connections at transit stations or terminals ease commuters' transfer among different transit routes and modes and increase the number of linked trips at the corridor level. In addition, it is claimed that the well-connected (fixed-guideway) transit system, accompanied by large parking lots in the vicinity of stations (relative to bus stops), improves direct access to key destinations like business centers, employment hubs, airports, universities, and hospitals, making it more likely to realize travel time savings.

Apart from intermodal connectivity at stations within the same corridor, the system integration encompasses linkage among different lines that traverse across adjacent corridors and are even operated by different local authorities. It is alleged that by erecting new fixed guideways that are compatible with the existing lines and facilities, seamless interline connectivity enhances the smoothness and simplicity of transit service, boosts transit patronage, and eliminates the amount of alighting and boarding required by interline transfer. In addition, the integrated transit system encourages the use of existing transit facilities which mainly refer to gauge tracks and stations, improving operating efficiency and exploiting the capacity at the system level. Trains are allowed to operate on tracks built and governed by other local authorities, breaking through the corridor boundary and restricting their physical operating scope. Inbound and outbound service frequency at existing stations, especially those in densely-populated zones, is higher after permitting multiple lines to pass.

The second mobility characteristics stem from transport operation, which is imparted by the total word frequency of keywords classified under the operation sub-category. In most of the corridors, the existing roadway networks become congested due to population and employment growth, calling for alternative traffic modes to alleviate roadway congestion and accommodate traffic needs. From the perspective of congestion reduction, transit services operating on separated guideways like light rail are regarded to be more advantageous than buses using existing vehicular ways (even in a high occupancy vehicle lane).

"The Build Alternative, by virtue of the inclusion of the LRT project, improves

> the consistency and reliability of transit service. By operating in its own right-of-way, the LRT's performance is enhanced by being isolated from traffic congestion. (The United States Department of Transportation Federal Transit Administration and Regional Public Transportation Authority, 2001)"

Boosted transit mode share arises from shifts of usage of cars to transit services, and thus reduces the dependence on road traffic. Active traffic modes such as cycling and walking are promoted to satisfy the first-mile and last-mile connectivity to public transport services. However these analyses typically neglect induced demand.

Aside from 'congestion', the words 'service', 'delay', and 'headway' point to other important aspects of transport operation: comfort and reliability. Reliability is a metric associated with on-time performance. Benefiting from the independence from the roadway network, light rail service operating on the exclusive guideways is claimed to be superior to buses in terms of service reliability.

> "It also enhances the reliability of connecting bus service by causing several routes to be shortened, allowing them to better achieve their schedules. The increased bus service in the No-Build Alternative would continue to operate on city streets that are forecast to be further congested. By comparison, the Build Alternative best achieves the goal of consistent and reliable transit service. (The United States Department of Transportation Federal Transit Administration and Regional Public Transportation Authority, 2001)"

Conflicts with other vehicles using the same roadway and delays at signalized road intersections degrade the reliability of buses. Transit Level Of Service (LOS) is a qualitative metric assessing patrons' on-board riding experiences that is the level of comfort on the train, especially during peak hours, and traveling speed. The higher passenger loads and higher average traveling speed of light rail fleets secure higher LOS. During peak time when limited seats are available for patrons, the level of comfort for standing riders is higher due to fewer jolts. Furthermore, the improved transit service has positive impacts on road LOS which improves the quality of automobile traffic services on the road and at key road intersections. Thus it is asserted shifting a great portion of traffic demand from road to public transport reduces roadway congestion, therefore improves road LOS.

The series of keywords under the ridership subcategory leads us to the last important aspect of mobility - traffic demand management. In comparison to buses, light rail carriages have higher passenger loads and appear to be more attractive to new riders. According to a survey of people who did not ride transit, transit must be fast, and transit stops must be close to homes and business areas and have enough park and ride lots (U.S. Department of Transportation Federal Transit Administration, Central Puget Sound Regional Transit Authority, 2002). The survey results show that the LRT would be more successful in attracting new riders. Without changing service schedule and frequency, it is argued the serving capacity of light rail can be economically expanded or compressed by adjusting the number of carriages per train, but that the serving capacity of buses is relatively fixed.

As illustrated in graph 7.3b, the *mobility* criterion received a stable level of attention between 1985-2000 but appeared to be less prioritized afterward. Among the four sub-criteria under the *mobility* criterion (in figure 7.4b), the bars representing 'operation' and 'ridership' have shrunk considerably in size since 1990, while the bars denoting 'integration' and 'accessibility' have remained the same.

Cost

The four keywords categorized into the *cost* criterion are 'cost', 'fund', 'financial', and 'investment', which together account for 0.77% of total words.

First, it is found that in the alternative evaluation criteria, the lower the required capital costs or Operation and Maintenance (OM) costs are, the higher the alternative ranks. Considering the costs of fleet procurement, civil works (tracks and stations), right-of-way acquisition (if necessary), and construction of other essential facilities, the light rail alternative is generally more capital-intensive than the bus.

Second, the *cost* criterion incorporates potential benefits associated with the alternative. It is measured by the Cost Effectiveness Index (CEI), which is an aggregate measure involving annualized capital costs, OM costs, and travel time-saving benefits and outputs the unit costs per patron. Although getting disadvantaged by expensive up-front capital costs, light rail alternatives are projected with a CEI higher than the bus, owing to the higher ridership and higher travel time savings. Moreover, light rail alternatives would result in better operating cost savings, have higher farebox revenues (as compared to bus alternatives), require lower operating subsidies, and thus generate higher overall farebox recovery ratios. The serving capacity of light rail can be adjusted without requiring additional drivers, resulting in no increase in labor costs and a relatively small increase in operating costs.

Last, how the project sponsor's affordability (including all sources like federal grants, state grants, local funding, and funding from the private sector) is relative to project costs determines the financial viability of project alternatives. It is observed that various efforts were made to preserve the light rail Locally Preferred Alternative (LPA). In the case of Houston's red line and purple line segments, Bus Rapid Transit Convertible (BRT Cvt.) initially beat light rail and was nominated to be the LPA largely due to its lower initial capital costs, but the BRT Cvt. LPA was eventually replaced by light rail given that the latter has a forecast ridership three-quarters higher than the former and needs minimum relocation. In addition, Houston compromised on project scope (like splitting the full-length LPA into a few minimum operable segments (MOS) and staging the construction) to preserve the light rail LPA and meet the local financial conditions.

> " The estimated ridership in 2030 for the LPA (LRT) is 74 percent higher than for the BRT-Convertible LPA. The environmental consequences of the two alternatives are similar. The LPA (LRT) would have greater noise, vibration, and visual impacts than the BRT-Convertible LPA. However, the LPA (LRT) would impact fewer properties and require fewer relocations. The BRT-Convertible LPA would cost less to construct initially than the LPA (LRT). However, the overall cost changes substantially when looking at the longer term. (The United States Department of Transportation Federal Transit Administration and Metropolitan Transit Authority of Harris County, Texas, 2008)"

The *cost* criterion has become less pronounced since 1990, as informed by the yellow line in figure 7.3b.

Construction and Engineering

The total word count of the major criterion *construction and engineering* accounts for 1.14% of the total words, ranked the second last. This criterion is straightforward, representing the technical difficulty associated with each candidate alternative. The EISs we reviewed generally didn't use much space to discuss this criterion because technically unattainable alternatives were crossed out before proceeding to the EIS stage. As illustrated by figure 7.3b, the degree of emphasis on this criterion has remained stable in the last three decades.

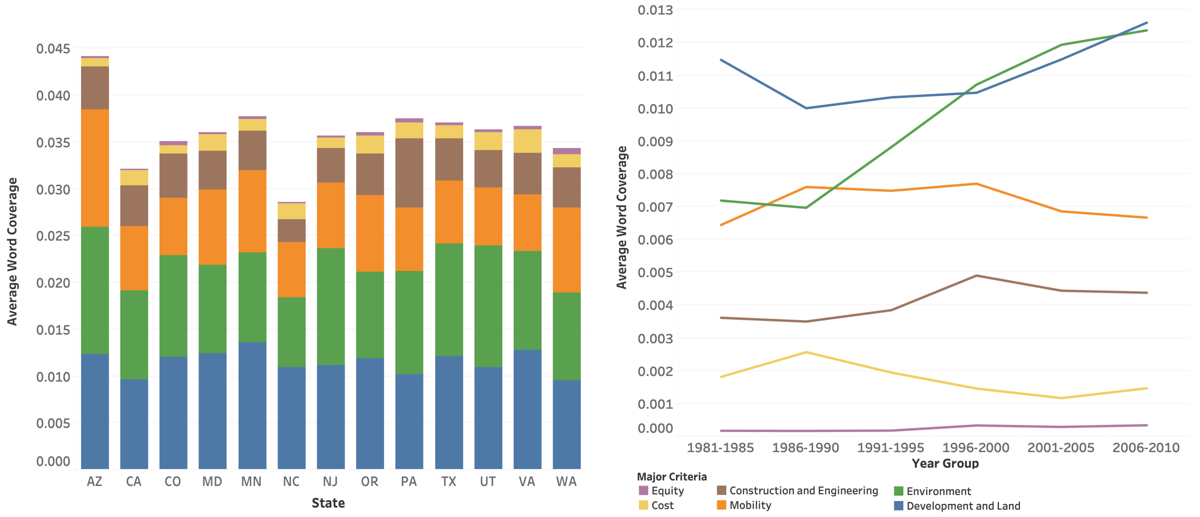
Equity

With a total word coverage rate of 0.12%, *equity* ranks last. The keywords (equity) that are deemed most important in the equity criterion even doesn't appear in the 1000 most frequently appearing word list. As shown by the flat purple line at the bottom of figure 7.3b, the equity criterion is continuously overlooked.

This criterion is conceptualized and incorporated to assess if both negative and positive impacts associated with the construction and operation of the proposed alternative are equally distributed across population sub-segments, particularly concerning about the poor, minorities, or discriminated subgroups. Specifically, it covers the following questions: whether all groups enjoy equal access to the proposed transit service (the number of the low-income groups concentrated boroughs served by the alternative); whether minority groups are disadvantaged by taking a disproportionate share of negative effects (environmental, displacement and mobility) relevant to positive effects as a result of the proposed alternative; and whether a particular group is financially squeezed to meet the funding requirement of the proposed alternative. Unlike the other criteria, *equity* is more ambiguously defined, lacks effective and coherent measures for assessment, and appears to be less prioritized in the overall alternatives' evaluation process. It is claimed that light rail outperforms buses given its superior ability to achieve the other criteria without sacrificing any subgroups (if there is, trade-off and compensation are in place to alleviate the negative impacts posed on that group), despite the fact that for the same budget, more people would be served by buses than LRT.

7.4 Conclusion

Grounded on the same set of light rail projects used in chapter 6, this chapter investigates the criteria used to evaluate and justify alternatives and examines whether the importance of these criteria has changed over time by engaging qualitative analysis and word frequency query techniques. The results reveal that six major criteria have been constantly engaged in alternatives' evaluation: development and land, environment, mobility, cost, construction, and engineering,



(a) The Average Word Coverage of Major Criteria by State

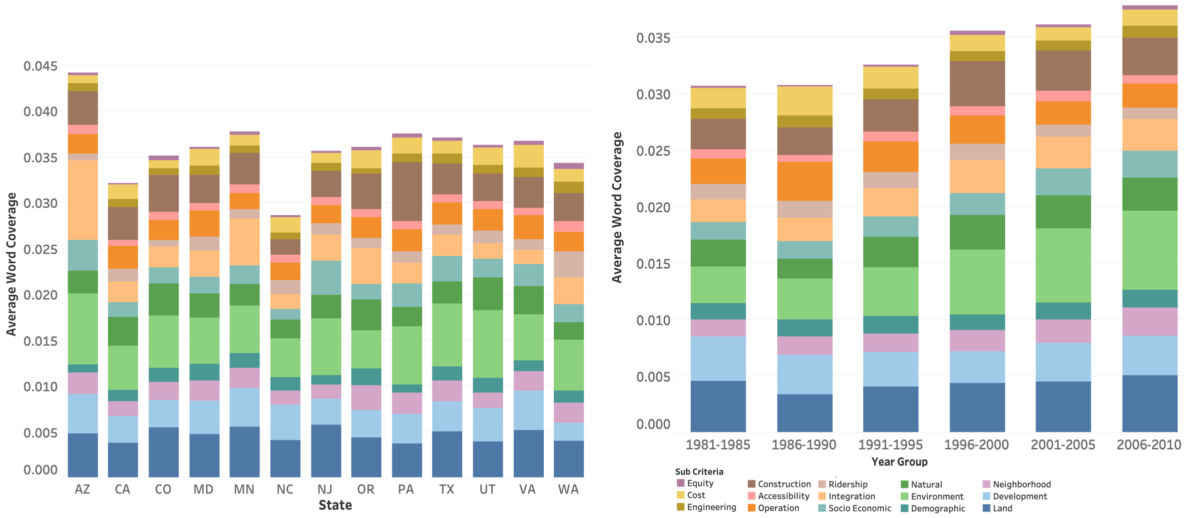
(b) The Average Word Coverage of Major Criteria by Year

Figure 7.3 Regional and Temporal Tendency of Major Criteria

as well as equity.

Development and land rank the first, and light rail alternatives, which were ultimately reckoned to be the LPA, outperform other modes in this criterion because of the alleged stronger potential for transferring land use patterns and boosting regional development. *Environmental* ranks the second. Quantitatively acquirable environmental consequences directly linked with human well-being, safety, air quality, and energy consumption are the changes in Vehicle Miles Travelled (VMT), where light rail beat bus due to the independence of fossil energy and minor impacts on the natural environment. *Mobility* ranks third, which is further decomposed to integration, accessibility, operation, and ridership. Given the alleged advantages of improving intermodal connectivity and system integration, enhancing accessibility to key destinations, providing comfortable and reliable transit service, and managing high passenger loads, light rail is superior to bus mode. The next criterion is *cost-effectiveness*. Although light rail requires intensive up-front capital investment, making it a less affordable alternative to project sponsors, various efforts were made to preserve it from being eliminated. *Construction & engineering* receives much less attention in EIS because technologically unattainable alternatives were crossed out before proceeding to the EIS stage. *Equity* appears to be the least prioritized criterion in alternatives analysis. It is sought out to be ambiguously defined and lacks effective and coherent measures for assessment.

The reduced level of emphasis on *mobility* and *cost* criteria that used to be the dominant



(a) The Average Word Coverage of Subcriteria by State

(b) The Average Word Coverage of Subcriteria by Year

Figure 7.4 Regional and Temporal Tendency of Subcriteria

factors influencing the alternatives' screening process, coupled with the increasing prioritization of *environment* and *development and land*, indicate that transport planning is evolving from return-oriented to multi-criteria-oriented. The *mobility*-based user benefits assessment methods used in many current BCAs might confront challenges in handling the need to embrace wider benefits.

It is noteworthy that word frequency analysis has limitations in revealing why projects are actually chosen. The word frequency results, including average word coverage and the changes in word coverage across years, only serve as rough proxies of evaluation focus. This is because the appearance of a word (or similar words) in the intermediate and final planning documents doesn't mean that it affects the final decision-making. The repetition frequency of a word (or similar words) is not the same as the actual weight it carries in decision-making.

Chapter 8

A Retrospective Study of Light Rail in the United States

8.1 Introduction

Although much research discusses the negative consequences of expanding public transit networks from the urban core to remote suburban areas, including the increasing number of long-distance commuters (Banister, 2011) and surging energy consumption (Nassir et al., 2016), it is widely argued that developing extensive transit network promotes transport equity, particularly for transit-dependent groups (Murray and Davis, 2001; Currie and Stanley, 2008), eases road traffic pressure and reduces pollution (May et al., 2000), as well as stimulates urban agglomeration (Salat and Ollivier, 2017).

Substantial funding has been earmarked for public transport development, and *post hoc* analyses justifying the economic validity of those investments have the aim to facilitate effective resource allocation and decision making. An extensive body of literature on transport project cost overrun has been established, yet one question regarding the best basis for assessing cost overrun (Odeck, 2004b) is inconclusive. Moreover, whether ridership ramp-up should be considered when assessing demand forecast accuracy is widely discussed. Arguments from proponents are that projects may undergo a ramp-up period to adequately penetrate the present traffic system and catch up to the full capability (Li and Hensher, 2010; Chang et al., 2010). Opponents insist that projects carrying a lower-than-expected number of passengers in initial years are prone to experience lower patronage in subsequent years. But studies dedicated to this topic are sparse. Last, the shortened travel times between key origins and destinations, which is the fundamental element for user benefit projection, are largely overlooked by the current literature, calling for more empirical evidence to assist decision-makers.

Based on the same set of US light rail projects used in chapter 6 and 7 (as per table A.3 in appendix A.1), this chapter aims to:

1. Explore (if any) systematic tendencies in cost and ridership estimates in multiple *ex ante* project stages by contrasting the forecast with subsequent observation; and
2. Retrospectively examine the accuracy of capital cost estimates, ridership forecasts, and transit travel times between paired origin and destination for studied US light rail systems where data are available.

8.2 Methodology

8.2.1 Project Cost

Each project's cost estimate is altered throughout the planning stages, including DEIS, FEIS, and FFGA (Final Funding Granting Agreement), which are extracted from planning documents released in the corresponding stage. Actual project costs are acquired by searching multiple sources, including FTA 'Before and After Study' and announcements published by the project sponsor authorities or contracted construction and consultancy companies. However, the cost estimates and as-built costs are reported in dollar values in different years, which are not directly comparable. So, according to equation 8.1, raw costs (C) have been adjusted for inflation to 2019 (denoted by C') by using US Consumer Price Index (CPI) prepared by World Bank.

$$C' = C \cdot \frac{CPI_{2019}}{CPI_{initial\ year}} \tag{8.1}$$

8.2.2 Ridership

Ridership is a key performance metric reflecting a proposed project's usage level. *Ex ante* user benefits projection and *ex post* assessment primarily relies on ridership. In this study, average weekday station boarding is designated to be the measure of transit ridership. In project appraisal, this measure is output by the ridership forecast model and offers a precise approximation of project-specific impact, which can be retrieved from planning documents. After project opening, station boarding statistics are generated by automatic fare collection systems, which are released on a quarterly or annual basis by transport operators or regional transport authorities.

For each project, we first documented all the proposed transit stations along the planned route segment. To avoid miscounting, we then cross-checked the actual system network to include stations outside the initial project scope and exclude unbuilt stations or stations with deferred delivery. Lastly, if stations were dropped or added, other stations may have higher ridership if they are substitutes or fewer if they are complements. The total average weekday boarding computed by the summation of boarding at all stations covered by the project is engaged as the indicator of ridership, eliminating the impact of missed or surged ridership at the station level on project-level ridership performance.

8.2.3 Project Performance Measure

A consistent performance measure weighing project costs against benefits is needed to trace and compare whether a project actually outperforms or underperforms its LPA.

Initially, the Benefit/Cost Ratio (BCR) was considered to be the primary performance metric assessing project cost-effectiveness, which is produced by BCA. Though the logic of BCA was noted to be universally engaged in project appraisal and selection, BCR was not reported in most projects' *ex ante* studies, so BCR is not used.

Then, the Ridership/Cost Ratio (RCR), which is similar to BCR, is employed to gauge project cost-effectiveness. As shown by equation 8.2, RCR is yielded by annual station boarding (calendar year) over project capital costs, reporting the unit cost at which the project can serve one additional rider boarding at the proposed stations. RCR retains the key elements considered in BCR and casts off various underlying assumptions required to express project benefits in monetary terms.

$$RCR = \frac{Annual\ Station\ Boarding}{C'} \tag{8.2}$$

However, the interpretability of RCR is restricted when projects with distinct serving capacities and investment scales are compared together. So ρ gauging the extent to which the LPA's RCR deviates from the actual RCR in the i^{th} year is introduced to create a fair comparison among different projects and eliminate the influence of project scale (see equation 8.3). By using the actual annual station boarding for different years, ρ allows for consecutive evaluations tracing whether the project approaches its initial target, thus enabling observation of whether the ramp-up effect gets weaker as the project gradually penetrates the local transport network. If $\rho_{Act_1/LPA}$ is higher than 1, the project hit the performance target stated in the LPA in its first-year operation. Further, if $\rho_{Act_2/LPA}$ is greater than $\rho_{Act_1/LPA}$, the project's second-year performance is better than the first year.

$$\rho_{Act_i/LPA} = \frac{R_{i_{Actual}}}{R_{LPA}} \tag{8.3}$$

8.2.4 Transit Travel Time

In the planning stages, given the fact that patrons are prone to perceive out-of-vehicle travel time as more onerous than in-vehicle time, planners apply weighted models to calculate average transit travel time. The weighted models use a 'weight factor' of 1 when accounting for in-vehicle travel time and apply tailored factors with values higher than 1 to evaluate different out-of-vehicle travel times, including first- and last-mile travel times to access transit services, dwelling times, and transfer times (transfer time suffers the highest penalty and thus are given the largest weight factor). As a result, the approximation of total transit travel time is influenced by various assumptions, parameters, and uncertainty. For instance, local transport planning authorities used their discretion in determining weighted factors multiplied by out-of-vehicle travel time, restricting the comparability of the total transit travel time projected for projects in different regions.

In addition, many projects reported zone-to-zone average transit travel time, which depends on numerous assumptions about the arrangement of out-of-vehicle travel experiences like transfer mode, dwelling time and etc. Difficulties in restoring those assumptions bring great challenges to *post hoc* assessment. To ensure the reliability of measures and comparability among projects, we decided to use unweighted weekday morning peak-hour station-to-station in-vehicle travel time as the primary measure of transit travel time. We found that this measure was applied and reported in 16 out of 42 projects. Travel time estimates are collected by scouring project FEISs. Google Distance Matrix API is engaged in extracting actual travel time. The settings are shown below:

1. Origin and Destination: The same set of paired origins and destinations (OD) is used for estimated and actual travel time, which is either proposed (or existing) transit stations or designated non-station landmarks.

2. Mode and routing preference: Routing preference is set to be 'fewer-transfers'. The primary mode is set as 'Transit'. The tram transit mode is picked when extracting light rail travel time. It is noted that although the transit mode is specified to be bus when requesting bus travel time, partial travel routes may still use other transit modes.

3. Departure time: The departure time starts from 8 am with a 10-min interval (to simulate morning peak-hour headway) and ends at 10 am, looping through all weekdays.

When calculating the travel time between a paired OD, a total of 65 travel time queries (13 trips per day times 5 days a week) are returned, and the actual travel time is computed by taking the average travel time of the 65 records.

The extent to which actual travel time differs from the estimates is measured in percent error (E), which is calculated as per equation 8.4 for light rail and 8.5 for bus, respectively. T denotes actual in-vehicle travel time, and t denotes the estimated travel time between the same OD pairs stated in the FEIS.

$$E_{LRT} = \frac{T_{Act_{LRT}}}{t_{LPA_{LRT}}} - 1 \quad (8.4)$$

$$E_{BUS} = \frac{T_{ACT_{BUS}}}{t_{LPA_{BUS}}} - 1 \tag{8.5}$$

8.3 Results

8.3.1 Are there any systematic tendencies of adjusting capital cost estimate and station boarding forecast?

Project costs rise consistently throughout the planning phase (see figure 8.1). Compared to DEIS cost estimates, FEIS cost estimates are on average 5.3% higher, followed by FFGA estimates at 16.5%. Outturn costs are 16.3% higher than DEIS estimates, closely matching the FFGA estimates upon which federal funds were granted. It is occasionally observed that FFGA cost estimates were adjusted upward since the commencement of project construction, although the escalation may not be necessarily paid for by the federal.

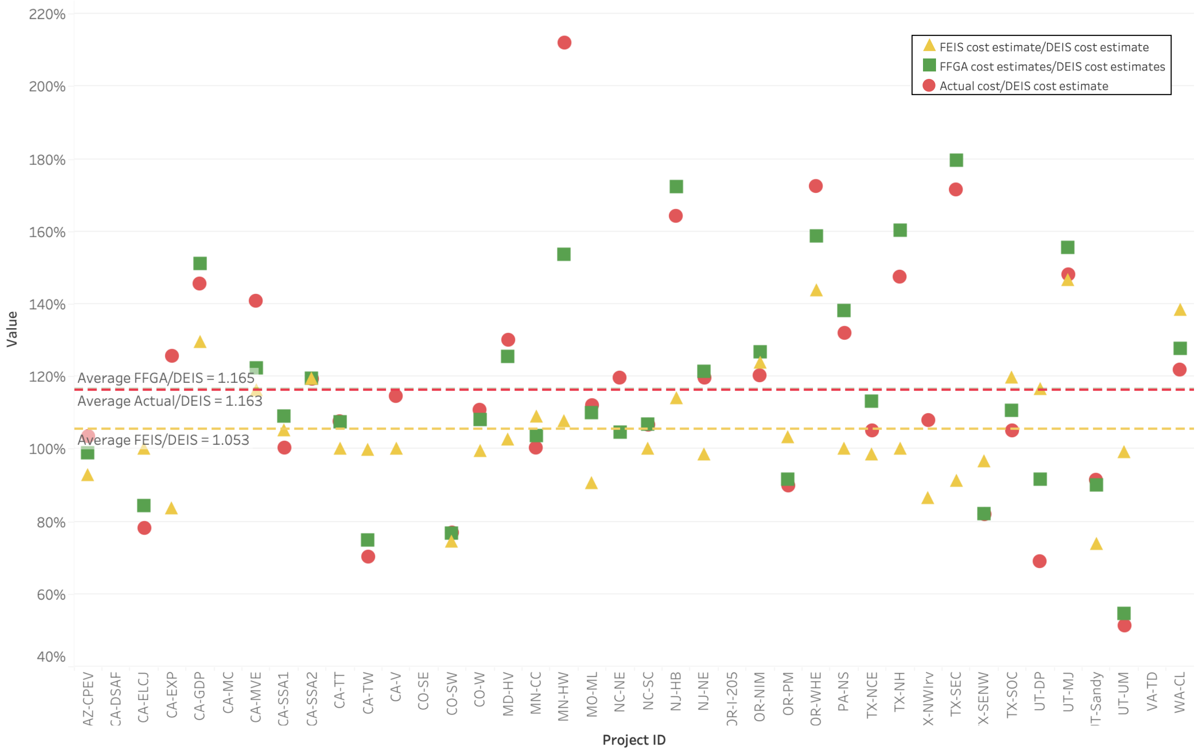


Figure 8.1 Changes in Cost Estimate among DEIS, FEIS, FFGA and the Actual Cost (n=40)

Changes in ridership forecast show no systematic pattern. It is discovered that no changes were made to ridership forecasts for roughly 48% (14 out of 29, the seven projects that don't have FEIS ridership estimates are excluded) of the projects mapped in figure 8.2. Ridership forecasts for about 30% (9 out of 29) of projects were altered upwards, although to various extents. For the remaining six projects whose ridership forecasts stated in the FEIS were lowered, their cost estimates increased in the FEIS. In addition, in most cases, no explicit reasons were provided to justify changes in the demand forecast. Moreover, 29 out of the 32 projects have actual first-year boarding data indicating that fewer passengers than expected were carried.

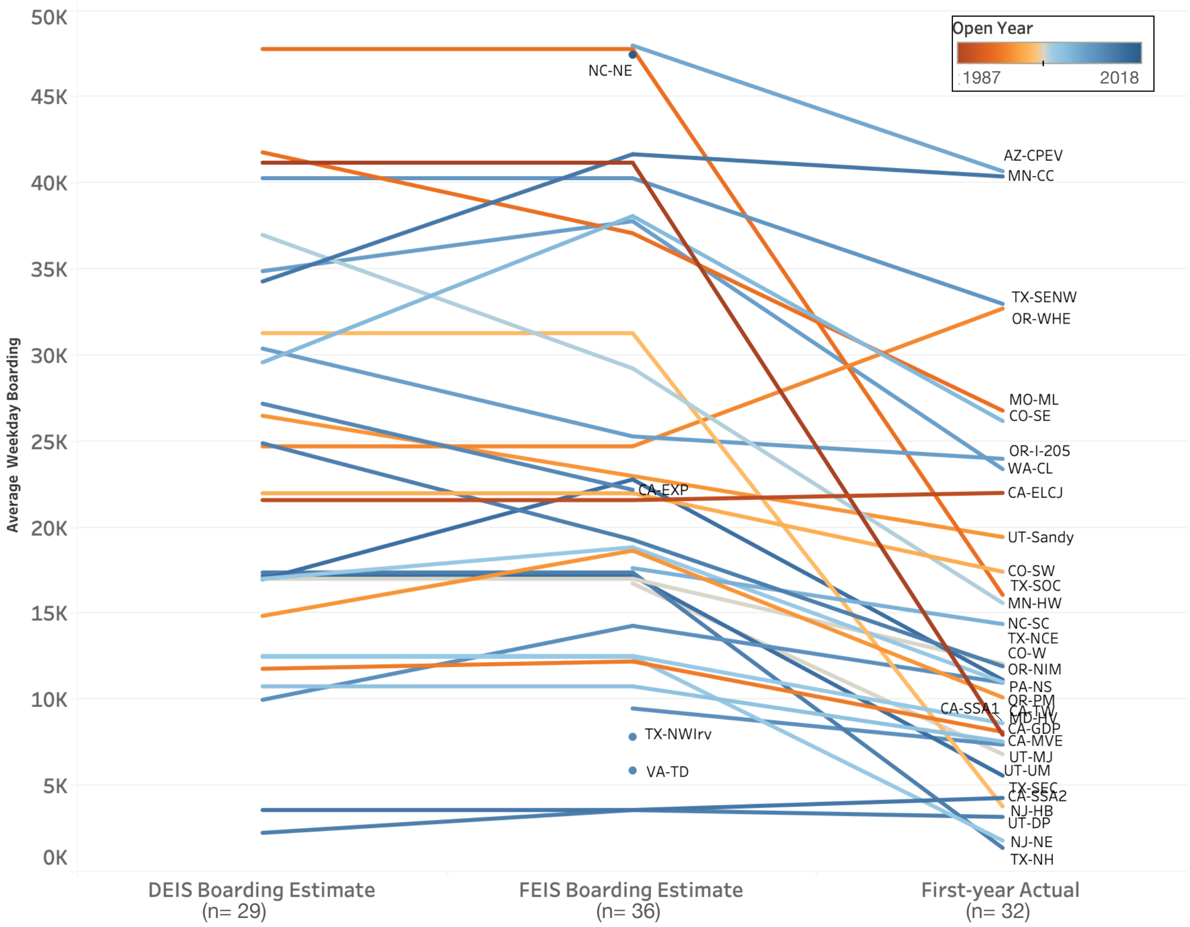


Figure 8.2 Changes in Ridership Forecasts between the DEIS and FEIS (n=36)

8.3.2 To what extent does the actual performance conform to the LPA?

As shown by figure 8.3, the number of projects opened for 5 years, 6-10 years, and over 10 years are 5 (25%), 5 (25%), and 10 (50%) respectively. First, five projects sustain or have achieved a ρ that exceeds 1 as of 2019, indicating actual performance superior to the LPA. Four out of the five have operated for more than a decade, and one project - the Minnesota Central Corridor - fulfilled 90% of the stated LPA's RCR after opening and exceeded the LPA's RCR in the second year. We see that 6 of the 15 projects (40%) have never hit the target specified in the LPA despite operating for more than 10 years. Their annual performance is either steady or showed downward tendencies, suggesting little possibility of reversing the current situation in the foreseeable future.

Second, considering that both the cost estimate and the actual outturn cost of a project are fixed, the changes in ρ observed year by year are purely driven by station boarding. The mean growth rate of ρ for all the observations displayed in figure 8.3 is 0.316% (standard deviation is 5.13, and minimum and maximum growth rate is -9.46% and 12.79%, respectively), which is far below the assumed annual population and employment growth rate (generally higher than 1%) used for ridership projection, attesting to potential optimism bias in *ex ante* user-benefit evaluation. In addition, the value of ρ slightly fluctuates around its mean, and no systematic uptrend or downtrend in the variation of ρ is observed when viewing the twenty projects collectively. This observation contradicts the expectation of projects in their early operation years (no more than 5 years), where rapid growth approaching its patronage potential is anticipated after project delivery.

Third, the ridership forecast horizon is generally 15-20 years, although a 5-year time window is applied occasionally. For the eight projects (with * sign or black rectangle) whose actual operational years have intersected with the endpoint of the forecast horizon, only three projects prevail over the LPA, with the remaining five carrying 20% - 76% fewer passengers than they were expected in the corresponding year. In terms of the remaining 12 projects that are halfway through the journey to the forecast year, they can barely reach their target in the corresponding year, given the current growth rate.

8.3.3 Transit Travel Time

Transit travel time between paired origin and destination is used to assess the relative mobility advantage over the baseline bus mode. Considering that in each project the incremental travel times of light rail relative to baseline bus mode are assessed across multiple OD pairs, project travel time performance is averaged by state. As a result, the measures and results displayed in figure 8.4 represent the state-average level.

First, as shown in the table in figure 8.4, the state average light rail travel time (in minutes) is

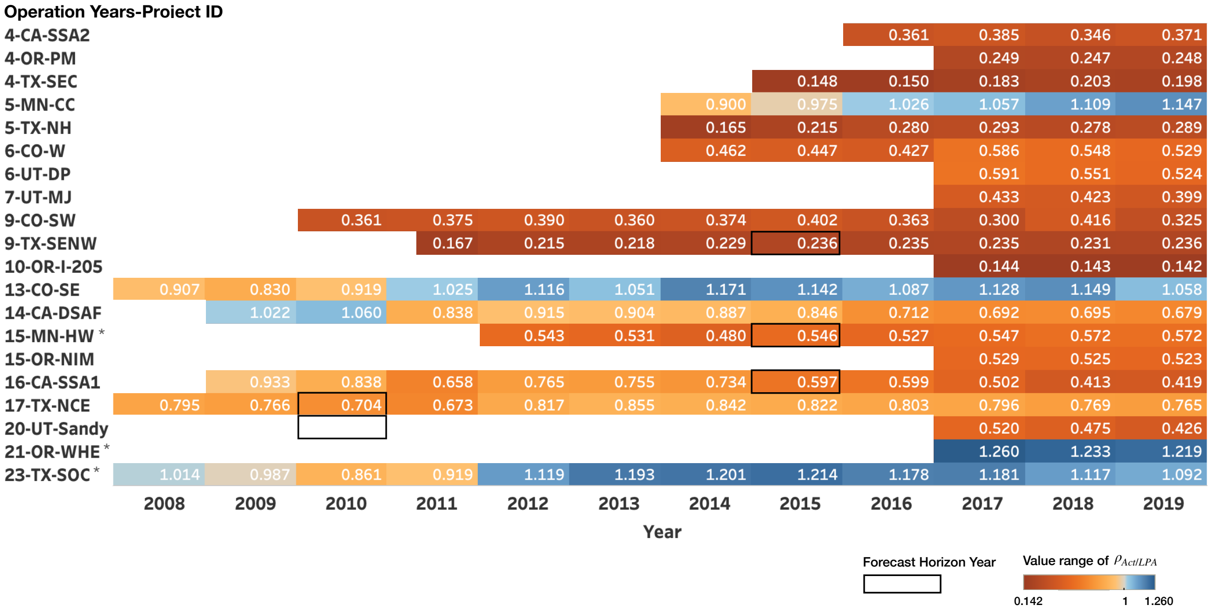


Figure 8.3 Variation of $\rho_{Act/LPA}$ over Years after Project Opening (n=20)

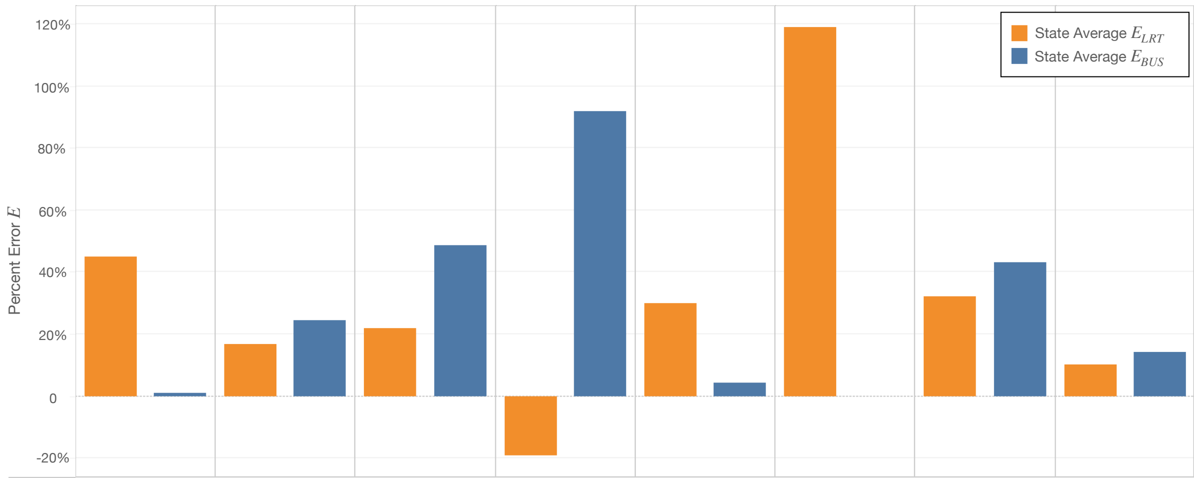
* The end point of the forecast horizon is before 2008.
1. The end point of the forecast horizon is after 2019 for projects without a red circle or *.
2. Projects are sorted in ascending order by the number of operation years.

shorter than bus given the same OD pairs, meaning that light rail offers faster passenger services than bus-based transit for those specific corridors.

Second, positive average E_{LRT}s are observed for 7 out of 8 states, substantiating that morning peak hour in-vehicle light rail travel times were systematically overstated in the *ex ante* stage. Accompany with the actual light rail travel time measured in minutes, the magnitude of overestimation ranges between 5.5 mins (in UT) - 21.09 mins (in AZ). Although the Pittsburgh North Shore Connector project in Pennsylvania has the highest E_{LRT} of 119%, the estimated travel time was overstated by 5.7 mins.

Third, on average, the actual bus travel time is also overstated. For the Central Phoenix light rail in Arizona and Hillsboro Extension in Oregon, E_{LRT} is larger than E_{BUS}, informing that the calculated incremental travel time savings are likely to be overstated. In contrast, E_{BUS} exceeds E_{LRT} for projects in California, Colorado, New Jersey, Taxes, and Utah, resulting in over-conservative estimates of the light rail.

Overall, although no systematic tendency of overstating or understating transit travel time saving is observed, the significant divergence of travel time estimate from the actual performance brings about concerns about the reliability of the incremental user benefits and the overall cost-effectiveness estimated by BCA.



State	AZ	CA	CO	NJ	OR	PA	TX	UT
No. of projects	1	2	3	1	1	1	5	2
Average Actual In-Vehicle LRT Time (mins)	46.80	51.67	34.50	17.67	45.25	10.67	22.86	54.43
Average Actual In-Vehicle BUS Time (mins)	73.00	76.29	53.29	34.33	67.75	-	43.95	77.57

Figure 8.4 An Overview of In-vehicle Transit Travel Time between Paired Origin and Destination by State

8.4 Conclusion

Based on 42 light rail segments opened between 1991-2018, this chapter examines if there are any systematic patterns in how cost estimates and ridership forecasts vary at various planning phases. It is observed that project costs rise constantly throughout the planning stages. Compared to the earliest official cost estimates reported in DEIS, subsequent estimates increase by 5.3%, 16.5%, and 16.3% in FEIS, final FFGA, and project completion. In contrast, changes in ridership forecast show no systematic pattern, where patronage forecasts for over 85% of projects either remained constant or adjusted upwards.

By engaging the ridership/cost ratio (RCR), which is analogous to BCR, we inspect whether actual project performance gets closer to the cost-effectiveness target stated in the FEIS LPA after years of operation. As of 2019, we first find that only 5 (out of 20) projects sustain or have achieved performance superior to the claims of the Locally Preferred Alternative, where four projects were delivered at least a decade ago and one project hit its target three years after opening. For the remaining 15 projects, their annual performance either steadily underperforms the LPA or shows downward tendencies. This finding informs the low possibility of reversing the current operational situation in the foreseeable future, negating the hypothesis that projects underperforming in initial operation years catch up to their full forecast demand when the ramp-up effect disappears. The optimism biases in patronage projection run through the expected project lifespan. Second, considering the changes in RCR are purely driven by patronage, an average growth rate of 0.316% is far below the assumed annual population and employment growth rate used for demand forecast and patronage projection This finding attests to potential optimism bias in *ex ante* user-benefit projection.

Regarding transit travel time, it is found that the actual morning peak hour in-vehicle travel time between the same OD pair for both bus and light rail mode were overstated in the FEIS. Although no systematic tendency of overstating or understating transit travel time is concluded, the significant divergence of travel time estimates from the actual performance brings about concerns about the consistency and reliability of the demand forecasts based on time savings, as well as incremental user benefits and the overall cost-effectiveness estimated by BCA. The observation that demand forecasts were too high despite travel times being too pessimistic raises additional concerns about the forecasting process.

Chapter 9

A Retrospective Study of Recent Passenger Rail Projects in Australia

9.1 Introduction

After decades of reliance on the bus, heavy rail, and tram (in Melbourne) as the primary transit mode connecting the inner and outer city, new fixed-guideway facilities have gradually revitalized in Australian public transport sector in the last two decades. One of the debates following this mania lies between light rail and Bus Rapid Transit (BRT). Claiming that light rail intensifies urban economic development and relieves road traffic congestion, almost all the states in Australia have heavily invested (or at least have planned to do so) to construct, retrofit, and extend light rail systems in the last a few decades (Keys, 2016; Currie and Burke, 2013). However, whether the overwhelming advocacy of fixed-guideway passenger rails, particularly light rail, over other alternative transit modes like BRT, is economically justifiable has been increasingly questioned after the renaissance. Hensher (2016) noted that in most cases where both light rail and BRT options were proposed and assessed by Benefit-Cost Analysis (BCA), BRT beat light rail but ended up with a rejection. Past research studied the Australian light rail boom from different perspectives, including but not limited to those published by (Currie and Burke, 2013; Currie et al., 2014; Currie and De Gruyter, 2016; Keys, 2016). Whereas many of the projects they covered were not completed at the time of study, the *ex post* actual operating performance was not considered.

Based on information about 6 Australian passenger rail projects delivered before 2021 (consisting of 8 passengers rail segments in Sydney, Gold Coast, Newcastle, and Canberra), this chapter disentangles whether the alternative reckoned to be worthwhile outperformed other candidates in *ex ante* stage and materializes its potential value as envisioned. Based on all the available evidence and data documenting project planning and operation, each project is assessed from the following two dimensions:

1. How good the preferred fixed-guideway option (primarily light rail) was demonstrated in *ex ante* BCA; and
2. To what extent the envisioned benefits of studied passenger rails have been realized?

The second dimension is approached from two perspectives: transit travel time between paired origins and destinations and the demand reflected by hourly boarding patronage.

9.2 AUS Projects and Data

Table 9.1 An Overview of Recent Australian Fixed-Guideway Projects

ID	Project Name	State	Type	City	Year Open	Capital Cost ($AUS mil) Estimate	Capital Cost ($AUS mil) Outturn	Length (km)	No. of Stops
1	(G:Link) G:Link Stage 1&2	QLD	LRT	Gold Coast	2014	$ 812	$ 1300	13	16
2	(L1) Dulwich Hill Line	NSW	LRT	Sydney	2014	$ 72.56	$ 176	5.6	9
3	(CapMetro) Capital Metro	ACT	LRT	Canberra	2018	$ 783	$ 698	12	13
4	(NLR) Newcastle Light Rail	NSW	LRT	Sydney	2019	$ 245	$ 368	2.7	6
5	(Metro NW) Metro Northwest	NSW	Metro	Sydney	2019	$ 7500-8500	$ 8300	36	13
6	(L2&L3) CBD and South East Light Rail	NSW	LRT	Sydney	2020	$ 1600	$ 3147	12	19

Tables 9.1 and 9.2 outlines the basic project information and the primary sources. To the best we can, we collected information from the planning stages, including reports and documents produced over multiple stages. Although Infrastructure Australia (IA) (Infrastructure Australia, 2021) and Bureau of Infrastructure, Transport and Regional Economics (BITRE) (Bureau of Infrastructure, Transport and Regional Economics, 2014) issued federal-level planning and evaluation frameworks, the light rail project appraisal mechanism under each Australian

Table 9.2 An Overview of Australian Fixed-Guideway Projects (Cont.)

ID	Project	Alternative Modes * Rejected	Alternative Modes * Considered	Demand Forecast Model	Year of Pub.	Report Type
1	G:Link	MR TU	Base BRT LRT	GCRT VISUM	2008	Draft Concept Design and Impact Management Plan
2	Syd L1	-	Base LRT	NSW STM	2010 2010 2010	Preliminary Environmental Assessment Environmental Assessment Final Project Definition Report
3	CapMetro	-	Base BRT LRT	CSTM	2012 2012 2014	Concept Design Report IA Project Submission Full Business Case
4	NLR	Bus	Base LRT	PTPM	2010 2016	Pre-Concept Design Report Review of Environmental Factors Submission Report
5	Metro NW	HR LRT TSW	Base LRT	PTPM	2006 2006 2011 2011 2012	Economic Appraisal Report Environmental Assessment IA Project Submission Project Definition Report Environmental Impact Statement
6	Syd L2&L3	-	Base LRT	PTPM	2013 2013 2014	Full Business Case Environmental Impact Assessment Preferred Infrastructure Submission Report

* MR- Elevated Monorail; TU- Tunnelling; HR- Heavy Rail; LRT- Light Rail; TSW- Transitway; BRT- Bus Rapid Transit.

state's jurisdiction differs. The discretionary planning processes lead to difficulties retrieving *ex ante* planning documents with the same title and produced in similar planning stages.

Gold Coast Rapid Transit Project (G:Link) In the 1997 Integrated Regional Transport Plan for South East Queensland, Gold Coast proposed a rapid transit system targeting the light rail transit mode to relieve road traffic congestion. The new initiative is intended to address environmental and safety concerns and accommodate the growing number of residents and tourists along the 13-km east coastal strip. After decades of planning, the Draft Concept Design and Impact Management Plan (Translink, Gold Coast City Council, and Queensland Transport, 2008) presented the most extensive analysis of stages 1 and 2, built in 2010 and 2016, and delivered in 2014 and 2017, respectively.

Sydney Dulwich Hill Line (Syd L1) The 5.6 km Dulwich Hill Line (previously known as Inner West Light Rail Extension Project) extended the existing light rail from Lilyfield to Dulwich Hill. It is the first stage of the 2010 NSW Government's Metropolitan Transport Plan (MTP) (NSW Government, 2012). The L1 extension retrofitted the derelict freight rail corridor. It was to be accompanied by a greenway component that was intended to promote active transport modes within the same corridor, an element that was subsequently discarded. Construction was initiated in 2010 and finalized in 2014, 2 years behind the initial schedule.

Sydney CBD and South East Light Rail (Syd L2&L3) As the second stage of the NSW MTP, the 12km project consists a mainline running through the City of Sydney that branched in two directions from Moore Park Station: L2 to Randwick and L3 to Junior's Kingsford. At the end of 2015, the closing of George Street symbolized the official commencement of construction. The construction progress underwent severe schedule delay, and the actual cost almost doubled the initial estimates. L2 traversing to Randwick was opened in December 2019, one year and seven months behind the initial schedule, and L3 was opened in March 2020, just prior to the first COVID lockdowns.

Newcastle Light Rail (NLR) The heavy rail line terminated at Newcastle terminus had been claimed to hinder the restoration of the town center, with suggestions about the cessation of operation for years since 2002 (RailCorp, 2010). The heavy rail stations east of Wickham were permanently shut down in 2014, following years of discussion and planning on the transit configuration and mode choice. Light rail was officially nominated and approved to be the key transport development component in the Newcastle Urban Transformation and Transport Program in 2016 (Audit Office of New South Wales, 2018). Construction work started in 2017 and was completed in the second half of 2018. The light rail opened to service in February 2019.

Sydney Metro Northwest (Metro NW) As the major transit service securing residents' access to jobs and manifold activities in the northwestern corridor, Sydney Metro Northwest (previously known as North West Rail Link) has experienced complicated planning processes since 1990s in the light of the best mode and route alignment linking Epping and regional hubs like Castle Hill and Rouse Hill (Transport Infrastructure Development Corporation, 2006). The 36km Metro line traverses between Tallawong (named Cudgegong in planning) and Cherrybrook and directly replaces the existing heavy rail line between Epping and Chatswood. The geotechnical work and tunneling started in 2011. Construction was completed in 2018, and the line officially began to operate in May 2019.

Canberra Capital Metro (CapMetro) In 1911, the American architect Walter Burley Griffin proposed a rapid transit line operating across the city center in his entry submitted to the competition of the Federal Capital of Australia plan (National Capital Authority). After decades of discussion, the full business case of this project was completed in 2014. The winning of the Labour party in the 2016 election secured that the project would be implemented as planned. The construction of the 12-km CapMetro light rail line (stage 1) connecting the northern regional center Gungahlin to the center of Canberra commenced in 2016 and was finalized at the end of 2018. The service opened in April 2019.

9.3 Methodology

Two methodologies correspond to the two dimensions are outlined in section 9.1. First, to address the effectiveness of the selected option over the other alternative options considered in *ex ante* BAC, all the available *ex ante* project planning and appraisal documents (listed in table 9.1) are scoured. Second, to reveal the extent to which the envisioned benefits were actually realized, forecast project capital costs, estimated station-to-station transit travel time, and projected patronage stated in *ex ante* documents are extracted. Then, audit reports or media releases issued by associated government departments are used as the primary source of information for actual project capital costs. Actual station-to-station in-vehicle transit travel times are collected using Google Distance Matrix API, with a 10-minute interval looping through the light rail operating hour during one week (including weekdays and weekends). Actual patronage statistics are acquired from the Open Data Portal of the corresponding state government.

9.4 Results

9.4.1 The Effectiveness of the Preferred Rail Option in *Ex ante* BCA

As shown by table 9.3, three out of the six passenger rail projects attached economic indicators output by *ex ante* BCA analysis. BRT (including the Transitway option for Metro NW, a grade-separated busway) beat the preferred alternative for all three projects. BRT option features low cost and higher unit benefit per unit cost (reflected by the Benefit-Cost Ratio

Table 9.3 *Ex ante* BCA Results for G:Link, CapMetro, and Metro NW

	G:Link (6%)*		CapMetro (7%)*		Metro NW (7%)*					
Mode	BRT	LRT	BRT	LRT	HR2	HR5	HR6	LR10	TSW7	TSW10
NPV Costs ($m)	724	812	248.5	524.1	1533	1931	2198	1079	386	686
NPV Benefits ($m)	1294	1346	491.8	534.9	2147	2285	2566	921	420	602
NPV ($m)	570	534	243.3	10.8	614	354	368	(158)	34	(84)
Benefit Cost Ratio	2.53	2.3	1.98	1.02	1.4	1.18	1.17	0.85	1.09	0.88

* The 6% and 7% are the discount rates used in BAC analysis.

(BCR). For Canberra CapMetro, the BCR for BRT is roughly two times as large as that for LRT. Nevertheless, BRT was ultimately rejected because light rail was given a higher score (19 for LRT vs. 17 for BRT) under the economic, social, and environmental triple bottom line evaluation method (ACT Environment and Sustainable Development Directorate, 2012). The higher score of LRT was asserted to be because of its superiority in fitting strategic planning and policy goals (including the Griffin Legacy), propping up future land use, improving road safety, reducing environmental externalities, and relieving road congestion.

9.4.2 Patronage

Figure 9.1 visualizes the actual patronage (total boarding per line per hour). The donut chart embedded in each line shows the percentage of actual patronage to the estimate for the same year. First, Syd L1 successfully hit its opening-year ridership target, and then it climbed in the following years of operation till 2020, when travel restriction was enforced as part of COVID-19 lockdown policy. Syd L1 was also non-operational for late 2021 and early 2022 due to cracks in the wheel arch found on all 12 LRT vehicles Harriet et al. (2021). Second, the remaining five projects failed to achieve the ridership target in the corresponding year, ranging between 10% for Syd L2&L3 and 57.5% for G:Link. Third, the demand on all the studied lines but Syd L2&L3 dropped since 2020, demonstrating the heavy blow of COVID on public transport services. Syd L2&L3 opened in the middle of December 2019, followed by the Christmas and New Year holidays and the pandemic outbreak. Its actual boarding touched the bottom immediately after the commencement of operation. As a result, it is the only line with an upward trend in actual demand.

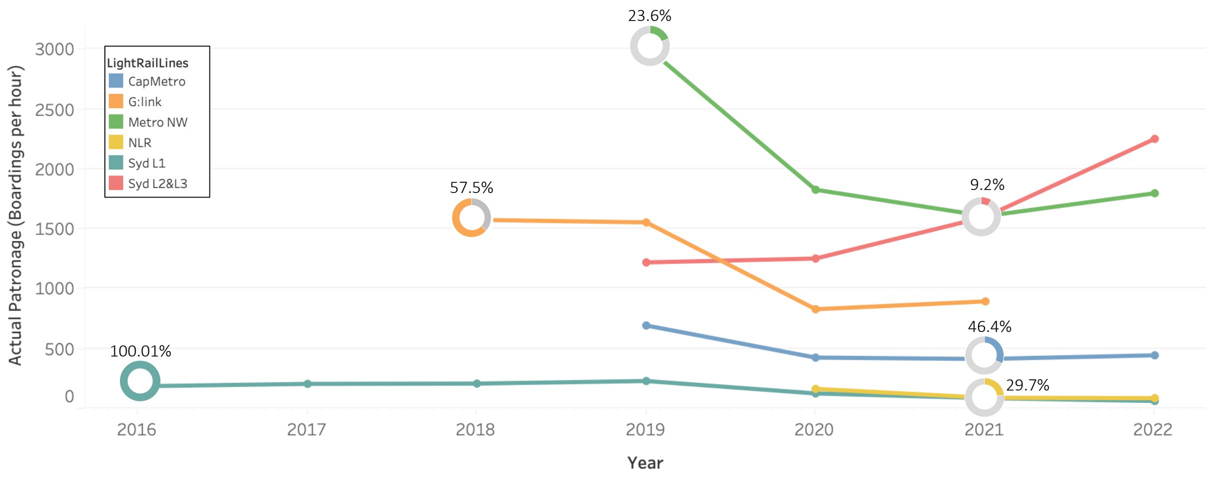


Figure 9.1 Actual Patronage vs. Forecast Patronage

9.4.3 Transit Travel Time

Figure 9.2 compares the forecast station-to-station in-vehicle travel time to the actual one for the given origin and destination pairs for five of the six passenger rails. First, the actual travel time of G:Link is, on average 8% shorter than forecast. Second, for the two projects in Sydney, the actual travel times delivered by Syd L1 and Metro NW are 4.5% and 4.8% longer than forecast, respectively. It is noteworthy that for Metro NW, the trips to Chatswood on Metro NW are either slightly faster than expected, but the trips to North Sydney require transfer to Sydney Trains are likely to be slower than expected. This could be attributed to Sydney Trains' unreliable journey time rather than Metro NW. Last, the actual travel time between the initiating and terminal stations is the same as anticipated for NLR but is slightly faster for CapMetro.

9.5 Discussion and Recommendation

In summary, the first insight is that the BRT beat the preferred passenger rail option in *ex ante* BCA analysis of G:Link, CapMetro, and Metro NW, although the BRT was ultimately rejected. This corroborates potential selection bias in transit project planning and decision-making in Australia. Second, Syd L1 successfully hit its opening-year ridership target, whereas the remaining five projects failed to achieve the patronage target in the corresponding year, ranging between 10% for Syd L2&L3 and 57.5% for G:Link. In addition, the demand on all the studied lines other than Syd L2&L3 dropped since 2020, demonstrating the heavy blow of

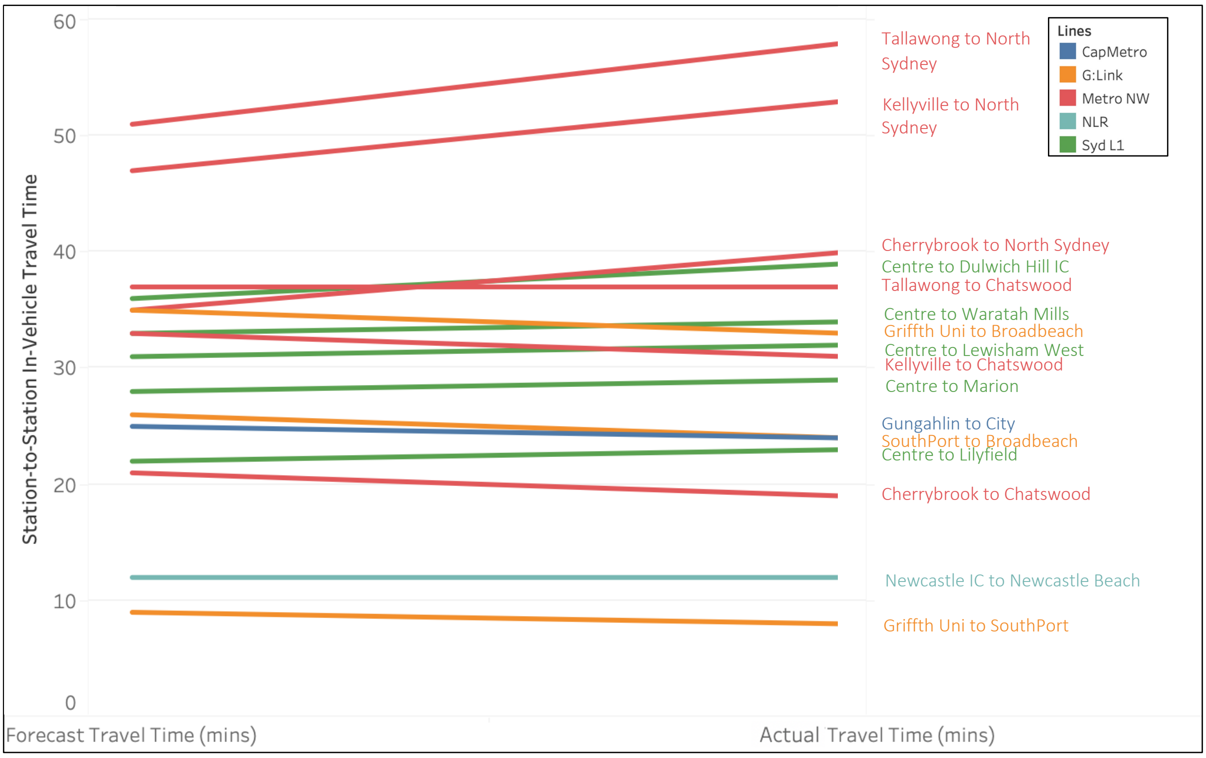


Figure 9.2 Actual Transit Travel Time vs. Forecast Transit Travel Time for given OD Pairs

COVID-19 and concomitant travel restrictions on public transport services. In this case, post-COVID observations are important to further justify this finding. Last, both overestimating and underestimating actual station-to-station in-vehicle travel time are observed.

Those preliminary findings substantiate that although the BRT option was demonstrated to be more cost-efficient, it was ultimately ruled out due to the alleged inability to contribute to the transformation of cities. In contrast, fixed-guideway passenger rails, particularly light rails, which dominated public transport construction in the last decade, have served fewer than the expected number of users since opening, giving new relevance to questions about the economic justifications and worthiness of public transport investment decisions.

Future research could further explore the reasons behind the wide variation between cost estimates and actual costs. In addition, further research on discarded project alternatives is needed to disentangle how ‘do-something’ options are evaluated and selected, providing lessons learned for future decision-making in *ex ante* stages.

Chapter 10

Time Savings vs Access-based Benefit Assessment of New York's Second Avenue Subway

10.1 Introduction

Copious literature and research have certified that in many cases the actual number of users of transport facilities is below projections, and this phenomenon is particularly severe in the case of public transport projects (Flyvbjerg, 2007, 2009; Voulgaris, 2019a; Pickrell et al., 1989; Bain and Polakovic, 2005; Mackinder and Evans, 1981). Given such results, the time-savings based benefit calculation approach adopted in the current BCA has been questioned and criticized.

Significant positive changes in the value of land where transport enhancement is proposed or completed have long been observed (Garrison et al., 1959). This observation induced debate about whether the alleged 'non-user benefits' accrued to property owners, given that the extent to which the land value appreciates is independent of the degree to which the land owners rely on the transport facilities, should be captured and considered as benefits beyond those accruing to transport users. However, Mohring (1961) stated that " increase in land value are not themselves net highway benefits. Rather, they reflect an actual or potential transfer of benefits derived from highways from one population group to another".

Accessibility, the measure of the ease of reaching valued potential destinations, has been widely applied as a metric to describe transport systems, its strong correlation with land value has been repeatedly observed and attested (Levinson and Wu, 2020; Sun et al., 2016; Wen et al., 2018; Lin and Hwang, 2004; Riekkinen et al., 2015; Dewees, 1976; Agostini and Palmucci, 2008; Hess and Almeida, 2007; Dubé et al., 2013). These findings introduce an opportunity to gauge the economic value of a transport project by estimating the change in the value of residential real estate.

In this chapter, we hypothesize that unlike the traditional perspective of quantifying travel time and cost savings, the change in the value of real estate better captures the economic impact of transport services more quickly, directly, and properly. Using the Second Avenue Subway in New York City as an example, we intend to validate the hypothesis by answering the following questions.

1. How do the actual travel time-saving (TTS) compare with the original forecast?
2. How does the change in access by transit caused by the Second Avenue Subway influence residential real estate prices and rents in surrounding neighborhoods?
3. How much is the appreciation in residential property value due to the announcement of the Second Avenue Subway and that due to the opening of the Second Avenue Subway?
4. How do the measures of residential property value and rent compare with actual and forecast travel time savings, and with project costs?
5. Was the Second Avenue Subway worthwhile?

10.2 An Introduction to the Second Avenue Subway

From the end of the nineteenth century to the beginning of the twentieth century, one subway line (Lexington Avenue Subway Line) and two elevated train lines (along Sixth & Ninth Avenue and Second & Third Avenue) operated across East Manhattan and were responsible for passenger transportation. In the 1920s, the two elevated train line services gradually ceased because of the filthy street, outmoded infrastructure and equipment, underserved travel demand, and expensive maintenance and renovation cost (Valk, 2016).

Since the cessation of elevated train lines, the construction of residential properties and

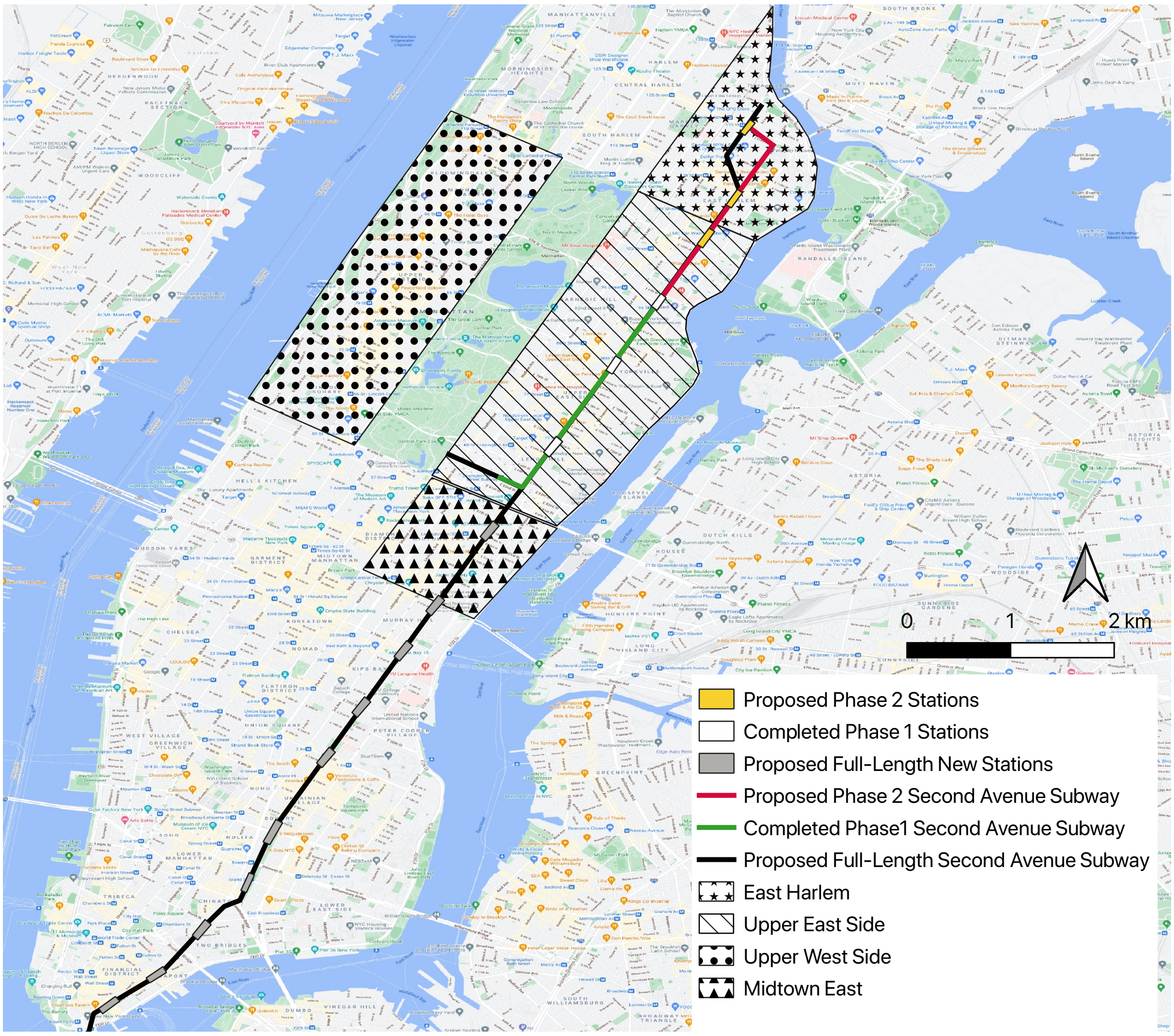


Figure 10.1 The Second Avenue Subway and Selected Neighborhoods in Manhattan

commercial buildings in the Upper East Side and Midtown East was still in full swing. The Lexington Avenue Subway, as the only rail service traversing East Manhattan, was incapable to cope with the growing demand for travel and commute (The Metropolitan Transportation Authority, 1999). As a result, the vision of a subway beneath Second Avenue, which could replace the elevated train lines and share the travel burden of Lexington Avenue Subway, had been ongoing since the 1920s. However, the construction of this subway has been repeatedly postponed due to events like the 1930's Great Depression, World War II, the Vietnam War, and the 1970's financial crisis (Plotch, 2015).

In 1999, the official publication of Draft Environmental Impact Statement (DEIS) symbolized that the construction of the Second Avenue Subway was being reconsidered. In DEIS, apart from the baseline 'No-Build Option', 3 out of the 11 'Build Options' entered into the final quantitative and engineering analysis stage. The Transportation System Management (TSM) alternative featured low-expense and attempted to relieve travel pressure by reducing the time headway of Lexington Avenue Subway and adding two new bus lanes serving between 96th Street and the Lower East Side. Alternative 1 proposed constructing five new stations and a new subway (Second Avenue Subway) operating between 65th Street and 125th Street and continuing using the existing Broadway line to the south of 63th Street. Alternative 2 differs from Alternative 1 by replacing the Broadway Subway line with a new light rail service. Alternative 1 was approved to be the locally preferred alternative project option, and the construction of the Second Avenue Subway was separated into phases (The Metropolitan Transportation Authority, 2004, 2018). In the Final Environmental Impact Statement (The Metropolitan Transportation Authority, 2004), the full-length Second Avenue Subway (including phases 1 and 2) was proposed to be an independent subway line extending 13.7 km from 125th Street in East Harlem to the Financial District in Lower Manhattan (as shown in figure 10.1). Phase 1 started construction in 2007 and was delivered in 2017, and phase 2 is still in the planning stage (The Metropolitan Transportation Authority, a). But the construction and operation time of the Second Avenue Subway to the south of 63th street has not been specified yet.

10.3 Data and Methodology

10.3.1 Time Saving Based Assessment

We intend to test the accuracy and efficiency of the travel time-savings method by comparing the computed actual time savings against the estimate reported in the Second Avenue Subway DEIS. In the DEIS, in contrast with the 'No Build' option, each project alternative impacts traffic mobility, individual travel behavior, system capacity, and access to transit facilities to varying degrees. As a result, the expected project benefit for each project alternative is gauged primarily based on how travel demand and travel time differ from the 'No Build' option. Those quantifiable project benefits are subdivided into five major groups:

1. Travel time savings;
2. Reduced peak-period subway crowding;
3. Reduced off-peak standing passengers;
4. Reduced non-recurring subway delays; and

5. Reduced auto and taxi travel.

We focus on the change in transit person travel time saving (TTS), which forms part of the first benefit group and occupies more than 70% of the total project benefit.

In order to compute the actual transit user TTS after the project opening, we need the actual transit travel time, observed ridership, monetized value per unit of TTS, and a calculation model to synthesize them together. Google Maps is used to measure actual travel time. Since the Second Avenue Subway phase 1 launched three new stations, we extract three actual travel time for each trip departing from one of the three new stations and destined to one of the six busy subway stations in Manhattan including Grand Central Terminal, Times Square (42nd Street), Chelsea (23rd Street), NYU Medical Center, Battery Park City (in West Lower Manhattan) and Wall Street Station (in East Financial District). The origin-destination pairs are the same as those reported in the DEIS. The first actual travel time forces the travel route along or at least partly along the new subway line. The other two are the minimum and maximum actual travel time for alternative travel routes that do not use the Second Avenue Subway, which aims at mimicking the 'no build' scenario. Then the actual TTS is calculated as the actual travel time along the new subway line minus the average of the minimum and maximum travel time for alternative routes. Observed ridership is exported from Average Weekday Subway Ridership on the MTA (The Metropolitan Transportation Authority, b). Abiding by FTA Section 5309, the unit monetization value of TTS is equivalent to a percentage of the average wage rate in the metropolitan area. The average hourly rate of $US 20.3 was adopted in calculating expected project benefit in DEIS, so we stick with this value but adjust for inflation. However, we lack access to the calculation model that was used in the adopted in DEIS and cannot directly output the monetized total transit person TTS. As a result, we can only compare if the TTS and ridership differ between the actual and the forecast conditions.

10.3.2 Access-Based Assessment

The kernel of access-based assessment lies in the correlation between real estate value (the explained variable) and explanatory variables covering property attributes and changes in transport conditions. This correlation is generally measured with hedonic regression analysis (Sheppard, 1999).

The first step is to collect housing prices. The real estate studied in this paper comprising the residential market, includes both rental and sold residential properties, although a portion of sold properties contain a mixture of residential and commercial units. We thus do not include the uplift (or loss in value) associated with commercial properties in the study area. We expect this means we are underestimating the gains associated with the project. Housing price data are exported from a database released by the New York Department of Finance. Data for the sold property are provided by Annualized Sales Update (The NYC Department of Finance, b) and rental property information are offered by Cooperative/Condominium Comparable Rental Income Archives (The NYC Department of Finance, a).

Then, two major factors were considered when choosing regression models analyzing how the Second Avenue Subway affects the price and accessibility of residential properties in adjacent neighborhoods. The first factor is time in the infrastructure timeline. The impact of the new subway on property sold price emerges far earlier than that on rental properties. This is because a buyer would expect house value appreciation immediately after the official announcement of subway construction, but a tenant would not realize any benefit until the opening of the new subway. Since the Second Avenue Subway began construction in 2007 and opened in 2017, the study time window for the sold property is 2006-2018 and that for rental property is 2016-2018. After removing $0 sales and properties with missing or problematic information, a total of 3770 properties sold from 2006 to 2018 were selected. However, the job accessibility data provided by the Accessibility Observatory at the University of Minnesota were unavailable before 2014 (Accessibility Observatory at the University of Minnesota). Only 1943 (51.54% of 3770 observations) properties sold during 2014-2018 were remained. In addition, 1458 rental condominiums and cooperatives with three-year rental history (2016-2018) provide a total of 4371 observations, which makes up the data frame for rental properties.

The second factor is whether we have repeat observations on the same property over years. We have information on the same rental properties across three years whereas we have different sold properties across five years. As a result, the rental property dataset forms a balanced panel dataset where the rental price and other property attributes are available for the same property every year from 2016 to 2018, and a panel regression model is applied. The sold property dataset is essentially a cross-sectional dataset which consists of different sold properties in each year, and a hedonic pricing model is engaged.

Table 10.1 Variable Names and Descriptions

Id	Variable	Unit	Sold	Rental	Description
1	Sale Price	$\$/m^2$	✓[1]		Sale price of the sold property in the year of selling.
2	ln(Sale Price)		✓		Natural Logarithm of the sale price of the sold property in the year of selling.
3	Unit Size	m^2	✓	✓	The gross m^2 of the property.
4	$A_{n,t,30}$	no. of jobs	✓	✓	The number of jobs that can be accessed from Census Block that the property (n) locates within 30 minutes (30) by transit (t).
5	Age	no. of years	✓	✓	The number of years that the building have existed till year 2019.
6	ΔD	meter	✓	✓	The distance to the nearest subway station before Second Avenue Subway minus that after the opening of Second Avenue Subway.
7	Type Res vs. Res & Com		✓		Assigning a value of 1 if the building is purely residential type and 0 if it contains both residential and commercial units.
8	Type Apt vs. Hos		✓		Assigning a value of 1 if the property is apartment and 0 if it is a house.
9	Time Const vs. Open		✓		Assigning a value of 1 if the property is sold during subway construction (before 2018); otherwise 0.
10	Rental Income	$\$/m^2$		✓	Unit gross annual rental income of the rental property in the year of rental.
11	ln (Rental Income)			✓	Natural logarithm of unit gross annual rental income of the rental property in the year of rental.
12	Total Units	no. of units	✓	✓	Total number of units in the building that the rental or sold property belongs.
13	Type Condo vs. Coop			✓	Assigning a value of 1 if the rental property if condominium and 0 if it is cooperative.
14	Type Elev vs. Wkup			✓	Assigning a value of 1 if the rental property has elevator; otherwise 0.
15	Y2016,Y2017, Y2018			✓	Assigning a value of 1 if the property is rented in the corresponding year, otherwise 0
16	Location 1: UES		✓	✓	Assigning a value of 1 if the property is rented or sold locates in Upper East Side, otherwise 0.
17	Location 2: UWS		✓	✓	Assigning a value of 1 if the property is rented or sold locates in Upper West Side, otherwise 0.
18	Location 3: EH		✓	✓	Assigning a value of 1 if the property is rented or sold locates in East Harlem, otherwise 0.
19	Location 4: ME		✓	✓	Assigning a value of 1 if the property is rented or sold locates in Midtown East, otherwise 0.

[1] A ✓denotes that this variable is applicable for sold property.

After selecting the regression model, variables set up for regression analysis have been outlined in table 10.1. The selection of independent variables follows the general principles of hedonic theory where a property can be decomposed into a bundle of characteristics. These characteristics are typically classified into five major categories: property (or lot) specific characteristics, neighborhood characteristics, geographical characteristics, proximity to adjacent transport facilities, and other control factors (i.e., spatial and temporal control factors or indicators of economic conditions) (Mohammad et al., 2013; Higgins and Kanaroglou, 2016). Among the various characteristics, property-specific traits and the proximity to adjacent transport facilities are considered the most important explanatory variables in this proof-of-concept study. These two categories assist in figuring out the causal relationship between transport improvements and property price changes. Variables 3, 5, 6, 7, 8, 12, 13, and 14 describe the specific characteristics of each property. Variables 7 & 8 and 13 & 14 are used as dummy variables to further classify sold and rental properties respectively. The 4^{th} variable: access to jobs by transit (t) from a property location (n) within 30-minutes (30) ($A_{n,t,30}$), which is available for each year from 2014-2018, is designated as a transport proxy to illustrate the impact of Second Avenue Subway. Job accessibility by other transport modes like auto or walking are dropped because the data are inconclusive. The 6^{th} variable the changes in distance to the nearest subway stations is also included as a supplementary variable describing the impact of the new subway.

In addition, variable 9 represents the temporal factor controlling for the impacts of temporal changes on property prices. It is a dummy variable that distinguishes whether a property is sold before (2014-2017) or after (2018) the opening of the new subway. But for rental properties, a year dummy variable is set up for each year (as shown by variable 15), with the year 2016 being the base year.

Variables 16-19 denote the neighborhood of the sold (rental) property, controlling for the impact of locational characteristics on property prices. Among the three new subway stations delivered as part of Second Avenue Subway phase 1, two of them are constructed in the Upper East Side and one in East Harlem. The second phase of the Second Avenue Subway will primarily be deployed in Midtown East, South of the Upper East Side. No other new subway line has been planned or constructed in recent decades in Upper West Side (King, 2011). We designated the Upper East Side to be the base group, which allows the observation of different intercepts for each neighborhood in the model and thus compares the uptrend of housing prices by zone.

Table 10.2 Comparison of Project Benefit Cost Results

(2.56% discount rate)[1]	MIS/DEIS			Actual TTS
Present Value[2]	TSM	Alternative 1 (LPA)	Alternative 2	in 2018
Initial Capital Cost	$172.31	$5140.67	$6630.18	$3970
50-year Customer and Social Benefits ($US mil)	$ 1,370.05	$ 6,759.34	$ 7,329.11	
50-year Transit Person TTS ($US mil)	$ 491.16	$ 4,809.70	$ 5,970.66	
Transit Person TTS as a Percent of Total Benefit	36%	71%	81%	
Annual Transit Person TTS in 2020 ($US mil) [3]	$ 27.83	$ 272.51	$ 338.30	
Annual Ridership in EH and UES (million) [4]	13.78	40.21	39.36	24.06 (59.85%)[6]
Transit TTS per trip in EH and UES (minutes)[5]	1.13	5.73	6.40	1.83 (37.50%)[6]

We modified this table based on the original table sourced from the DEIS established by The Metropolitan Transportation Authority (1999).

[1] In line with the analysis method applied MTA in preparation for DEIS, the discount rate is 2.65%.

[2] The base year applied when discounting project cost and benefits to present value is the year of construction begin, which is 2004 for alternatives in DEIS and 2007 for Actual(2018). And a 50-year forecast horizon is taken when accumulate the present value for customer and social benefits.

[3] The annual TTS is estimated based on the fully operation of the entire Second Avenue Subway in 2020, while in fact only phase 1 was opened before 2020.

[4] EH stands for East Harlem and UES denotes Upper East Side. Second Avenue Subway phase 1 primarily locates in these two neighbourhoods.

[5] This is the AM peak hour transit TTS per trip that originates from stations in East Harlem and Upper East Side.

[6] This percentage denotes the 2018 actual annual ridership and transit TTS per trip as a percentage of the estimated ones in Alt 1.

10.4 Analysis Results

10.4.1 Time Saving Analysis

Table 10.2 summarizes the travel time saving analysis for the Second Avenue Subway. The 50-year accumulated transit person TTS accounts for more than 70% of 50-year accumulated customer and social benefits for Alternatives 1 and 2. The weight of this benefit item is far lower in the TSM alternative because no new rail service was planned under this option.

When switching the focus to the annual patronage departing from stations in East Harlem and Upper East Side, the goal of serving 40 million users per annum (in Alternative 1) has been missed. The actual number of travelers boarding the Second Avenue Subway from new stations in those two neighborhoods was 24.06 million in 2018 (59.85% of the anticipated 40.2 million passengers).

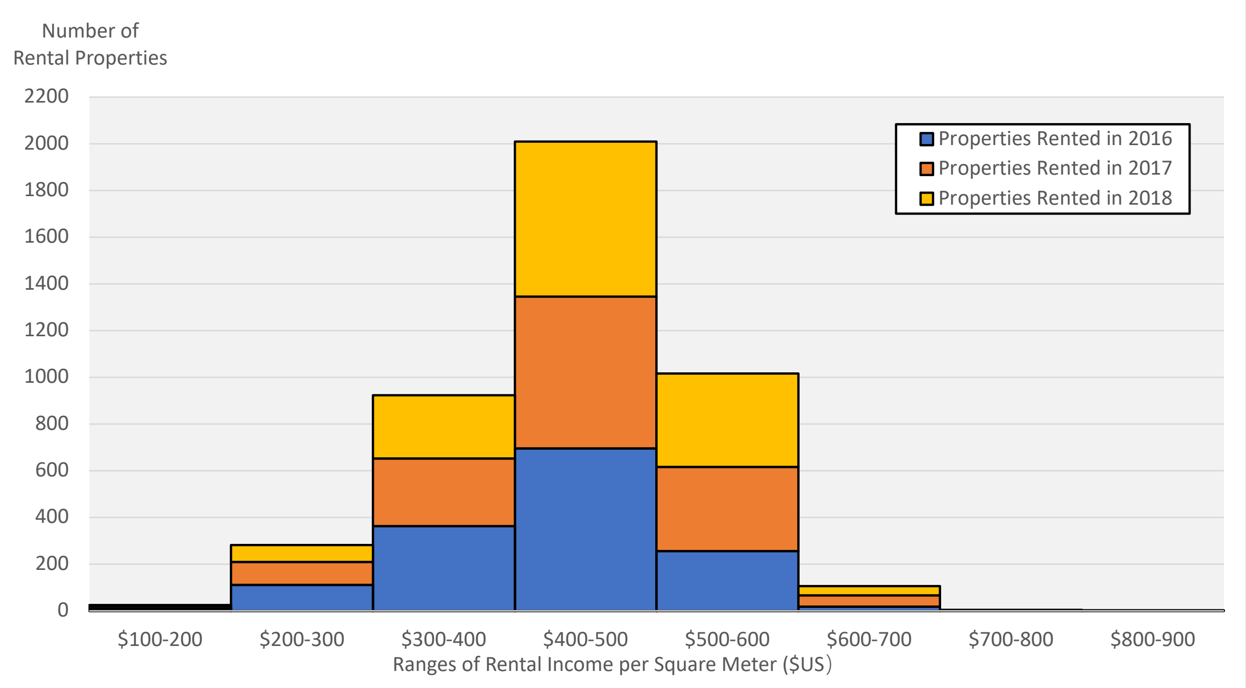


Figure 10.2 Frequency Distribution of Rental Price per m^2 by Year (N=4371)

And in terms of the travel time saving per trip, the objective of reducing the average AM Peak hour transit travel time per trip (including both in-vehicle and out-of-vehicle travel time) by 4.8 minutes was missed for these stations. Grounded on the real-time AM Peak hour travel time extracted from Google Map (as per table 10.3), the actual transit TTS per trip is 1.83 minutes, accounting for only 32% of the expected 5.73 minutes for the same station pairs. The TTS for trips heading to New York University (NYU) Medical Center is negative, implying that traveling via Second Avenue Subway extends the travel time. This is because travelers have to select M15 between 110th St and 96th St, and M34 bus service between 63th St and NYU Medical Center.

The estimated TTS was projected for the to-be-completed 6-km northern Second Avenue Subway Line, so the actual transit patronage might hit the target after the opening of the second phase. But the TTS for trips heading to south Manhattan (Times Square, Chelsea and Financial District) may not be significantly improved until the operation of full-length Second Avenue Subway, including succeeding phases connecting to Hanover Square in southern Manhattan.

Table 10.3 Average Travel Time Savings per trip AM Peak Hour (Minutes)

Trip Origin	Trip Destination	MIS/DEIS TSM	MIS/DEIS Alternative 1 (LPA)	MIS/DEIS Alternative 2	Actual 2018 TTS
East Harlem:					
(East 110th St.	Grand Central Terminal	0	-1	-1	0
between First	Times Square (42nd St.)	0	14	15	7.5
and Second	Chelsea (23rd St.)	0	17	18	6
Aves)	NYU Medical Center	8	0	0	-3.5
	West Lower Manhattan (Battery Park)	0	11	11	6.5
	East Financial District (Wall St.)	0	10	10	3.5
Upper East Side:					
(East 86th St.	Grand Central Terminal	0	1	1	-1
between Second	Times Square (42nt St.)	0	9	9	15
and Third Aves)	Chelsea (23rd St.)	1	15	15	8
	NYU Medical Center	6	0	0	-4.5
	West Lower Manhattan (Battery Park)	1	6	6	3.5
	East Financial District (Wall St.)	1	2	6	1.5
Upper East Side:					
(East 86th St. and	Times Square	-2	0	0	1
Lexington Ave)	NYU Medical Center	2	0	0	-9.5
	East Financial District	0	2	6	-6.5
Average		1.1	5.7	6.4	1.8

TTS per trip under alternative project options are extracted from DEIS, which were reported in integers. Actual TTS per trip and the average TTS per trip are calculated by us so the results were rounded to one decimal place.
DEIS assumes Phase 1 and Phase 2 of the Second Avenue Subway built. Actual Travel Time Savings are based only on Phase 1.

10.4.2 Rental Properties

The descriptive statistics for rental properties are displayed in table 10.4, and the distribution of rental price per m^2 is displayed in figures 10.2 and 10.3. The results of panel pooling regression models for rental properties are outlined as per table 10.5.

We first fit the model using specifications including property size, age and type attributes and time dummies, along with the job accessibility by transit within 30 minutes. This model is tagged as Model 1 in table 10.5. In comparison with Model 1, the following two models in table 10.5 added the change of distance to the nearest subway station and location dummies. As informed by the adjusted R^2 listed in table 10.5, the goodness of fit of models improves when including these additional variables.

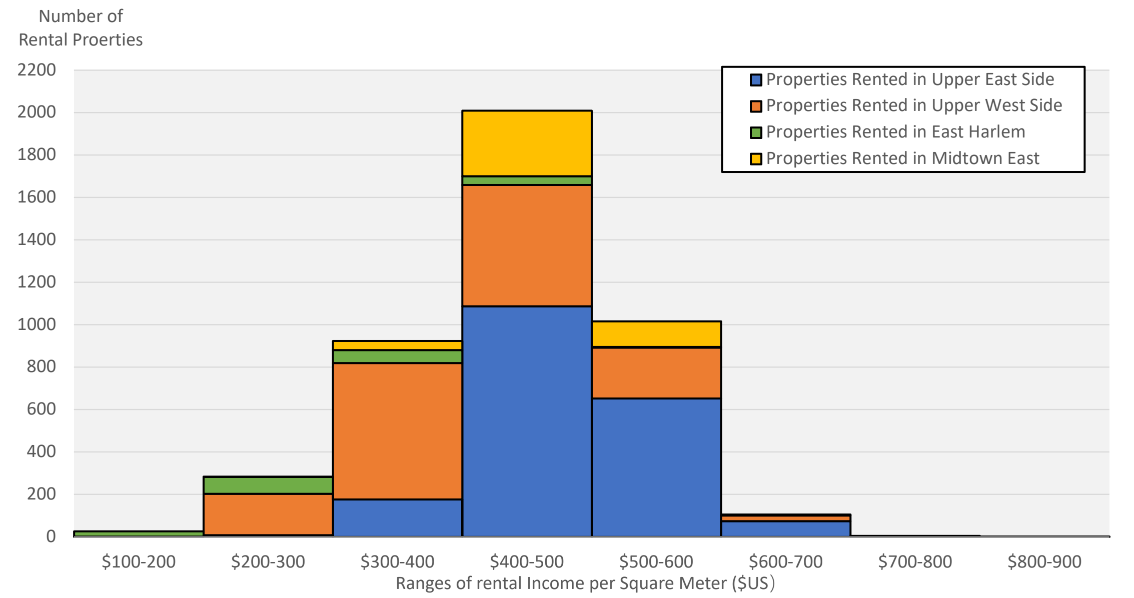


Figure 10.3 Frequency Distribution of Rental Price per m^2 by Region (N=4371)

Table 10.4 Descriptive Statistics for Rental Properties (2016-2018): N = 4371

Continuous Variable	Mean	Median	SD.	Min	Max
Rental Income (P_R) (\$/m^2)	443.17	450.65	88.84	162.26	852.80
$ln(P_R)$	6.07	6.11	0.22	5.09	6.75
Unit Size (Z) (m^2)	130	110	80	24	724
$A_{n,t,30}$ (no. of jobs)	1,710,579	1,766,966	409,503	224,472	2,633,033
Age (no. of year)	81	91	29	6	139
Total Units (U) (no. of units)	80	52	87	6	936
ΔD(m)	42.30	0	107.69	0	459.98

Dummy Variable	Description	N	%
Condo vs. Coop	Condominium (1)	1293	30%
	Cooperative (0)	3078	70%
Elev vs. Wkup	Elevator Apartment (1)	3804	87%
	Walkup Apartment (0)	567	13%
Location	1: UES	2001	46%
	2: UWS	1683	39%
	3: EH	207	5%
	4: ME	480	11%
Y2016		1457	33%
Y2017		1457	33%
Y2018		1457	33%

Given that the dependent variable in table 10.5 is LnRentInc, the coefficient for each independent variables can be interpreted as a proportion instead of absolute dollar values. First, according to Model 1, the gross rental income per m^2 will increase by 2.06% if the total number of employment opportunities that are accessible within 30 minutes by transit increases by

Table 10.5 Panel Pooling Regression Model Results for Rental Properties (2016-2018): $ln(P_R)$ (\$ per (m^2)) as a function of independent variables

		Model 1	Sig.	Model 2	Sig.	Model 3	Sig.
	Constant	5.829	***	5.653	***	5.951	***
1	$A_{n,t,30}$	2.06E-07	***	2.67E-07	***	1.72E-07	***
		(1.111)		(1.270)		(1.630)	
2	Unit Size (Z)	5.40E-04	***	6.08E-04	***	3.82E-04	***
		(1.204)		(1.211)		(1.294)	
3	Age	-1.42E-03	***	-1.16E-03	***	-1.21E-03	***
		(1.496)		(1.511)		(1.743)	
4	Type Condo(1) vs. Coop(0)	0.054	***	0.062	***	0.090	***
		(1.260)		(1.263)		(1.293)	
5	Type Elev(1) vs. Wkup(0)	-0.108	***	-0.081	***	-0.097	***
		(1.375)		(1.396)		(1.475)	
6	Y2017	0.013	.	0.005		0.017	**
		(1.357)		(1.361)		(1.368)	
7	Y2018	0.028	***	0.017	*	0.034	***
		(1.379)		(1.386)		(1.401)	
8	Total Units	-1.26E-05		-7.54E-05	*	-7.06E-05	*
		(1.238)		(1.245)		(1.272)	
9	ΔD			6.39E-04	***	1.63E-04	***
				(1.231)		(1.634)	
10	Location 2: UWS					-0.154	***
						(1.506)	
11	Location 3: EH					-0.406	***
						(1.516)	
12	Location 4: ME					-0.069	***
						(1.304)	
	N	4371		4371		4371	
	Adj. R^2	0.238		0.319		0.465	
	p-value	$< 2.2E-16$		$< 2.2E-16$		$< 2.2E-16$	

[1] Variance Inflation Factor (VIF) is listed in parentheses under the estimated coefficient for every independent variable.

100,000. The value of this coefficient gets larger when the ΔD joins the model, and the correlation between them is low as confirmed by a VIF of 1.231. And the coefficient on ΔD in Model 2 indicates that a 6.39% incremental in gross rental income per m^2 would be observed if the distance to the nearest subway station shortens by 100 meters as a result of the opening of the Second Avenue Subway line. Such an observation corroborates our hypothesis that the Second Avenue Subway shows significant positive impacts on housing prices in adjacent zones. Next, the coefficients on the year dummies in row 6 and 7 has the envisaged sign (positive), showing that the annual Rental Income per m^2 in 2017 and 2018 is higher than 2016. The coefficients in row 7 are slightly bigger than those in row 6, implying that the rental prices in the four selected neighborhoods in Manhattan show an uptrend since the opening of the new subway line. In Model 3, the sign of coefficient on location dummies are all negative, meaning that the rental price in Upper East Side is higher than rental premises in neighborhoods without new transit services. Lastly, rows 2 to 5 account for property-specific features, which are all of statistical significance. The unit rental price is higher if the size of the property is larger and if the age of it is younger. Condominiums are more expensive than cooperatives.

It is notable that walk-up apartments are more expensive than elevator apartments in our sample. The mean rental price per m^2 for elevator apartments is $US 444.17, which is $US 8 higher than that for walk-up apartments. But the median for the former group ($US 449.52) is higher than that for the later group ($US 459.57). One possible reason is that we only have 567 walk-up apartments in our sample, which is far smaller than the sample size for the elevator apartments (3804).

10.4.3 Sold Properties

The descriptive statistics for sold properties are displayed in table 10.6. The frequency distribution of sold price per m^2 is shown as figure 10.4 and figure 10.5.

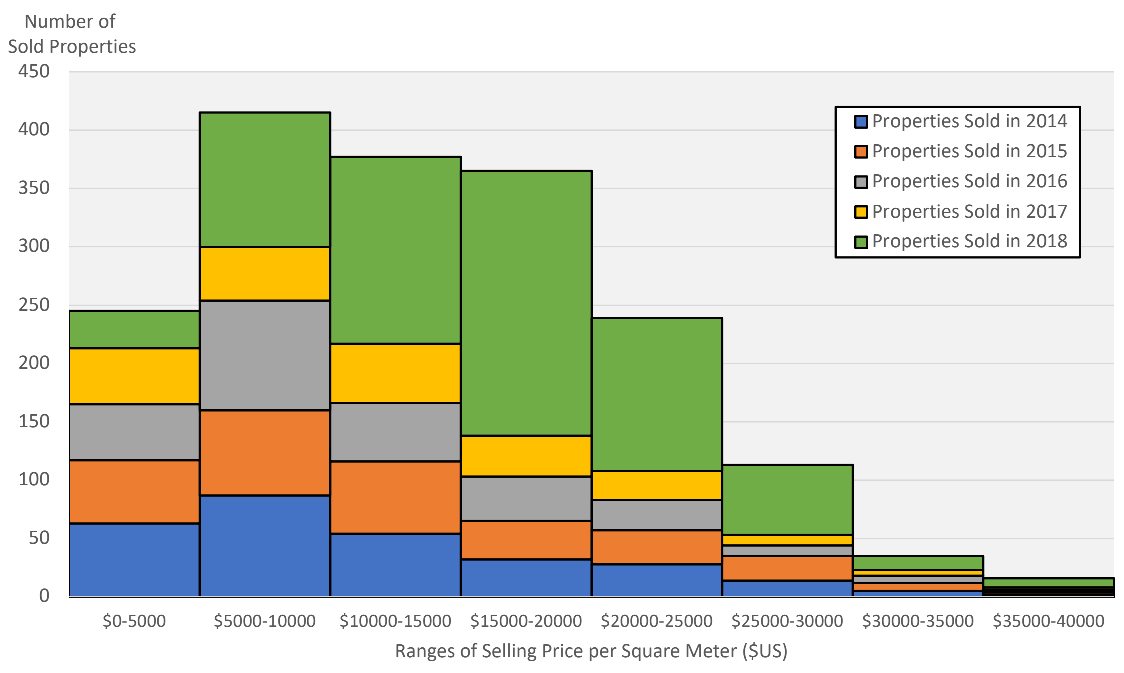


Figure 10.4 Frequency Distribution of Sold Price per m^2 by Year (N=1805)

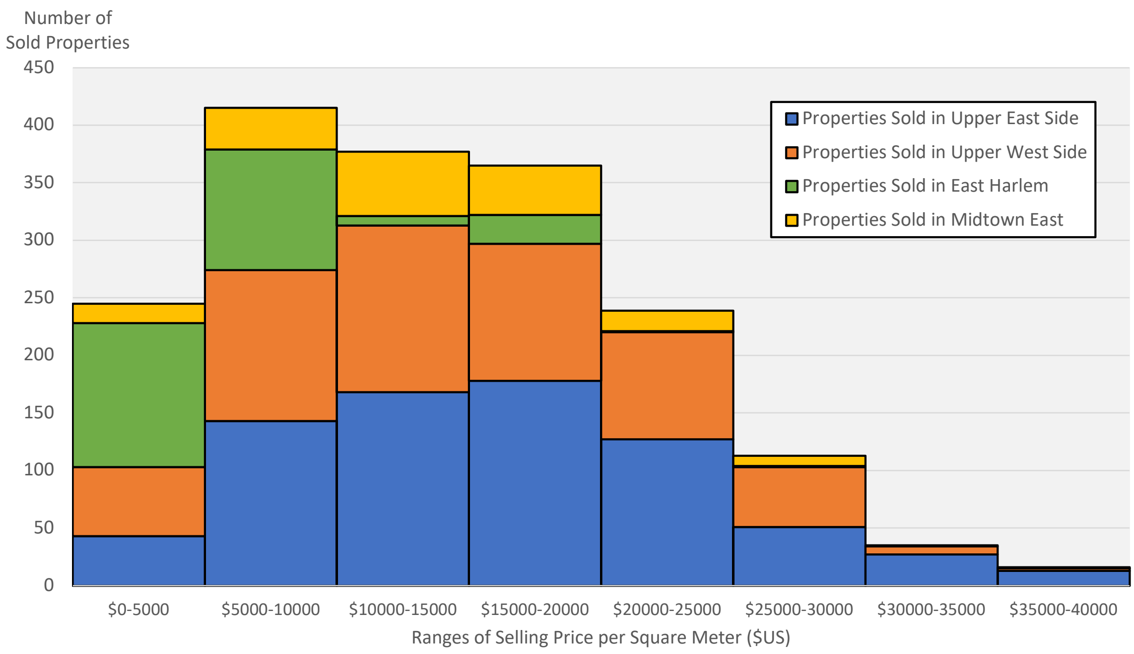


Figure 10.5 Frequency Distribution of Sold Price per m^2 by Region (N=1805)

Table 10.6 Descriptive Statistics for Sold Properties (2014-2018): N = 1805

Continuous Variable	Mean	Median	SD.	Min	Max
Sales Price (S_P) ($\$/m^2$)	13,758.41	13,182.44	7,938.98	0.28	37,398.32
$ln(S_P)$	9.21	9.49	1.22	-1.27	10.53
Unit Size (Z) (m^2)	153	94	149	8	1440
$A_{n,t,30}$ (no. of jobs)	1,590,381	1,650,543	501,538	175,607	2,570,441
Age (no. of year)	84	104	42	3	150
ΔD(m)	55.29	0	119.34	0	450.09

Dummy Variable	Description	N	%
Type Res vs. Res & Com	Residential Units Only (1)	1187	66%
	Residential n. Commericial (0)	618	34%
Type Apt vs. Hos	Apartment (1)	1386	77%
	House (0)	419	23%
Time Const vs. Open	Construction 2014-2017 (1)	839	46%
	Opening 2018 (0)	966	54%
Location	1: UES	750	42%
	2: UWS	609	34%
	3: EH	265	15%
	4: ME	181	10%

The panel pooling models show satisfactory fitting degree when dealing with the panel dataset of rental properties. Then we move to test the hedonic pricing model fit to the five-year cross-sectional sold property dataset, and the results are summarized in table 10.7.

In Models 1 and 2, the sign of coefficients on $A_{n,t,30}$ remains positive and statistically sig-

Table 10.7 Hedonic Pricing Model Result for Sold Properties (2014-2018): lnP_S (\$ per m^2) as A Function of Independent Variables

		Model 1	Sig.	Model 2	Sig.	Model 3	Sig.
	Constant	9.147	***	8.996	***	9.823	***
1	$A_{n,t,30}$	2.72E-07	***	3.23E-07	***	4.50E-08	
		-(1.164)[1]		(1.235)		(2.089)	
2	Age	-2.67E-03	***	-2.43E-03	**	-2.71E-03	***
		-(1.419)		(1.430)		(1.455)	
3	Unit Size (Z)	9.99E-04	***	1.02E-03	***	8.21E-04	***
		-(1.339)		(1.340)		(1.364)	
4	Type Res(1) vs. Res&Com(0)	0.213	**	0.212	**	0.227	***
		-(1.464)		(1.464)		(1.500)	
5	Type Apt(1) vs. Hos(0)	-0.429	***	-0.431	***	-0.381	***
		-(1.706)		(1.707)		(1.717)	
6	Time: Const(1) vs. Open(0)	-0.233	***	-0.228	**	-0.251	***
		-(1.662)		(1.663)		(1.681)	
7	ΔD			8.38E-04	***	-6.05E-04	*
				(1.082)		(1.836)	
8	Location 2: Upper West Side					-0.356	***
						(1.748)	
9	Location 3: East Harlem					-0.848	***
						(2.275)	
10	Location 4: Midtown East					-0.439	***
						(1.367)	
	N	1805		1805		1805	
	Adj. R Squared	0.115		0.128		0.150	
	p-value	$<$ 2.2E-16		$<$ 2.2E-16		$<$ 2.2E-16	

[1] Variance Inflation Factor (VIF) is listed in parentheses under the estimated coefficient for every indepdnent variable.

nificant, showing that the selling price per m^2 will increase by 2.72% (3.23% in Model 2) if the total number of jobs that are reachable within 30 minutes by transit increase by 100,000. The coefficient on ΔD in Model 2 can be interpreted as that the selling price per m^2 will increase by 8.38% if the distance to the nearest subway station reduced by 100 meters as a result of the opening of the Second Avenue Subway line. The negative coefficient on the year dummy in row 6 conveys that the unit selling price is higher after the delivery of the new subway. And in Model 3, the negative sign of coefficients on the three location dummies sustains that buyers are willing to pay premium prices for properties in the Upper East Side. Those findings further corroborate that our hypothesis about the positive impact of Second Avenue Subway on housing prices is credible in the case of sold property.

Finally, coefficients in row 4 manifest that sellers may expect a lower selling price if the property is situated in a building containing both commercial and residential units. In addition, as informed by coefficients in row 5, houses (townhouses) are much more expensive than apartments.

10.5 Access-Based Economic Benefits Assessment

The appreciation in residential real estate value is calculated using two distinct approaches: changes in accessibility to jobs (section 10.5.1) and that plus shortened distance to the nearest subway station (section 10.5.2).

10.5.1 Job-Accessibility-based Property Value Appreciation

After the official announcement of the Second Avenue Subway Phase 1 project in 2007, this information was reflected in the change of distribution of job opportunities in surrounding neighborhoods. As per the first 2 models in table 10.7 and all 3 models in table 10.5, increases in the number of reachable jobs lift up house price, which mirrors the economic value created by the Second Avenue Subway from the perspective of residents and tenants. This is the rationale behind the job-accessibility-based property value appreciation method. Equation 10.1 and 10.2 address the computation of house value appreciation (sale price and rental income) for each available year, and equation 10.3 and 10.4 discount those values. The second item in equation 10.1 and 10.2 counts the change of $A_{n,t,30}$ in the Census block that the property (n) locates between the year that the property is sold (or rented) and 2014 (or 2016).

Spatial valuation of property uplift:

Sold Properties:

$$V_{A,S,Y_S} = \sum_{n_S=1}^{N_S} \beta_{721} \cdot (A_{n_S,t,30,Y_S} - A_{n_S,t,30,2014}) \cdot P_{S_{n_S,Y_S}} \cdot Z_{n_S} \cdot U \tag{10.1}$$

Rented Properties:

$$V_{A,R,Y_R} = \sum_{n_R=1}^{N_R} \beta_{531} \cdot (A_{n_R,t,30,Y_R} - A_{n_R,t,30,2016}) \cdot P_{R_{nR,Y_R}} \cdot Z_{n_R} \cdot U \tag{10.2}$$

Present value (discounted) (PV) of value appreciation:

$$PV(V_{A,S}) = \sum_{y_S=1}^{5} \frac{V_{A,S,y_S}}{(1+r)^{(y_S-2007)}} \tag{10.3}$$

$$PV(V_{A,R}) = \sum_{y_R=1}^{3} \frac{V_{A,R,y_R}}{r} \tag{10.4}$$

where:

- β_{721} is the 1^{st} coefficient in model 2 table 10.7.
- β_{531} is the 1^{st} coefficient in model 3 table 10.5.
- N_S and N_R are the number of sold and rented properties, respectively.
- n_S and n_R index each individual property that was either actually or assumed to be sold, and actually or assumed to be rented, respectively.
- P_S,P_R is Sales Price, Rental Income per m^2, respectively.
- r is the discount rate applied.
- U is number of Units per building, which exceeds one when more than one unit are sold (or rented) in property S (or R).
- $V_{A,S}$ and $V_{A,R}$ stand for value appreciation in sold and rented property due to change in access, respectively.
- Y_S and Y_R are the year a property gets sold, Y_S=2014, 2015, 2016, 2017 and 2018, or rented, Y_R=2016, 2017 and 2018, respectively.

- y_S and y_R index years for sold properties and rented properties, respectively.

- Z is Unit Size (m^2).

In addition, sold properties here include both actual sold properties and presumptive sold properties. The latter group is produced based on the assumption that if the rental properties were sold out on the year of rental. We have repeated data on the same rental properties for three years (2016-2018), but we cannot assume that each rental property is sold and resold in each of the three years. We select 2018 as the year when all the rental properties were sold. The sold prices of the rental properties are estimated by engaging model 3 in table 10.7.

Similarly, rented properties here contain both rental properties that were actually rented and sold properties that are assumed to be rented at market rates. The aforementioned process has been performed for rented properties. We have five-year data (2014-2018) for sold properties, and we borrow model 3 in table 10.5 to compute the expected rental price for them. However, coefficients in model 3 table 10.5 are obtained based on rental properties rented during 2016-2018. In order to be consistent with model 3, which does not cover what has happened in the rental property market before 2016, we retain properties sold between 2016 and 2018 and calculate their expected rental price.

As displayed by equation 10.3 and 10.4, different discounting methods are applied to sold properties and rented properties respectively. Property sale is a one-off trade, and the price at which the deal was closed has already included the future price uplift caused by the opening of the new transport project. But it is a different story for rented properties. Rental is a series of consecutive deals. The rent moves upward from the pre-project level to the post-project level at which the properties will be rented in the future. As a result, a perpetuity discounting model is used.

10.5.2 Shortened-Distance-based Property Value Appreciation

A positive correlation between reduced distance to the nearest subway station and house price is observed in model 2 table 10.7 and model 2&3 table 10.5, which sheds light on estimating real estate value appreciation via DV method.

Equation 10.5 and 10.6 indicates the computation of house value appreciation (sale price and rental income) for each available year, and the discount process is the same as the AV method (equation 10.3 and 10.4). The second item in equation 10.5 and 10.6 accounts for how the straight-line distance to the nearest subway station differs before (D_B) and after (D_A) ($\Delta D = D_B - D_A$) the opening of the subway.

Sold Properties:

$$V_{D,S,Y_S} = \sum_{n_S=1}^{N_S} \beta_{727} \cdot (D_{Before,n_S} - D_{After,n_S}) \cdot P_{S_{n_S}} \cdot Z_{n_S} \cdot U \quad (10.5)$$

Rented Properties:

$$V_{D,R,Y_R} = \sum_{n_R=1}^{N_R} \beta_{539} \cdot (D_{Before,n_R} - D_{After,n_R}) \cdot P_{R_{n_R}} \cdot Z_{n_R} \cdot U \quad (10.6)$$

where:

- β_{727} is the 7^{th} coefficient in model 2 table 10.7.
- β_{539} is the 9^{th} coefficient in model 3 table 10.5.
- D_{Before} is the straight-line distance from the property to its nearest subway station before the opening of the Second Avenue Subway.
- D_{After} is the straight-line distance from the property to its nearest subway station after the opening of the Second Avenue Subway.
- $V_{D,S}$ and $V_{D,R}$ stand for value appreciation in sold and rented property respectively due to change in distance.

10.6 Comparison of Access-based and Time-saving Approach

The total value appreciation in properties, benefit-cost ratio (BCR) and net present value (NPV) calculated by job-accessibility measure and shortened-distance measure, along with a sensitivity analysis for different discount rates (displayed in table 10.8).

Table 10.8 Sensitivity Analysis for Residential-value-based Project BCR Computation

Present Values [1] ($ US mil)		Discount Rate 1%	2%	2.65%[2]	3%	4%	5%	6%	7%
Project Cost		(4,063)[3]	(3,872)	(3,756)	(3,695)	(3,530)	(3,377)	(3,234)	(3,101)
Access-based[4]	$V_{A,S}$	12,875	11,600	10,846	10,462	9,446	8,536	7,722	6,993
	BCR1[6]	3.17	3.00	2.89	2.83	2.68	2.53	2.39	2.26
	NPV1	8,812	7,728	7,090	6,767	5,915	5,159	4,488	3,892
	$V_{A,R}$	24230	12115	9143	8077	6058	4846	4038	3461
	BCR2	5.96	3.13	2.43	2.19	1.72	1.43	1.25	1.12
	NPV2	20,167	8,243	5,388	4,381	2,527	1,469	804	361
Access-based & Distance-based[5]	$V_{A,S}$	15,279	13,766	12,872	12,416	11,210	10,131	9,165	8,299
	$V_{D,S}$	5,351	4,818	4,503	4,343	3,920	3,541	3,203	2,900
	Total	20,630	18,585	17,375	16,760	15,130	13,672	12,368	11,198
	BCR3[7]	5.08	4.80	4.63	4.54	4.29	4.05	3.82	3.61
	NPV3	16,567	14,712	13,619	13,064	11,599	10,295	9,134	8,098
	$V_{A,R}$	20,196	10,098	7,621	6,732	5,049	4,039	3,366	2,885
	$V_{D,R}$	9,074	4,537	3,424	3,025	2,269	1,815	1,512	1,296
	Total	29,270	14,635	11,045	9,757	7,318	5,854	4,878	4,181
	BCR4	7.20	3.78	2.94	2.64	2.07	1.73	1.51	1.35
	NPV4	25,207	10,763	7,289	6,061	3,787	2,477	1,644	1,081

[1] All values have been discounted to year 2007 when Second Avenue Subway Phase 1 actually started to construct, and the unit of account is $US million.
[2] The discount rate of 2.65% is designated by Federal Transit Administration when preparing Environmental Impact Statement for Second Avenue Subway Phase 1.
[3] Values in parentheses are expenditures (outflows), and negatively contribute to Net Present Value.
[4] Under Access-based section,the calculation of total $V_{A,S}$ uses coefficients in Model 1 table 10.7 and $V_{A,R}$ uses coef. in Model 1 Table 10.5.
[5] Under Access-based & Distance-based section,the calculation of total $V_{A,S}$ and $V_{D,S}$ uses coefficients in Model 2 table 10.7 and $V_{A,R}$ and $V_{D,R}$ uses coef. in Model 3 Table 10.5.
[6] BCR1(2) is the benfit cost ratio calculated by $V_{A,S}(V_{A,R})$ divided by project cost, and NPV1(2) is the result of $V_{A,S}(V_{A,R})$ minus project cost.
[7] BCR3(4) is calculated by the sum of total $V_{A,S}(V_{A,R})$ and total $V_{D,S}(V_{D,R})$ divided by project cost, and NPV3(4) is the result of the sum minus project cost.

First, as shown by the Access-based section, if we only consider the impact of job accessibility, we find that the BCR based on sold properties' value appreciation ranges between 2.26 to 3.17, and that the BCR based on rented values lies between 1.12-5.19. When adding the influence of shortened distance to the nearest subway station (Access-based & Distance-based section), we observe that the BCR range for sold properties jumps to 3.61-5.08, and that that range for rental properties rises to 1.35-7.2. The range for BCR of rented properties is wider because the perpetuity discounting model is more sensitive to the variation of the discount rate (since rents are in the future, while sold valuations are in the present, and already embed market expectations about discounted values). Second, property value appreciation triggered by

Table 10.9 Comparison of Project Cost Effectiveness Measures

(2.56% discount rate)[1]	MIS/DEIS			Actual		
Present Value ($US billion)[2]	TSM	Alternative 1 (LPA)	Alternative 2	TTS 2018	$(V_{A,S}+ V_{D,S})$	$(V_{A,R}+ V_{D,R})$
Initial Capital Costs[3]	$ (0.17)	$ (5.14)	$ (6.63)	$ (3.97)	$ (3.97)	$ (3.97)
50-year Customer and Social Benefits	$ 1.37	$ 6.76	$ 7.33			
Sold Property Value Appreciation[4]					$ 17.37	
Rented Property Value Appreciation[5]						$ 11.04
Cost Effectiveness Measures						
NPV ($US billion)	$ 1.20	$ 1.62	$ 0.70		$13.62	$7.29
BCR	7.95	1.31	1.11	<1	4.63	2.94

We modified this table based on the original table sourced from the DEIS established by The Metropolitan Transportation Authority (1999).

[1] In line with the analysis method applied MTA in preparation for DEIS, the discount rate is 2.65%.

[2] The base year applied when discounting project cost and benefits to present value is the year of construction beginning, which is 2004 for alternatives in DEIS and 2007 for Actual(2018). And a 50-year forecast horizon is taken when accumulating the present value for customer and social benefits.

[3] Raw project costs for DEIS alternatives are reported in 1997 $US, and the actual project was lastly updated in 2017. All project cost has been inflated to $US 2018 with the Gross Domestic Product deflator established by the World Bank.

[4] This is the sum of AV and DV if all properties were sold, listed in table 10.8.

[5] This is the sum of AV and DV if all properties were rented, listed in table 10.8.

reduced distance to the nearest subway station is far smaller than that caused by improved job accessibility, conveying that house price is more sensitive and responsive to variation in job accessibility.

In short, all the BCRs in table 10.8 are greater than 1 and all the NPVs are positive, epitomizing that the value appreciation in residential properties in adjacent neighborhoods is large enough to cover the total project cost of Phase I of the Second Avenue Subway. We anticipate including commercial properties would increase BCR and NPV further.

Table 10.9 summarizes the BCA results for the Second Avenue Subway. First, the actual total capital cost for phase I was about $US 4 billion, which is 77.15% of the total (phase I and II) estimated project cost $US 5.1 billion for Alternative 1. However, as specified in 1999 DEIS (The Metropolitan Transportation Authority, 1999), a total of $US 5.1 billion was planned for constructing 5 new subway stations and the 6-km long northern Second Avenue Subway line (From 64th Street to 129th street). It has already spent more than $US 4 billion to build the first phase of Second Avenue Subway (63th Street to 96th Street), which is about 3 km long and has 3 new subway stations (The Metropolitan Transportation Authority, 2017).

Furthermore, if we convert the total capital cost to unit cost, the actual unit cost of $US 1.4 billion/km is much higher than the estimated cost of $US 850 million/km in DEIS in real dollars. The actual unit cost is also higher than the unit cost of the proposed full-length Second Avenue Subway (13.7 km from 125th Street in East Harlem to the Financial District in Lower Manhattan), which is approximately $US 1.2 billion/km (total cost is now predicted to be $US 16.8 billion) (The Metropolitan Transportation Authority, 2004). The remainder of the originally proposed northern part of the Second Subway Avenue Line (99th Street to 125th Street), namely the second phase of the Second Avenue Subway line, will be delivered later than 2025 (The Metropolitan Transportation Authority, 2004, 2018). As a result, both the total capital cost and the unit cost of phase 1 Second Avenue Subway exceed expectations.

Then, among the three alternatives, the highest BCR is observed in TSM option because of the lowest initial capital outflow, but both TSM and Alternative 2 were eliminated in the preliminary engineering analysis. Alternative 1 was the locally preferred alternative which is comparable to the actual condition in 2018. The BCR of Alternative 1 is 1.31. As discussed in section 10.4.1, if we only consider the $US 4.8 billion transit TTS benefit, the BCR of Alternative 1 is approximately equal to 0.95. However, the actual annual transit patronage and transit TTS per trip in 2018 is only 60% and 37.5% of the expectations in Alternative 1, and the actual capital cost is higher than the predicted cost. The actual BCR of phase 1 is lower than 1.

But when we move to the residential properties' value appreciation, both for sold properties and rental properties, the NPVs and BCRs outperform those for alternative project options listed in DEIS. The total capitalized value appreciation in sold properties is $US 17.37 billion, which is over four times larger than the project cost. For rented properties, the value appreciation amounts to $US 11.04 billion, nearly three times the total project cost. In the project planning phase, these non-user gains should have been reckoned with grounded on that this value increment stems from Second Avenue Subway and is transferred to property owners as true economic wealth. In accordance with the decision rule of NPV and BCR, the results generated by property value appreciation approaches are in strong support of the decision on approving and constructing the Second Avenue Subway.

10.7 Implications on Value Capture

In the US, historically prevailing funding sources earmarked for transport infrastructure construction are taxes levied on motor fuel, fees charged for the use of roadways and public transit services, and general purpose taxes like property taxes (Zhao et al., 2012; Istrate and Levinson, 2011). They insist that the sustainability of those funding sources is nevertheless increasingly uncertain due to the emergence of clean energy, the transformation of vehicle type and the public resistance to tax rises. Value capture, an alternative mechanism to finance public infrastructure, uses the gains accrued to land or property value and ultimately received by private owners to recoup the costs incurred to construct the public infrastructure (Batt, 2001; Mathur, 2014). In comparison to the traditional project financing scheme, value capture strategies remain sparsely applied in the US. Value capture is more commonly considered and adopted by transit projects rather than by road projects (Batt, 2001). Findings from this paper may provide some insights.

First, as of the two-year operation of the Second Avenue Subway, the accumulated property value appreciation has exceeded the upfront capital cost, demonstrating the significant impact of transit infrastructure on property value and thus indicating the viability of value capture strategy. But be careful when drawing on this experience since New York is one of the most expensive cities in the world, the continuation of land value appreciation here is doubtless greater than cities which are sparsely populated and less prosperous.

Second, unlike many traditional funding sources which are collected mainly grounded on the actual usage or operational status of the transport infrastructure, value capture strategies apply to the capitalized incremental accessibility generated by the new subway service. Given its independence from actual usage, cash inflows created under value capture are supposed to be foreseeable and sustainable.

Third, because different types of property transactions materialize value appreciation in distinct manners, customized value capture strategies on different transactions can be employed to ensure that different benefit inflows cover cost outflows of similar natures. Specifically, property purchase transactions initiated at early project planning stage and realize appreciation gains in larger size, which suit to accumulate benefit streams to recover upfront capital expenditure. Appreciation gains acquired through property lease emerge after project completion, in smaller size but at higher frequency, which might be able to cover periodic project operation and maintenance costs. Alternatively, a more general land value tax can be used, which will eventually recover the gains in terms of property value appreciation.

10.8 Conclusion

In this paper, we hypothesize that unlike the traditional perspective of quantifying travel time and cost savings, the change in the value of real estate better captures the economic impact of transport services more quickly, directly, and properly. In the case of the New York Second Avenue Subway project, first we find that both the observed transit ridership and the transit TTS per trip are lower than the forecast, so the actual transit person TTS benefit, which accounts for more than 70% of the total project economic benefit, is lower than originally estimated. Although transit patronage is expected to rise after completing the second phase of the Second Avenue Subway, TTS for trips heading to South Manhattan may not be significantly improved until the operation of the full-length Second Avenue Subway.

Second, a strong positive correlation between job accessibility by transit and housing price (both selling price and rental price) has been observed. According to the panel pooling model and hedonic model, if the total number of job opportunities that are accessible within 30 minutes by transit increases by 100,000, the rental price per m^2 is expected to increase by 1.7%-2.67%, and the selling price per m^2 is anticipated to rise by 2.72% - 3.23%.

Third, the net present value of appreciation in residential property value due to the announcement of the Second Avenue Subway ranges from $US 3.8 billion to $US 8.8 billion, depending on the discount rate applied. The net present value of appreciation in residential rent due to the opening of the Second Avenue Subway ranges from $US 361 million to $US 20.2 billion, depending on the discount rate applied.

Furthermore, in table 10.8, all BCRs are greater than 1 and all the NPVs are positive, implying that the appreciation in residential properties is large enough to cover the total project cost. In contrast, the BCR weighing TTS against the total project is less than one. As a result, in accordance with the decision rule of BCR and NPV, the value appreciation of residential properties brought by Second Avenue Subway is greater than the project cost, so constructing this subway is supported.

In summary, the access-based property value and rental value uplift assessment methods remedy many issues in the problematic traditional time-saving based BCA evaluation method, and provide implications on using value capture strategy as an alternative project financing mechanism. Including and quantifying the economic impact of a new transport project on surrounding real estate may provide insightful information when evaluating and selecting transport projects. We also suggest this may be simpler to analyze than the traditional travel time savings approach as it does not require a full transport model, simply public transport schedules and real estate data.

It should be noted that the hedonic model in this study only engaged locational characteristics, property-specific structural attributes, as well as spatial and temporal control factors as independent variables to explain property price change. Other factors (e.g. neighborhood quality, amenity characteristics, demographic features, etc.) that also could affect property prices were excluded. The choice of independent variables affects the model's ability to explain the movement in property prices. In addition, the hedonic model is a partial equilibrium model, meaning that property price uplift observed in the vicinity of the new subway line may be partially or fully offset by price reduction elsewhere (beyond the control areas), implying the possibility of overstating the net effect on regional (or even national) real resources and productivity gain.

Chapter 11

Conclusions and Discussion

This dissertation aimed to disentangle the worthiness of engaging Benefit/Cost Analysis (BCA) as an aid in assisting decision-making. This dissertation comprises a succession of independent studies each delving into one or more relevant dimensions through which whether adopting BCA process adds value could be assessed. The joint theme rests in that only when there are positive benefits to doing a BCA can the various costs of doing it be managed and covered.

11.1 Summary of Research

In response to the research gaps identified in the introduction section, the key research contributions are summarised in figure 11.1.

Chapter 2 illustrates the conceptual framework guiding the evaluation of the costs and benefits of using BCA. Given the constraint that the majority of cost and benefit items are intangibles, this primary focus on evaluating the value added by using BCA is narrowed to investigate whether the tangible benefits of engaging BCA exceed zero by assessing the performance of BCA through five key dimensions: accuracy, appropriateness & consistency, fiscal sustainability, transparency and replicability, and comprehensiveness.

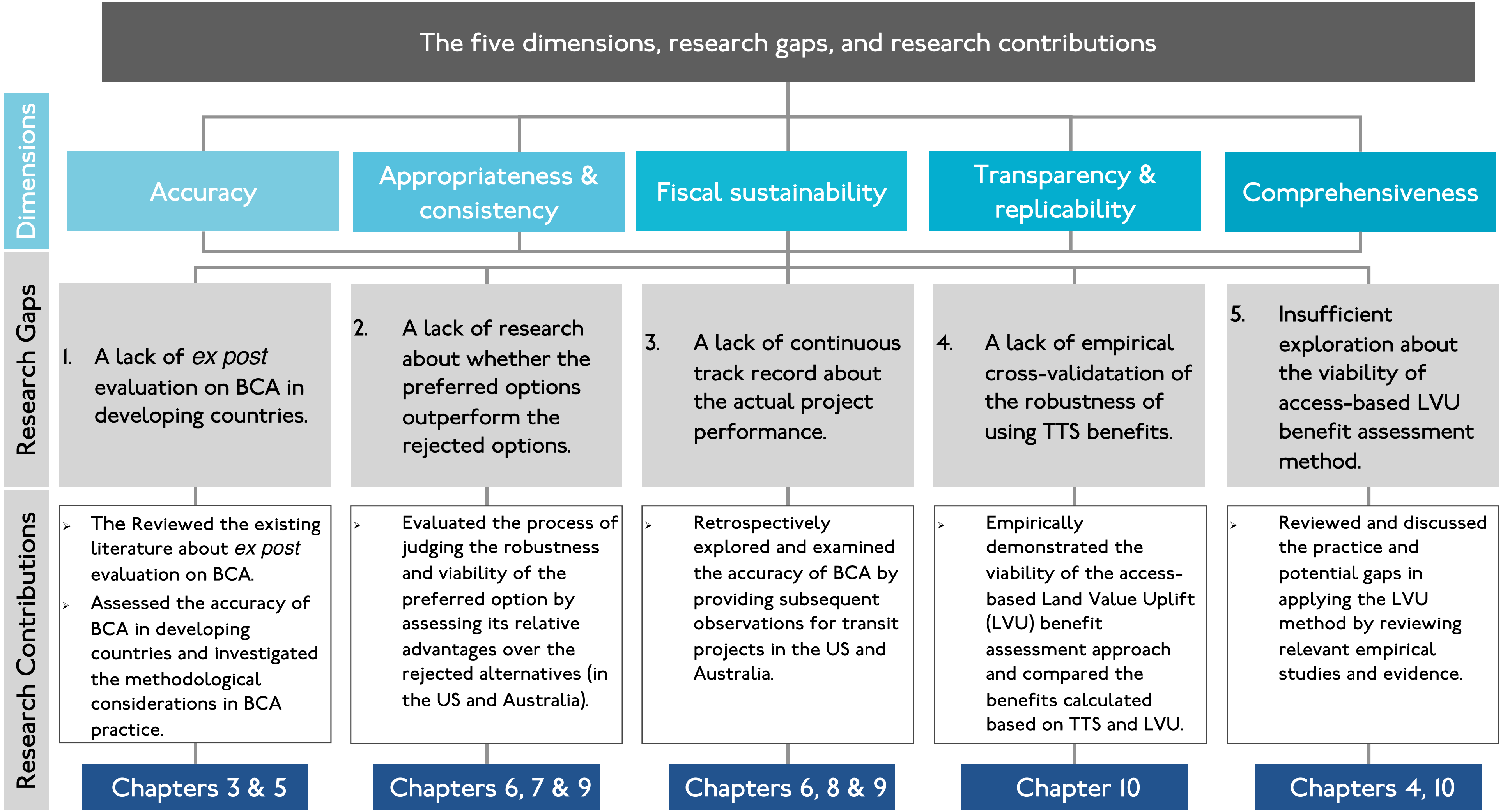


Figure 11.1 The five dimensions, research gaps, and research contributions

Chapter 3 firstly reviews the current practice of BCA in the transport sector by looking into cost evaluation, benefit projection, the involvement of other comprehensive project benefits, and the overall project performances in developed countries. Then, activated by the common observation that the predicted performance of the selected alternative persistently deviates from its actual performance, we explore and discuss how selection bias, funding incentives, assessment tools, and evaluation criteria impact project alternative analysis in which the locally preferred alternative is sorted out. This chapter then summarizes critiques on the benefit assessment methods embedded in the present BCA process and investigates the robustness of an alternative approach - the access-based land value uplift method. Finally, to develop a proper understanding of BCA, the concerns and criticisms observed in the literature review were categorized into three groups: quality of inputs to BCA, BCA itself, and the role of BCA in the decision-making process. Except for the criticisms of BCA itself, that covers deficiencies in the conceptual and empirical basis of the BCA framework (i.e. a lack of inclusion of distributional and intergenerational effects), criticisms from the other two angles potentially apply to other tools and frameworks aiding decision-making.

Based on existing empirical studies researching into the capitalization effect of access benefits induced by transport improvements to property value, chapter 4 reviews the current practice and identifies potential gaps in using the access-based land value uplift method in BCA. The study design lacking proper control over changes in locational factors and temporal effects hinders us from precisely evaluating project-specific incremental impacts. Further, proximity to transport services, namely various distance measures, is widely employed as the primary indicator of properties' locational features. Distance measures are mode-insensitive and neglect the quality or number of opportunities reachable at trip destinations, which is incapable of fully depicting accessibility gains as a result of transport improvements. An overwhelming research enthusiasm for capitalization effects on the residential property sector provides limited evidence about the interplay between property values and transport projects from a broader and general view.

Grounded on 59 roadways funded by Asian Development Bank (ADB), chapter 5 expanded the discussion on the accuracy of BCA results to the developing world and investigated the appropriateness and consistency of ADB's choice of the social discount rate, non-market evaluation, and counterfactual baseline case. It reveals that the average cost overrun is 10.71%, which is smaller than that reported in other international evidence. A systematic tendency of understating both the present value of costs and benefits is identified, whereas the underestimation of economic benefits is too small to counterbalance the underestimation of costs, resulting in an overall project EIRR of 5.4% which is lower than the social discount rate of 12%. Suggested by the evidence that the vast majority of projects still have an *ex post* BCR above 1 and that the shadow price adopted when calculating TTS is determined fairly and adjusted realistically, investing in the projects selected by using BCA successfully secures the overall return on investment and reinforcing the accuracy and credibility of BCA results.

chapter 6 prepares a complete 'alternative history' for 43 US light rail segments and lines, evaluating and investigating the process of judging the robustness and viability of the selected option by inspecting the competing alternatives that were ultimately discarded. First, it was corroborated that LRT is chosen over the bus in most cases when they are proposed together, attesting to concerns about the existence of selection bias and discrimination in early-stage appraisal and decision-making. Second, the limited modal diversity observed in the alternatives' analyses at EIS stages raised the concern that some worthwhile alternatives might be undermined in the planning stages. Third, evaluating candidate alternatives that primarily differ in route alignment using the existing quantitative criteria (costs and ridership) is hard to fully address the relative advantages of alternatives. The underdeveloped 'do-something' options raise concerns regarding the quality and reliability of the inputs to BCA, which turns to affect the ultimate recommendation framed based on BCA results. Fourth, in many cases, it was sought out that the LPA was not the best 'do-something' alternative in terms of the demonstrated cost-effectiveness, indicating potential opportunity costs of rejecting more economical courses of action which could have likely managed prospective demand at much lower costs, and thus would have enabled more projects to be built and more people to have been served. Last, the findings that alternatives with a higher rate of return were generally declined implies that BCA and its results seem to have limited contribution to *ex ante* transport investment decision-making. These empirical findings are aligned with many criticisms of problematic inputs to BCA and the limited weight carried by BCA in decision-making.

Using the same set of light rail projects as the previous chapter, chapter 7 finds out that six major criteria have been constantly engaged in alternatives' evaluation: development and land, environment, mobility, cost, construction, and engineering, as well as equity. Although light rail requires intensive up-front capital investment, it is always alleged to be superior to other competing modes (particularly the bus mode) given its strong potential for transferring land use patterns, boosting regional development, minimizing negative impacts on the natural environment, improving intermodal connectivity and system integration, enhancing accessibility to key destination, providing comfortable and reliable transit service, and managing high passenger load. It should be noted that word frequency analysis only serves rough proxies of evaluation focus. As a result, this analysis approach is limited in revealing why projects are actually chosen.

Chapter 8 retrospectively examines (if any) systematic tendencies in cost estimate, ridership projection, and travel time forecast produced in *ex ante* BCA using 43 light rail projects in the US, attempting to disentangle whether the Locally Preferred Alternative (LPA) reckoned to be worthwhile materialize its potential value as envisioned. Project cost overrun and ridership shortfalls remain to be prominent issues. Costs rise constantly throughout the planning stages. By tracking actual annual ridership in subsequent years, the majority of projects either steadily underperform the LPA or show downward tendencies, negating the hypothesis that projects underperforming in initial operation years catch up to their full forecast demand when the ramp-up effect disappears. The significant divergence of morning peak hour in-vehicle travel time between the same OD pair for both bus and light rail mode brings about doubt about the reliability of the demand forecasts based on time savings, the incremental user benefits, and the overall cost-effectiveness estimated by BCA.

Based on 6 recent passenger rail projects in Australia, chapter 9 investigates if preferences for a specific public transport mode exist in the project planning stage and whether the preferred mode justifies its viability after being delivered. Although the BRT option invariably beats the preferred passenger rail option in *ex ante* BCA, it always ended up with a rejection gesture, implying that discrimination against BRT depends on decision-making since the early planning stages. In contrast, fixed-guideway passenger rail systems that are more costly to build and in the end serve fewer than the expected number of users were always given the green light. Those findings give new relevance to questions about the economic justifications and worthiness of public transport investment decisions grounded on BCA.

Chapter 10 presents a case study for the Second Avenue Subway in New York City to test the hypothesis that unlike the perspective of quantifying travel time and cost savings in traditional BCA, the change in the value of real estate better captures the economic impact of transport services more quickly, directly, and properly. Both the observed transit ridership and the transit TTS per trip are lower than the forecast, suggesting low possibilities that the actual BCR of this project could conform to the original estimation and exceed the threshold of 1. The strong positive correlation between job accessibility by transit and housing price offers an opportunity to approximate real estate value uplift that is attributable to the new subway segment. The BCRs calculated using this new method are all well above 1 when different discount rates are tested, shedding light on the viability of using value capture strategy.

The aforementioned findings and research contributions support the testing of the five hypotheses set out at the beginning of this thesis. The hypothesis testing results, alongside the original hypotheses, have been shown in figure 11.2. In response to the first hypothesis that the primary information input into and output by BCA are accurate to assist decision-making, findings described in chapter 5 correspond to this, given that the accuracy of BCA for road projects in Asian developing countries is better than that reported by other international evidence. But the observations in chapter 8 and 9 don't support this, demonstrating that the validity of this hypothesis depends on the context.

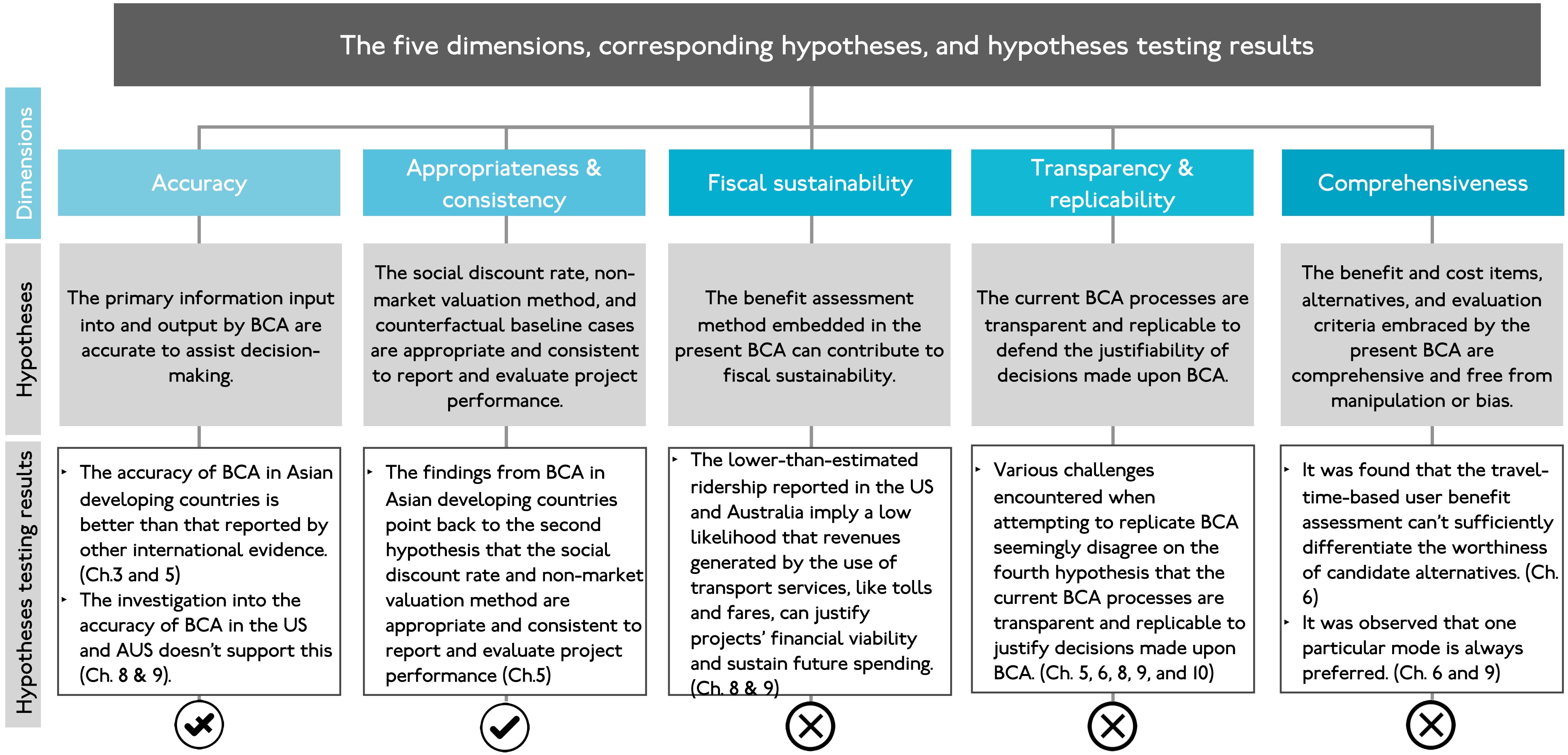


Figure 11.2 The five dimensions, hypotheses, and hypotheses testing results

Chapter 5 also presents that the shadow price adopted when calculating TTS is determined fairly and adjusted realistically. Applying a uniform 12% social discount rate to assess investments funded by the Asian Development Bank, although indicates excessive risk aversion, ensures the comparability of BCA results and secures the overall return on investment. In the US, the 'do-nothing' option is separated from the 'do-minimum' option, and appointing the latter as the baseline for evaluating other 'do-something' alternatives secures the realism of the appraisal of alternatives. All these findings point back to the second hypothesis that the social discount rate and non-market valuation method are appropriate and consistent to report and evaluate project performance.

Can the benefit assessment approach embedded in the existing BCA process contribute to fiscal sustainability, as the third hypothesis would suggest? The lower-than-estimated ridership reported in the US (chapter 8) and Australia (chapter 9) imply the low likelihood that revenues generated by the use of transport services, like tolls and fares, can justify projects' financial viability and sustain future spending.

As mentioned throughout this dissertation, various challenges encountered when attempting to replicate BCA seemingly disagree on the fourth hypothesis that the current BCA processes are transparent and replicable to justify decisions made upon BCA.

It is finally hypothesized that the alternatives, the benefit and cost items, as well as evaluation criteria embraced by the present BCA are comprehensive and free from manipulation or bias. The findings from chapter 6 that the travel-time-based user benefit assessment is unable to fully differentiate the worthiness of candidate alternatives, and the phenomenon observed in chapter 6 and 9 that one particular mode is always preferred don't support this hypothesis.

Returning to the initial questions inspiring this dissertation:

- Do the results output by BCA actually add value and impact decision-making? and
- Is BCA trustworthy enough that politicians should use it?

The findings in this thesis corroborated some practical issues (i.e. measurement and valuation problems) underlying the application of BCA. As explained in chapter 3 and 4, these practical issues are classified into three categories: deficiencies in the inputs to BCA, the technique and empirical basis of BCA itself, as well as the limited role of BCA in decision-making.

The poor quality of inputs to BCA, including various estimates and options under investigation, would likely result in poor quality results, compromising the investment decisions made upon the results. Using NMV monetize various user benefits, as one of the core processes underpinning the conventional BCA, is also subject to various practical difficulties. The findings that in the US and Australia the ultimate preferred alternative persistently under-performs the 'do-minimum' and second-best 'do-something' options remind us of the opportunity costs. More projects could have served more people with the same budget, and prospective demand could have been managed by more economical courses of action. More importantly, this reveals that BCA carries limited weight in decision-making because options with a higher rate of return were generally declined.

Indeed, the wide investment decision-making process embraces many factors, and choices between alternatives are the responsibility of decision-makers, not BCA. BCA as an investment assurance tool typically assesses the relative advantages of alternative options (or projects) from the economic perspective. As such, BCA can inform but cannot direct decision-makers, particularly when decision-makers' objectives are maximizing aggregate social welfare (accounting for social equity and environmental sustainability) rather than cost-effectiveness. Discounting BCA in decision-making may not necessarily be navigating politicians to the wrong decisions. Multilateral financial institutions like Asian Development Bank (ADB) demonstrate sound value of using BCA to assist project decision making. This might be ascribed to the institutional characteristics of not being elected officials requiring exogenous funding sources. For instance, the influx of repayments made by the borrowing member countries and financial contributions made by the relatively wealthier members (i.e., Australia, China, South Korea, and Japan) make up the funding that can be disbursed by ADB. Nevertheless, sufficient due diligence and intervention seemingly secure the path to the right projects, protecting investors' interest and maintaining good investment records.

However, the problematic mobility-oriented and travel-time-based benefit assessment methodology embedded in the conventional transport BCA, as demonstrated by the empirical studies in the US and Australia, cannot leverage the value of the concepts of BCA. Abandoning BCA and switching to other decision-making tools or frameworks are not risk-free solutions because the flaws of inputs quality and the limited role in decision-making potentially apply to all frameworks and tools. The feasibility of incorporating changes in land use and real estate value into project-specific incremental benefit assessment via access measures, as corroborated in the

New York Second Avenue Subway project (in chapter 10) and many other empirical studies conducted in major cities across the globe (see chapter 4), could potentially mitigate some measurement and valuation problems. Using the access-based method potentially outsources the valuation issues related to NMV to the real estate market, as the unit dollar value of access changes is informed by property/land value uplift. Land or property are market goods, although the real estate market is not a perfectly competitive market either. This method also aligns with the changes in policy focus that benefits accrued to non-users (i.e., WEBs) (as an externality) are increasingly accepted and evaluated in addition to TTS to capture the benefits end up in productivity and land market.

As a result, it should be noted that the research and findings in this thesis are not challenging the theoretical basis for BCA. Rather, this thesis demonstrates that there are gaps between theory and practice. In theory, theory should have precisely captured the truly additional benefits ascribed to transport investment. However in practice, as demonstrated by numerous findings presented in this thesis, the empirical implementation of the theory, alongside the idealized assumptions, confronted many challenges. In a nutshell, as the quote says, “In theory, theory and practice are the same. But in practice, they are different”.

11.2 Limitations and Future Research

The new land value uplift assessment method comes amid some practical difficulties and has limitations. One of the limitations lies in that land value is driven by numerous interconnected factors. Disentangling the specific proportion of land value uplift associated with accessibility improvements triggered by a transport intervention from other concurrent factors can be challenging. It is noteworthy that the hedonic pricing model, although acting as a fundamental approach to decomposing land value, is essentially a partial equilibrium model projecting land value changes within the designated study area. It is limited in terms of distinguishing the ‘transferring’ parts from the ’net growth’ part in observed land value uplift under a general equilibrium condition.

In addition, evaluating land value and changes in land value might suffer potential measurement and valuation issues. For instance, land value evaluation is subject to the availability, reliability, promptness, and quality of land value data. The lack of sound historical land value data which assists in establishing causal relationships may further complicate the land value uplift decomposition processes.

Grounded on the principle that only when there are positive benefits of conducting a BCA can the costs of doing it be satisfied, this dissertation assesses the value of using BCA from the tangible benefits wedge (as shown in figure 2). Narrowing down the scope enables us to concentrate on the critical dimensions impacting the tangible benefit wedge, leaving much room for exploring the remaining wedges. Future research could depart from the cost wedges. Among all the available evaluation tools informing and aiding public decision, BCA always ranked the top and is compelled by many government institutions. As a required or even mandated part of a project business case or environmental impact assessment, BCA processes are either outsourced to external experts or completed in-house. The tangible costs of doing a BCA vary with the project's scale and scope and the experts' experience and competence. Government spending in regulating and monitoring BCA processes is anticipated to have a profound influence on the transparency and accountability of BCA processes. Given that the costs of BCA ultimately affect the quality of the resulting information and the decision, several related questions arise:

1. Whether the costs of doing BCA change over time and across public sectors?
2. Whether the quality of BCA correlates with the costs of doing it?
3. Has the quality or accuracy of BCA been improved when more stringent monitoring systems are established?

In addition, the access-based land value uplift benefit assessment method sheds light on future investment decisions in the transport sector. Given that the feasibility of the new method has been corroborated by the subway project in New York, this method can be tailored and applied to evaluate investments in other modes of transport, which might interest not only national transport departments but also multilateral organizations and banks who seek to leverage resources to enhance regional development.

The existing BCA methodology and application are far from perfect, and its evolution needs to continue.

Appendix A

Appendix

A.1 An Overview of the US Light Rail Projects

Table A.1 Project Overview

No.	Project ID	State-Project Name	Line Name	City
1	AZ-CPEV	AZ-Central Phoenix/East Valley LRT	-	Phoenix
2	CA-PE	CA-Capitol Extension	Orange Line	Santa Clare
3	CA-DSAF	CA-Downtown Sacramento-Folsom	Gold Line	Sacramento
4	CA-ELCJ	CA-El Cajon Extension	Orange Line	San Diego
5	CA-GDP	CA-Guadalupe Line LRT	Green Line	San Jose
6	CA-EXP	CA-Mid-City/Exposition Phase 1	E Line	Los Angeles
7	CA-MC	CA-Mid-Coast Corridor LRT	Blue Line	San Diego
8	CA-MVE	CA-Mission Valley East LRT	Green Line	San Diego
9	CA-SSA1	CA-South Sacramento LRT Phase 1	Blue Line	Sacramento
10	CA-SSA2	CA-South Sacramento LRT Phase 2	Blue Line	Sacramento
11	CA-TT	CA-T Third Street LRT Phase 1	T Line	San Francisco
12	CA-TW	CA-Tasman West LRT	Green Line	Santa Clare
13	CA-V	CA-Vasona Extension	Green Line	Santa Clare
14	CO-SE	CO-Southeast Corridor LRT	E Line	Denver
15	CO-SW	CO-Southwest LRT Project	D Line	Denver
16	CO-W	CO-West Corridor LRT	W Line	Denver
17	MD-HV	MD-BWI International Airport Extension	-	Baltimore
18	MD-HV	MD-Hunt Valley Extension	-	Baltimore
19	MN-CC	MN-Central Corridor LRT	Green Line	Minneapolis-St. Paul
20	MN-HW	MN-Hiawatha LRT	Blue Line	Minneapolis
21	MO-ML	MO-MetroLink	Red Line	St. Louis
22	NC-NE	NC-Northeast Corridor LRT	Lynx Blue Line	Charlotte
23	NC-SC	NC-South Corridor LRT	Lynx Blue Line	Charlotte
24	NJ-HB	NJ-Hudson Bergen MOS 1\MOS2	-	Jersey City
25	NJ-NE	NJ-Newark-Elizabeth	-	Newark
26	OR-I-205	OR-I-205/Portland Mall LRT	Max Green Line	Portland
27	OR-NIM	OR-North Corridor Interstate Max	Max Yellow Line	Portland
28	OR-PM	OR-Portland-Milwaukie LRT	Max Orange Line	Portland
29	OR-WHE	OR-Hillsboro LRT	Max Blue Line	Portland
30	PA-NS	PA-North Shore LRT Connector	All Lines	Pittsburgh
31	TX-NCE	TX-North Central Extension	Red Line	Dallas
32	TX-NH	TX-North Hardy MetroRail Red Line	Red Line	Houston
33	TX-SENW	TX-Northwest Corridor LRT to Farmers Branch	Green Line	Dallas
34	TX-NWIrv	TX-Northwest Corridor LRT to Irving DFW Airport	Orange Line	Dallas
35	TX-SOC	TX-South Oak Cliff	Blue Line	Dallas
36	TX-SENW	TX-Southeast Corridor LRT	Green Line	Dallas
37	TX-SEC	TX-Southeast Corridor LRT	Purple Line	Houston
38	UT-DP	UT-Draper Transit Corridor	Blue Line	Salt Lake City
39	UT-MJ	UT-Mid Jordan LRT	Red Line	Salt Lake City
40	UT-Sandy	UT-Sandy Line	Blue Line	Salt Lake City
41	UT-UM	UT-University \Medical CenterLRT	Red Line	Salt Lake City
42	VA-TD	VA-The Tide Light Rail	-	Norfolk
43	WA-CL	WA-Central Link Initial Segment	Line 1	Seattle

Table A.2 Project Overview (Continued)

No.	Project ID	Operator	Type[1]	Length (km)	Mode Considered	Alts' No.[2]	Build Alts' Type[3]
1	AZ-CPEV	Valley Metro	In. L	32.7	Bus, LRT	3	B2
2		VTA	Ext.	13.2	Bus, LRT	3	A
3	CA-DSAF	SacRT	Ext.	33.5	Bus, LRT	3	A
4	CA-ELCJ	MTS	Ext.	17.9	Bus, LRT	7	C
5	CA-GDP	VTA	In. L	32.2	Highway, Bus, LRT, CR,	14	C
6	CA-EXP	MetroRapid	Ext.	15.8	Bus, BRT, LRT	5	C2
7	CA-MC	MTS	Ext.	17.5	Bus, LRT, CR	7	C
8	CA-MVE	MTS	Ext.	9.5	Bus, LRT	3	A
9	CA-SSA1	SacRT	Ext.	18.2	Roadway, Bus, LRT	13	B
10	CA-SSA2	SacRT	Ext.	11.1	Bus, LRT	3	A
11	CA-TT	MuniMetro	Ext.	8.7	Bus, LRT	4	B2
12	CA-TW	VTA	Ext.	12.2	Bus, LRT	8	C
13	CA-V	VTA	Ext.	10.9	Bus, LRT	2	A
14	CO-SE	RTD	Ext.	30.8	Bus, LRT	2	A
15	CO-SW	RTD	Ext.	14	Bus, LRT	2	A
16	CO-W	RTD	In. L	19.5	Bus, LRT	3	A
17	MD-HV	MTA	Ext.	3.9	Bus, LRT	5	B
18	MD-HV	MTA	Ext.	6.6	Bus, LRT	8	B
19	MN-CC	Metro Transit	In. L	17.7	LRT, BRT	4	C
20	MN-HW	Metro Transit	In. L	18.7	Highway, Bus, LRT	18	C
21	MO-ML	BSDA	In. L	29	Bus, LRT	5	C
22	NC-NE	CATS	Ext.	15.4	Bus, LRT	4	B
23	NC-SC	CATS	Ext.	15.8	Bus, LRT	4	B
24	NJ-HB	NJ Transit	In. L	24.8	Bus, LRT, AGT/Monorail	9	C
25	NJ-NE	NJ Transit	In. L	1.6	Bus, LRT	6	B
26	OR-I-205	TriMet	In. L	13.4	Bus, LRT	2	A
27	OR-NIM	TriMet	In. L	9.1	Bus, LRT	2	A
28	OR-PM	TriMet	Ext.	11.7	Bus, LRT	4	B
29	OR-WHE	TriMet	Ext.	10	Bus, LRT	6	B
30	PA-NS	PRT	Ext.	40.2	Bus, LRT	5	B
31	TX-NCE	DART	Ext.	9.7	Bus, LRT	5	B
32	TX-NH	METRO	Ext.	8.5	BRT, BRT Conv., LRT	7	C
33	TX-SENW	DART	Ext.	28.3	Bus, LRT	9	B
34	TX-NWIrv	DART	Ext.	15	Bus, LRT	2	A
35	TX-SOC	DART	In. L	15.4	Bus, LRT	16	B2
36	TX-SENW	DART	Ext.	16.4	Bus, LRT	4	B
37	TX-SEC	METRO	In. L	10.9	BRT, BRT Conv., LRT	7	C
38	UT-DP	UTA	In. L	13.8	Bus, LRT	4	B2
39	UT-MJ	UTA	In. L	17.1	Bus, LRT	3	A
40	UT-Sandy	UTA	In. L	24.1	Bus, LRT	12	B
41	UT-UM	UTA	Ext.	2.5	Bus, LRT	7	B
42	VA-TD	Hampton Roads Transit	In. L	11.8	Bus, LRT	3	A
43	WA-CL	SoundTransit	In. L	25.1	Bus, LRT	6	B2

[1] Project type includes Initial Line (In. L.) and Extension (Ext.).
[2] The number of alternatives considered, including the 'no-build' and TSM alternatives.
[3] The four types of build alternatives are explained in section 6.4.1.

Table A.3 Project Overview (Continued)

No.	Project ID	C'_{DEIS} [4]	C'_{FEIS}	C'_{FFGA}	C'_{Actual}	DEIS Year	FEIS Year	FFGA Year	Actual Year
1	AZ-CPEV	1597.66	1485.8	1576.97	1655	2001	2002	2008	2008
2						1998	1999		
3	CA-DSAF	-	305.37	-	635.48	1999	2000	-	2005
4	CA-ELCJ	287.29	287.29	242.02	224.48	1985	1986	1986	1989
5	CA-GDP	623.76	807.2	942.46	906.93	1981	1983	1987	1987
6	CA-EXP	902.66	755.34	-	1133	2001	2005	-	2012
7	CA-MC	681.69	170.58	193.7	193.7	2000	2001	2003	2003
8	CA-MVE	488.54	568.03	598.02	688.03	1997	1998	2005	2005
9	CA-SSA1	312.52	329.12	340.83	313.6	1994	1997	1997	2004
10	CA-SSA2	258.97	308.95	309.04	309.04	2007	2008	2014	2014
11	CA-TT	678.15	679.8	729.1	729.1	1998	1998	2007	2007
12	CA-TW	781.28	779.91	584.25	548.97	1991	1992	1997	1997
13	CA-V	414.72	414.72	-	474.53	1999	2000	-	2005
14	CO-SE	0	1221.79	1181.91	1181.91	1999	1999	2006	2006
15	CO-SW	375.8	279.36	287.77	289.07	1999	1999	1999	1999
16	CO-W	745.68	741.17	804.92	825.85	2003	2003	2013	2013
17	MD-HV	98.49	88.97	199.39	206.63	1991	1993	1993	1995
18	MD-HV	98.49	88.97	199.39	206.63	1990	1993	1993	1995
19	MN-CC	1057.19	1151.45	1095.39	1059.91	2006	2009	2014	2014
20	MN-HW	492.02	529.91	755.5	1043.47	1983	1985	2003	2003
21	MO-ML	757.68	685.49	833.25	848.24	1984	1987	1994	1994
22	NC-NE	1198.07	-	1251.84	1430.89	2010	2010	2018	2018
23	NC-SC	567.52	567.52	605.08	605.08	2002	2003	2007	2007
24	NJ-HB	1682.12	1920.36	2898.53	2763.51	1992	1996	2000	2000
25	NJ-NE	249.35	245.83	302.44	297.96	1997	1998	2000	2004
26	OR-I-205		701.7	727.51	727.51	1998	2004	2009	2009
27	OR-NIM	385.94	477.91	489.38	464.23	1997	1999	2000	2004
28	OR-PM	1860.72	1923.52	1703.44	1672.58	2008	2010	2015	2015
29	OR-WHE	966.23	1388.97	1531.49	1665.38	1993	1994	1996	1996
30	PA-NS	469.69	469.69	649.3	619.18	2000	2002	2011	2011
31	TX-NCE	626.51	617.04	708.76	658.76	1996	1997	1999	2002
32	TX-NH	474.53	474.62	760.72	699.07	2006	2010	2013	2013
33	TX-SENW	612.13	677.9	1747.19	1747.19	2002	2003	2010	2010
34	TX-NWIrv	984.07	850.77	-	1062.19	2008	2008	-	2012
35	TX-SOC	626.87	750.61	693.85	658.12	1990	1991	1993	1994
36	TX-SENW	612.13	677.9	1747.19	1747.19	2002	2003	2010	2010
37	TX-SEC	485.07	442.23	871.16	832.29	2006	2006	2015	2015
38	UT-DP	246.84	288	225.66	169.82	2009	2010	2013	2013
39	UT-MJ	414.6	608.5	644.48	614.36	2005	2007	2011	2011
40	UT-Sandy	550.88	406.31	494.95	503.9	1994	1994	1992	1997
41	UT-UM	563.41	558.32	308.07	289.39	1997	1999	2002	2002
42	VA-TD	-	250.09	469.25	371.3	2002	2005	2012	2012
43	WA-CL	2652.39	3673.78	3384.96	3230.87	1997	1999	2009	2009

[4] C' refers to inflation adjusted project costs.

A.2 The List of Stopwords used in the Content Analysis of the US Light Rail Projects' EISs

Initial	Stopwords
A	a; about; above; after; again; against; all; am; an; and; any; are; aren't; aren't; as; at
B	be; because; been; before; being; below; between; both; but; by
C	can; can't; can't; cannot; could; couldn't; couldn't
D	did; didn't; didn't; do; does; doesn't; doesn't; doing; don't; don't; down; during
E	each
F	few; for; from; further
H	had; hadn't; hadn't; has; hasn't; hasn't; have; haven't; haven't; having; he; he'd; he'll; he's; he'd; he'll; he's; her; here; here's; here's; hers; herself; him; himself; his; how; how's; how's
I	i; i'd; i'll; i'm; i've; i'd; i'll; i'm; i've; if; in; into; is; isn't; isn't; it; it's; it's; its; itself
L	let's; let's
M	me; more; most; mustn't; mustn't; my; myself
N	no; nor; not
O	of; off; on; once; only; or; other; ought; our; ours; ourselves; out; over; own
S	said; same; say; says; shall; shan't; shan't; she; she'd; she'll; she's; she'd; she'll; she's; should; shouldn't; shouldn't; so; some; such
T	than; that; that's; that's; the; their; theirs; them; themselves; then; there; there's; there's; these; they; they'd; they'll; they're; they've; they'd; they'll; they're; they've; this; those; through; to; too
U	under; until; up; upon; us
V	very
W	was; wasn't; wasn't; we; we'd; we'll; we're; we've; we'd; we'll; we're; we've; were; weren't; weren't; what; what's; what's; when; when's; when's; where; where's; where's; which; while; who; who's; who's; whom; whose; why; why's; why's; will; with; won't; won't; would; wouldn't; wouldn't
Y	you; you'd; you'll; you're; you've; you'd; you'll; you're; you've; your; yours; yourself; yourselves

Table A.4 The List of Stopwords used in the Content Analysis in Chapter 7

A.3 The 1000 Most Frequently Appearing Words Output by the General Word Frequency Queries

Table A.5 The 1000 Most Frequently Appearing Words Output by the General Word Frequency Queries

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
1	alternatives'	41154	1.18%	environmentally	16213	0.37%
2	impacts	30698	0.88%	characteristics	1327	0.03%
3	areas'	27257	0.78%	reconstructions	639	0.01%
4	corridors	26660	0.76%	responsiveness	5583	0.13%
5	projects	23917	0.68%	approximations	4800	0.11%
6	transitions	22124	0.63%	administrators	2796	0.06%
7	stations	21303	0.61%	establishments	1868	0.04%
8	lrt	21134	0.6%	accommodations	1809	0.04%
9	streets	20942	0.6%	appropriations	1654	0.04%
10	using	17946	0.51%	considerations	1524	0.03%
11	parks	17757	0.51%	jurisdictions'	1159	0.03%
12	rails	14831	0.42%	investigations	889	0.02%
13	constructs	14608	0.42%	undergrounding	704	0.02%
14	souths	13663	0.39%	communications	659	0.01%
15	buildings	13574	0.39%	alternatives'	36904	0.84%
16	environmentally	13197	0.38%	significantly	5414	0.12%
17	including	12963	0.37%	neighborhoods	5060	0.11%
18	plans	12725	0.36%	residentially	4723	0.11%
19	proposing	12256	0.35%	southeasterly	3551	0.08%
20	locator	12088	0.35%	northwesterly	2017	0.05%
21	servicing	11710	0.34%	substantiated	1733	0.04%
22	operators'	11527	0.33%	contamination	1587	0.04%
23	aligns	11354	0.32%	contributions	1369	0.03%
24	northe	11201	0.32%	incorporation	1325	0.03%
25	exists	11189	0.32%	privatization	1210	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
26	develops	11130	0.32%	participation	1119	0.03%
27	transports	11091	0.32%	modifications	931	0.02%
28	city	10654	0.3%	international	849	0.02%
29	lights	10307	0.3%	comprehensive	712	0.02%
30	bus	9683	0.28%	southwesterly	707	0.02%
31	tables	9430	0.27%	constructive	19264	0.44%
32	providing	9387	0.27%	historically	10139	0.23%
33	siting	9373	0.27%	increasingly	8403	0.19%
34	roads	9323	0.27%	associations	5305	0.12%
35	avenues	9311	0.27%	continuously	4007	0.09%
36	sections	9212	0.26%	commercially	3826	0.09%
37	noises	8945	0.26%	capitalizing	3689	0.08%
38	traffic	8879	0.25%	coordinators	3043	0.07%
39	within	8670	0.25%	consequently	2144	0.05%
40	studying	8588	0.25%	recreational	2119	0.05%
41	west	8564	0.25%	metropolitan	2060	0.05%
42	lands	8543	0.24%	governments’	1364	0.03%
43	along	8522	0.24%	cumulatively	1298	0.03%
44	linings	8496	0.24%	particularly	1174	0.03%
45	requiring	8103	0.23%	distribution	1032	0.02%
46	centers	8002	0.23%	respectively	964	0.02%
47	improving	7995	0.23%	interchanges	922	0.02%
48	levels	7928	0.23%	destinations	906	0.02%
49	facility	7843	0.22%	institutions	858	0.02%
50	costs	7669	0.22%	architecture	827	0.02%
51	systems	7649	0.22%	sufficiently	668	0.02%
52	potentials	7634	0.22%	expenditures	636	0.01%
53	results	7580	0.22%	transitions	25441	0.58%
54	east	7493	0.21%	evaluations	6051	0.14%
55	drafts	7318	0.21%	identifying	5938	0.13%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
56	increasingly	7219	0.21%	determining	4670	0.11%
57	new	7087	0.2%	extensively	3959	0.09%
58	designs	6849	0.2%	pedestrians	3781	0.09%
59	historically	6812	0.19%	discussions	3476	0.08%
60	stating	6808	0.19%	maintenance	3179	0.07%
61	additive	6739	0.19%	assessments	3102	0.07%
62	mitigative	6736	0.19%	relocations	2922	0.07%
63	effects	6692	0.19%	interstates	2339	0.05%
64	statements	6659	0.19%	sensitivity	2204	0.05%
65	publicly	6620	0.19%	anticipated	2180	0.05%
66	county	6589	0.19%	acquisition	2150	0.05%
67	options	6459	0.18%	passengers’	2042	0.05%
68	resources’	6396	0.18%	financially	2014	0.05%
69	regions	6384	0.18%	benefitting	1934	0.04%
70	property	6269	0.18%	opportunity	1911	0.04%
71	lanes	6170	0.18%	floodplains	1873	0.04%
72	routing	6144	0.18%	accordingly	1846	0.04%
73	also	6101	0.17%	archaeology	1841	0.04%
74	figures	6078	0.17%	expressions	1766	0.04%
75	analysis	6027	0.17%	summarizing	1693	0.04%
76	accessing	5980	0.17%	preliminary	1653	0.04%
77	measuring	5945	0.17%	investments	1512	0.03%
78	crossings	5906	0.17%	technically	1486	0.03%
79	ways	5816	0.17%	descriptive	1450	0.03%
80	vehicles	5791	0.17%	landscaping	1376	0.03%
81	travels	5578	0.16%	elimination	1366	0.03%
82	chapters	5558	0.16%	individuals	1220	0.03%
83	community	5471	0.16%	expressways	1170	0.03%
84	ones	5434	0.16%	groundwater	1134	0.03%
85	intersects	5406	0.15%	electricity	1061	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
86	significantly	5405	0.15%	circulators	1023	0.02%
87	avings	5321	0.15%	immediately	1012	0.02%
88	locals	5318	0.15%	disruptions	1007	0.02%
89	sans	5284	0.15%	efficiently	876	0.02%
90	federation	5261	0.15%	memorandums	795	0.02%
91	years’	5243	0.15%	percentages	747	0.02%
92	mayes	5211	0.15%	occupations	747	0.02%
93	affects	5103	0.15%	encouraging	739	0.02%
94	quality	5031	0.14%	permanently	723	0.02%
95	two	5029	0.14%	threatening	713	0.02%
96	centrally	5013	0.14%	conventions	712	0.02%
97	waters	4988	0.14%	stormwaters	710	0.02%
98	timings	4911	0.14%	methodology	703	0.02%
99	rights	4804	0.14%	minneapolis	701	0.02%
100	activity	4794	0.14%	substations	673	0.02%
101	residentially	4782	0.14%	corresponds	667	0.02%
102	0	4711	0.13%	exclusively	650	0.01%
103	university	4583	0.13%	concretions	643	0.01%
104	majority	4540	0.13%	operators’	13581	0.31%
105	hours	4532	0.13%	transports	12485	0.28%
106	downtowns	4504	0.13%	mitigative	9358	0.21%
107	evaluative	4492	0.13%	potentials	8783	0.2%
108	identify	4486	0.13%	resources’	8459	0.19%
109	vibrators	4383	0.13%	statements	7891	0.18%
110	follows	4362	0.12%	federation	6790	0.15%
111	considers	4353	0.12%	intersects	6204	0.14%
112	district	4342	0.12%	relatively	4830	0.11%
113	highly	4336	0.12%	boulevards	4685	0.11%
114	sources	4293	0.12%	structures	4496	0.1%
115	generally	4188	0.12%	conditions	4135	0.09%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
116	bases	4153	0.12%	implements	4111	0.09%
117	tsm	4135	0.12%	university	4058	0.09%
118	associations	4094	0.12%	processing	3497	0.08%
119	currents	4069	0.12%	minimizing	3435	0.08%
120	directs	4060	0.12%	describing	3245	0.07%
121	highways	4035	0.12%	urbanizing	3092	0.07%
122	grading	4031	0.12%	completion	2872	0.07%
123	approximation	4008	0.11%	addressing	2710	0.06%
124	miles	4003	0.11%	sacramento	2709	0.06%
125	tracks	3992	0.11%	washington	2497	0.06%
126	peaks	3911	0.11%	preserving	2424	0.06%
127	rivers	3905	0.11%	permitting	2343	0.05%
128	roadways	3900	0.11%	congestion	2281	0.05%
129	creeks	3897	0.11%	consulting	2270	0.05%
130	totals	3896	0.11%	displacing	2248	0.05%
131	sidings	3866	0.11%	represents	2117	0.05%
132	trips	3842	0.11%	recommends	2045	0.05%
133	occurs	3806	0.11%	separators	1820	0.04%
134	needs	3801	0.11%	california	1806	0.04%
135	structures	3793	0.11%	vegetative	1775	0.04%
136	commercially	3763	0.11%	agreements	1555	0.04%
137	percent	3739	0.11%	throughout	1555	0.04%
138	neighborhoods	3737	0.11%	concentric	1512	0.03%
139	valleys	3731	0.11%	redevelops	1509	0.03%
140	airs	3723	0.11%	applicator	1399	0.03%
141	driving	3700	0.11%	executives	1390	0.03%
142	feet	3697	0.11%	previously	1324	0.03%
143	relatively	3664	0.1%	committees	1313	0.03%
144	visually	3612	0.1%	automobile	1245	0.03%
145	lists	3551	0.1%	commission	1237	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
146	numbers	3543	0.1%	guidelines	1200	0.03%
147	agency	3531	0.1%	exceptions	1195	0.03%
148	dallas’	3501	0.1%	committing	1086	0.02%
149	populous	3493	0.1%	experience	1077	0.02%
150	boulevards	3471	0.1%	scheduling	1050	0.02%
151	riding	3457	0.1%	organizing	1031	0.02%
152	eis	3439	0.1%	households	1028	0.02%
153	dart	3429	0.1%	endangered	994	0.02%
154	engines	3391	0.1%	conformity	974	0.02%
155	residing	3388	0.1%	amendments	961	0.02%
156	reports	3361	0.1%	waterfront	956	0.02%
157	segments	3334	0.1%	conserving	937	0.02%
158	lakes	3287	0.09%	aesthetics	935	0.02%
159	conditions	3268	0.09%	carrollton	933	0.02%
160	changing	3263	0.09%	practicing	886	0.02%
161	presents	3263	0.09%	decreasing	878	0.02%
162	expects	3234	0.09%	comparison	866	0.02%
163	departs	3228	0.09%	willamette	857	0.02%
164	busy	3225	0.09%	excavators	855	0.02%
165	lows	3225	0.09%	procedures	824	0.02%
166	funds	3216	0.09%	connectors	824	0.02%
167	bridging	3205	0.09%	components	822	0.02%
168	determining	3193	0.09%	northbound	809	0.02%
169	meets	3165	0.09%	complexity	802	0.02%
170	offices	3150	0.09%	southbound	755	0.02%
171	estimators	3115	0.09%	submitting	748	0.02%
172	however	3107	0.09%	treatments	711	0.02%
173	adjacent	3075	0.09%	apartments	696	0.02%
174	extensively	3066	0.09%	provisions	693	0.02%
175	employs	3065	0.09%	compliance	687	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
176	implements	3059	0.09%	compatible	669	0.02%
177	railroads’	3033	0.09%	calculator	629	0.01%
178	informs	2985	0.09%	projects’	37549	0.85%
179	adversely	2983	0.09%	corridors	31494	0.71%
180	capitalizing	2971	0.09%	including	17336	0.39%
181	continuously	2942	0.08%	servicing	14476	0.33%
182	nearly	2938	0.08%	proposing	13405	0.3%
183	serving	2928	0.08%	providing	12986	0.29%
184	southeasterly	2907	0.08%	requiring	10361	0.24%
185	industry	2874	0.08%	improving	8746	0.2%
186	wetlands	2860	0.08%	additives	8548	0.19%
187	programs	2851	0.08%	accessing	8293	0.19%
188	draperer	2841	0.08%	comments’	8077	0.18%
189	lots	2823	0.08%	crossings	7525	0.17%
190	deis	2818	0.08%	downtowns	6807	0.15%
191	period	2808	0.08%	measuring	6802	0.15%
192	environs	2805	0.08%	community	6650	0.15%
193	units	2799	0.08%	centrally	5953	0.14%
194	assessments	2781	0.08%	districts	5497	0.12%
195	futures	2773	0.08%	considers	5181	0.12%
196	severity	2757	0.08%	generally	5012	0.11%
197	reducing	2755	0.08%	adversely	3676	0.08%
198	three	2753	0.08%	railroads	3591	0.08%
199	describing	2745	0.08%	estimator	3286	0.07%
200	spacing	2728	0.08%	managment	3277	0.07%
201	parts	2704	0.08%	available	3139	0.07%
202	airports	2699	0.08%	documents	3110	0.07%
203	100	2674	0.08%	materials	3048	0.07%
204	mains	2672	0.08%	standards	3010	0.07%
205	nations	2661	0.08%	specifics	2848	0.06%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
206	pedestrian	2649	0.08%	utilizing	2809	0.06%
207	urbanizing	2612	0.07%	preparing	2731	0.06%
208	connects	2577	0.07%	criterias	2657	0.06%
209	fta	2572	0.07%	surfacing	2412	0.05%
210	pers	2570	0.07%	involving	2411	0.05%
211	actions	2566	0.07%	averaging	2397	0.05%
212	managing	2564	0.07%	comparing	2349	0.05%
213	metro	2558	0.07%	economics	2334	0.05%
214	maintenance	2556	0.07%	therefore	2217	0.05%
215	processing	2538	0.07%	approving	2087	0.05%
216	limits	2521	0.07%	ridership	2079	0.05%
217	due	2472	0.07%	milwaukie	2045	0.05%
218	standards	2467	0.07%	elevators	2033	0.05%
219	santa	2460	0.07%	receiving	2022	0.05%
220	ofthe	2442	0.07%	regulator	1912	0.04%
221	supports	2436	0.07%	guideways	1854	0.04%
222	housing	2433	0.07%	emissions	1764	0.04%
223	trains	2414	0.07%	commuting	1749	0.04%
224	placing	2412	0.07%	generated	1742	0.04%
225	minimizing	2403	0.07%	hillsboro	1686	0.04%
226	materials	2393	0.07%	bicycling	1676	0.04%
227	discussion	2390	0.07%	registers	1634	0.04%
228	growth	2380	0.07%	pollution	1605	0.04%
229	volumes	2378	0.07%	transfers	1596	0.04%
230	tunnels	2359	0.07%	temporary	1587	0.04%
231	millions	2358	0.07%	mobilized	1578	0.04%
232	consists	2356	0.07%	speciales	1562	0.04%
233	blvd	2331	0.07%	necessary	1516	0.03%
234	views	2329	0.07%	forecasts	1490	0.03%
235	terms	2320	0.07%	enhancing	1483	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
236	capitols	2307	0.07%	similarly	1464	0.03%
237	soils	2298	0.07%	replacing	1431	0.03%
238	criteria	2297	0.07%	allegheny	1429	0.03%
239	available	2295	0.07%	featuring	1400	0.03%
240	portions	2289	0.07%	primarily	1399	0.03%
241	utilizing	2285	0.07%	surrounds	1337	0.03%
242	species'	2282	0.07%	distances	1300	0.03%
243	wells	2276	0.07%	directors	1286	0.03%
244	thirds	2269	0.06%	decisions	1244	0.03%
245	specifics	2222	0.06%	moderator	1237	0.03%
246	prefers	2215	0.06%	reduction	1189	0.03%
247	annuals	2196	0.06%	revisions	1181	0.03%
248	finally	2193	0.06%	retailing	1157	0.03%
249	purposes	2192	0.06%	movements	1142	0.03%
250	reviews	2188	0.06%	expansive	1133	0.03%
251	relocations	2176	0.06%	combining	1120	0.03%
252	2000	2145	0.06%	integrity	1101	0.02%
253	works	2144	0.06%	parklands	1083	0.02%
254	freeways	2129	0.06%	sidewalks	1077	0.02%
255	acts	2114	0.06%	interests	1075	0.02%
256	opens	2103	0.06%	baltimore	1005	0.02%
257	congestion	2098	0.06%	divisions	1003	0.02%
258	summary	2093	0.06%	installed	994	0.02%
259	shown	2091	0.06%	screening	983	0.02%
260	texas'	2087	0.06%	receptors	981	0.02%
261	cbd	2080	0.06%	americans	945	0.02%
262	hovs	2075	0.06%	francisco	935	0.02%
263	diego	2071	0.06%	september	901	0.02%
264	minority	2068	0.06%	drainages	900	0.02%
265	averaging	2058	0.06%	guadalupe	879	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
266	preparing	2051	0.06%	parallels	871	0.02%
267	controls	2048	0.06%	mountains	871	0.02%
268	comparing	2038	0.06%	charlotte	866	0.02%
269	salts	2031	0.06%	orienting	857	0.02%
270	2001	2024	0.06%	character	835	0.02%
271	capacity	2023	0.06%	acquiring	817	0.02%
272	los	2016	0.06%	proximity	816	0.02%
273	acrs	2014	0.06%	elizabeth	812	0.02%
274	boards	2014	0.06%	frequency	805	0.02%
275	economics	2012	0.06%	restricts	802	0.02%
276	protects	2009	0.06%	retaining	795	0.02%
277	documents	2005	0.06%	baselines	784	0.02%
278	details	1990	0.06%	sediments	751	0.02%
279	hazards	1974	0.06%	modifying	731	0.02%
280	commuting	1972	0.06%	producing	727	0.02%
281	sensitivity	1971	0.06%	questions	718	0.02%
282	indices	1969	0.06%	exposures	715	0.02%
283	ranging	1965	0.06%	supplying	711	0.02%
284	selects	1959	0.06%	employees	702	0.02%
285	revenue	1956	0.06%	occupying	665	0.02%
286	missions	1954	0.06%	financing	661	0.01%
287	administrators	1945	0.06%	sincerely	659	0.01%
288	demands	1931	0.06%	vehicular	659	0.01%
289	days	1928	0.06%	municipal	641	0.01%
290	express	1926	0.06%	officials	626	0.01%
291	acquisition	1924	0.06%	achieving	623	0.01%
292	passengers’	1920	0.05%	advancing	622	0.01%
293	phasing	1900	0.05%	stations	26191	0.59%
294	northwesterly	1892	0.05%	sections	14217	0.32%
295	habitats	1886	0.05%	develops	13533	0.31%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
296	therefore	1885	0.05%	systems’	10016	0.23%
297	completed	1878	0.05%	publicly	9804	0.22%
298	authorizing	1874	0.05%	facility	9670	0.22%
299	recreational	1870	0.05%	studying	8867	0.2%
300	surfacing	1868	0.05%	property	8681	0.2%
301	policy	1866	0.05%	chapters	7313	0.17%
302	displacing	1864	0.05%	vehicles	7014	0.16%
303	involving	1855	0.05%	analysis	6556	0.15%
304	ridership	1846	0.05%	routings	6467	0.15%
305	zoning	1837	0.05%	activity	5982	0.14%
306	represents	1835	0.05%	currents	5371	0.12%
307	ends	1835	0.05%	bridging	5229	0.12%
308	eligible	1833	0.05%	portland	5204	0.12%
309	schools	1831	0.05%	majority	5159	0.12%
310	signals	1826	0.05%	vibrator	5130	0.12%
311	four	1821	0.05%	segments	4675	0.11%
312	singly	1820	0.05%	changing	4629	0.11%
313	nature	1818	0.05%	residing	4279	0.1%
314	largely	1817	0.05%	roadways	4132	0.09%
315	coordinators	1812	0.05%	presents	4106	0.09%
316	consequently	1802	0.05%	highways	4081	0.09%
317	expressways	1800	0.05%	populous	3937	0.09%
318	less	1786	0.05%	supports	3793	0.09%
319	remains	1784	0.05%	wetlands	3739	0.08%
320	buses	1783	0.05%	adjacent	3737	0.08%
321	longs	1779	0.05%	programs	3591	0.08%
322	turns	1773	0.05%	reducing	3381	0.08%
323	possibly	1758	0.05%	industry	3380	0.08%
324	anticipated	1753	0.05%	connects	3310	0.08%
325	washington	1749	0.05%	severity	3310	0.08%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
326	1990	1747	0.05%	environs	3278	0.07%
327	brt	1730	0.05%	species’	3257	0.07%
328	fields	1723	0.05%	consists	2946	0.07%
329	comments	1718	0.05%	summarys	2837	0.06%
330	addressing	1717	0.05%	portions	2813	0.06%
331	group	1711	0.05%	protects	2785	0.06%
332	daily	1702	0.05%	millions	2773	0.06%
333	safety	1701	0.05%	appendix	2759	0.06%
334	clara	1699	0.05%	airports	2741	0.06%
335	ratings	1697	0.05%	controls	2653	0.06%
336	incoming	1691	0.05%	purposes	2617	0.06%
337	family	1688	0.05%	habitats	2568	0.06%
338	guideways	1684	0.05%	minority	2522	0.06%
339	platforms	1677	0.05%	revenues	2476	0.06%
340	contains	1674	0.05%	concerns	2470	0.06%
341	jordan	1672	0.05%	councils	2468	0.06%
342	energy	1672	0.05%	capacity	2412	0.05%
343	200’ve	1671	0.05%	eligible	2398	0.05%
344	types	1666	0.05%	schools’	2290	0.05%
345	separators	1653	0.05%	conducts	2208	0.05%
346	permitting	1653	0.05%	possibly	2177	0.05%
347	points	1647	0.05%	removing	2165	0.05%
348	elements	1641	0.05%	elements	2111	0.05%
349	issuing	1640	0.05%	contains	2057	0.05%
350	inity	1636	0.05%	platform	2036	0.05%
351	sees	1635	0.05%	settings	1990	0.05%
352	emissions	1634	0.05%	incoming	1964	0.04%
353	mid	1627	0.05%	missions	1952	0.04%
354	conducts	1623	0.05%	defining	1932	0.04%
355	jose	1618	0.05%	freeways	1930	0.04%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
356	california	1614	0.05%	wildlife	1896	0.04%
357	floodplains	1606	0.05%	branches	1834	0.04%
358	extends	1601	0.05%	maintain	1772	0.04%
359	concerns	1600	0.05%	assuming	1716	0.04%
360	grounds	1596	0.05%	vicinity	1684	0.04%
361	april	1583	0.05%	typicals	1616	0.04%
362	generated	1580	0.05%	creating	1591	0.04%
363	2005	1566	0.04%	founding	1581	0.04%
364	opportunities	1564	0.04%	southern	1564	0.04%
365	branching	1557	0.04%	capitols	1540	0.03%
366	charlotte	1556	0.04%	cultures	1526	0.03%
367	enhanced	1552	0.04%	equipped	1522	0.03%
368	data	1551	0.04%	although	1517	0.03%
369	pollution	1549	0.04%	category	1469	0.03%
370	denver	1549	0.04%	termined	1444	0.03%
371	utah	1543	0.04%	subjects	1440	0.03%
372	metropolitan	1541	0.04%	closings	1413	0.03%
373	persons	1532	0.04%	november	1404	0.03%
374	baselineive	1532	0.04%	patterns	1363	0.03%
375	elevators	1531	0.04%	’primary	1356	0.03%
376	settings	1530	0.04%	feasibly	1328	0.03%
377	wildlife	1525	0.04%	december	1312	0.03%
378	responsiveness	1523	0.04%	monitors	1284	0.03%
379	old	1520	0.04%	ensuring	1284	0.03%
380	typically	1516	0.04%	security	1223	0.03%
381	financially	1515	0.04%	boundary	1189	0.03%
382	made	1514	0.04%	performs	1188	0.03%
383	goals	1512	0.04%	requests	1185	0.03%
384	hillsboro	1501	0.04%	footings	1177	0.03%
385	shows	1497	0.04%	approach	1161	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
386	400	1494	0.04%	emerging	1147	0.03%
387	likes	1491	0.04%	contacts	1141	0.03%
388	models	1487	0.04%	pleasing	1086	0.02%
389	links	1474	0.04%	recently	1076	0.02%
390	500’	1473	0.04%	hearings	1065	0.02%
391	assuming	1473	0.04%	carrying	1041	0.02%
392	concentric	1468	0.04%	colleges	1040	0.02%
393	defining	1465	0.04%	focusing	1031	0.02%
394	similarly	1464	0.04%	applying	1011	0.02%
395	preliminary	1460	0.04%	barriers	992	0.02%
396	benefits	1459	0.04%	parkways	990	0.02%
397	appendix	1459	0.04%	gateways	982	0.02%
398	irving	1458	0.04%	disturbs	979	0.02%
399	preserving	1453	0.04%	campuses	976	0.02%
400	since	1448	0.04%	northern	911	0.02%
401	recommends	1448	0.04%	channels	898	0.02%
402	regulations	1444	0.04%	february	897	0.02%
403	minutes	1436	0.04%	broadway	882	0.02%
404	established	1434	0.04%	indirect	875	0.02%
405	surveys	1430	0.04%	function	874	0.02%
406	newark	1430	0.04%	colorado	856	0.02%
407	median	1427	0.04%	attracts	854	0.02%
408	plazas	1420	0.04%	socially	853	0.02%
409	none	1419	0.04%	updating	849	0.02%
410	2006	1416	0.04%	advisory	837	0.02%
411	bays	1412	0.04%	accounts	834	0.02%
412	small	1395	0.04%	predicts	829	0.02%
413	allows	1395	0.04%	strategy	828	0.02%
414	firstly	1393	0.04%	weekdays	826	0.02%
415	redevelops	1385	0.04%	problems	822	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
416	substantial	1385	0.04%	terminus	806	0.02%
417	mobilize	1385	0.04%	hospital	805	0.02%
418	specially	1378	0.04%	farmers'	805	0.02%
419	northeast	1376	0.04%	analyzed	793	0.02%
420	causing	1374	0.04%	slightly	782	0.02%
421	considerations	1370	0.04%	adequate	770	0.02%
422	removing	1369	0.04%	cleaning	763	0.02%
423	accordingly	1360	0.04%	refining	749	0.02%
424	maintain	1357	0.04%	trolleys	742	0.02%
425	vegetative	1355	0.04%	research	715	0.02%
426	hills	1351	0.04%	collects	681	0.02%
427	non	1341	0.04%	closures	675	0.02%
428	plants	1332	0.04%	products	671	0.02%
429	overall	1331	0.04%	stadiums	665	0.02%
430	utas	1330	0.04%	policing	650	0.01%
431	differs	1328	0.04%	examined	634	0.01%
432	either	1327	0.04%	database	632	0.01%
433	equipped	1325	0.04%	patrons'	631	0.01%
434	although	1322	0.04%	headways	629	0.01%
435	five	1320	0.04%	forester	628	0.01%
436	order	1320	0.04%	villages	627	0.01%
437	transfers	1319	0.04%	proceeds	627	0.01%
438	uprr	1311	0.04%	presence	624	0.01%
439	interchanges	1306	0.04%	prevents	609	0.01%
440	creating	1304	0.04%	impacts	36307	0.82%
441	flows	1298	0.04%	streets	25306	0.57%
442	2002	1298	0.04%	locator	14908	0.34%
443	taxing	1297	0.04%	avenues	12136	0.28%
444	freight	1297	0.04%	finally	11762	0.27%
445	landscaping	1294	0.04%	traffic	11043	0.25%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
446	founding	1291	0.04%	designs	9966	0.23%
447	maps	1291	0.04%	linings	9487	0.22%
448	objects	1289	0.04%	centers	9308	0.21%
449	registers	1288	0.04%	easting	9179	0.21%
450	southern	1285	0.04%	effects	8898	0.2%
451	full	1280	0.04%	results	8771	0.2%
452	category	1280	0.04%	stating	8677	0.2%
453	june	1279	0.04%	regions	8592	0.19%
454	depends	1272	0.04%	travels	6378	0.14%
455	accommodate	1266	0.04%	affects	6313	0.14%
456	making	1265	0.04%	timings	6153	0.14%
457	forecasts	1263	0.04%	figures	6126	0.14%
458	pacific	1263	0.04%	quality	5893	0.13%
459	runs	1255	0.04%	prefers	5862	0.13%
460	homes	1254	0.04%	follows	5617	0.13%
461	approving	1254	0.04%	percent	5567	0.13%
462	riders’	1254	0.04%	options	5139	0.12%
463	avoids	1253	0.04%	sidings	4988	0.11%
464	values	1246	0.04%	driving	4748	0.11%
465	higher	1246	0.04%	sources	4608	0.1%
466	termined	1239	0.04%	directs	4543	0.1%
467	investments	1239	0.04%	departs	4332	0.1%
468	trails	1236	0.04%	grading	4277	0.1%
469	300’vc	1229	0.04%	numbers	4243	0.1%
470	amount	1222	0.03%	informs	4162	0.09%
471	many	1220	0.03%	offices	4105	0.09%
472	fixed	1219	0.03%	reports	4053	0.09%
473	closings	1218	0.03%	dallas’	4018	0.09%
474	houston	1217	0.03%	valleys	4009	0.09%
475	characteristics	1211	0.03%	visuals	3996	0.09%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
476	councils	1200	0.03%	engines	3944	0.09%
477	scoping	1199	0.03%	futures	3885	0.09%
478	speeds	1195	0.03%	reviews	3852	0.09%
479	squares	1187	0.03%	expects	3641	0.08%
480	broadly	1182	0.03%	placing	3555	0.08%
481	exceeds	1182	0.03%	nations	3526	0.08%
482	throughout	1181	0.03%	however	3506	0.08%
483	1999	1175	0.03%	spacing	3487	0.08%
484	origins	1172	0.03%	employs	3360	0.08%
485	temporary	1167	0.03%	serving	3258	0.07%
486	appropriations	1163	0.03%	phasing	3224	0.07%
487	passing	1162	0.03%	volumes	3091	0.07%
488	automobile	1162	0.03%	growthe	2908	0.07%
489	necessary	1161	0.03%	housing	2871	0.07%
490	markets	1159	0.03%	authors	2865	0.07%
491	blocks	1157	0.03%	selects	2726	0.06%
492	shortly	1157	0.03%	details	2600	0.06%
493	distance	1155	0.03%	issuing	2547	0.06%
494	archaeology	1153	0.03%	signals	2465	0.06%
495	factors	1152	0.03%	indices	2465	0.06%
496	owns	1151	0.03%	natures	2258	0.05%
497	just	1151	0.03%	tunnels	2247	0.05%
498	must	1150	0.03%	hazards	2219	0.05%
499	refers	1149	0.03%	ranging	2151	0.05%
500	sounds	1148	0.03%	demands	2122	0.05%
501	towns	1141	0.03%	annuals	2099	0.05%
502	cultures	1139	0.03%	ratings	2051	0.05%
503	steel	1134	0.03%	norfolk	2042	0.05%
504	legend	1134	0.03%	extends	1982	0.04%
505	seconds	1123	0.03%	remains	1894	0.04%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
506	vicinity	1123	0.03%	surveys	1866	0.04%
507	southwesterly	1122	0.03%	largely	1847	0.04%
508	lowers	1121	0.03%	regards	1798	0.04%
509	descriptive	1117	0.03%	grounds	1764	0.04%
510	mixing	1116	0.03%	causing	1706	0.04%
511	sacramento	1114	0.03%	overall	1670	0.04%
512	regarding	1114	0.03%	persons	1656	0.04%
513	beste	1112	0.03%	valuing	1621	0.04%
514	malls	1110	0.03%	objects	1611	0.04%
515	imports	1110	0.03%	shoring	1608	0.04%
516	receptors	1110	0.03%	shortly	1577	0.04%
517	2004	1107	0.03%	minutes	1553	0.04%
518	movements	1107	0.03%	seconds	1525	0.03%
519	primarily	1104	0.03%	freight	1497	0.03%
520	consulting	1104	0.03%	amounts	1468	0.03%
521	except	1103	0.03%	houston	1465	0.03%
522	moderation	1102	0.03%	october	1432	0.03%
523	surroundings	1100	0.03%	greater	1428	0.03%
524	inc	1099	0.03%	assists	1416	0.03%
525	bicycle	1098	0.03%	plants’	1409	0.03%
526	replacing	1097	0.03%	takings	1407	0.03%
527	’primary	1094	0.03%	imports	1392	0.03%
528	ramps	1094	0.03%	peoples	1378	0.03%
529	technically	1089	0.03%	letters	1364	0.03%
530	artery	1088	0.03%	network	1363	0.03%
531	retailing	1088	0.03%	january	1344	0.03%
532	executives	1087	0.03%	origins	1319	0.03%
533	dfw	1081	0.03%	factors	1314	0.03%
534	powers	1076	0.03%	efforts	1307	0.03%
535	july	1073	0.03%	markets	1305	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
536	elizabeth	1073	0.03%	scoping	1300	0.03%
537	modes	1071	0.03%	squares	1292	0.03%
538	notes	1066	0.03%	differs	1284	0.03%
539	patterns	1065	0.03%	storage	1283	0.03%
540	governs	1065	0.03%	depends	1275	0.03%
541	colleges	1064	0.03%	fishing	1265	0.03%
542	households	1064	0.03%	exceeds	1260	0.03%
543	pages	1063	0.03%	passing	1235	0.03%
544	mos	1060	0.03%	parcels	1233	0.03%
545	dba	1057	0.03%	springs	1232	0.03%
546	receiving	1057	0.03%	arounds	1201	0.03%
547	summarizing	1055	0.03%	pacific	1193	0.03%
548	people	1054	0.03%	various	1186	0.03%
549	dating	1052	0.03%	without	1183	0.03%
550	featuring	1050	0.03%	density	1162	0.03%
551	phoenix	1049	0.03%	records	1129	0.03%
552	greater	1047	0.03%	reasons	1115	0.03%
553	takings	1044	0.03%	western	1077	0.02%
554	cumulatively	1041	0.03%	maximum	1068	0.02%
555	contributions	1040	0.03%	staging	1037	0.02%
556	parkways	1031	0.03%	casings	1035	0.02%
557	feasibly	1030	0.03%	company	1026	0.02%
558	previously	1030	0.03%	sharing	1026	0.02%
559	campus	1026	0.03%	streams	1025	0.02%
560	busways	1026	0.03%	lengths	1024	0.02%
561	600	1025	0.03%	reflect	1017	0.02%
562	alters	1024	0.03%	medical	1015	0.02%
563	contamination	1021	0.03%	methods	1002	0.02%
564	unionized	1021	0.03%	physics	979	0.02%
565	lefts	1014	0.03%	expands	977	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
566	various	1012	0.03%	phoenix	975	0.02%
567	floods	1012	0.03%	owners’	972	0.02%
568	streams	1010	0.03%	rapidly	952	0.02%
569	vacant	1010	0.03%	commons	947	0.02%
570	oaks	1009	0.03%	subways	942	0.02%
571	around	1003	0.03%	scaling	896	0.02%
572	density	1002	0.03%	geology	875	0.02%
573	network	983	0.03%	notices	855	0.02%
574	boundary	980	0.03%	outside	855	0.02%
575	groundwaters	980	0.03%	library	855	0.02%
576	monitors	976	0.03%	accepts	843	0.02%
577	fills	975	0.03%	ambient	838	0.02%
578	delays	974	0.03%	dollars	787	0.02%
579	individuals	973	0.03%	aerials	786	0.02%
580	jobs	969	0.03%	justice	777	0.02%
581	six	968	0.03%	hunting	774	0.02%
582	stops	967	0.03%	appears	774	0.02%
583	reduction	966	0.03%	extents	750	0.02%
584	2025	963	0.03%	already	750	0.02%
585	widely	962	0.03%	growing	747	0.02%
586	efforts	962	0.03%	example	741	0.02%
587	meters	958	0.03%	varying	737	0.02%
588	parcels	957	0.03%	cutting	714	0.02%
589	2015	955	0.03%	savings	705	0.02%
590	eliminated	953	0.03%	highest	697	0.02%
591	decisions	952	0.03%	obtains	688	0.02%
592	800’	950	0.03%	masters	688	0.02%
593	colorado	950	0.03%	eastern	686	0.02%
594	lengths	947	0.03%	erosion	676	0.02%
595	aerials	946	0.03%	corners	676	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
596	cars	946	0.03%	whether	676	0.02%
597	forms	946	0.03%	partial	675	0.02%
598	subways	945	0.03%	whiting	665	0.02%
599	integrity	944	0.03%	another	663	0.02%
600	walls	944	0.03%	pilings	651	0.01%
601	screening	943	0.03%	clearly	650	0.01%
602	incorporated	943	0.03%	heights	646	0.01%
603	november	942	0.03%	trinity	643	0.01%
604	shoring	941	0.03%	members	639	0.01%
605	disturbs	939	0.03%	natives	635	0.01%
606	covers	935	0.03%	roberts	634	0.01%
607	gateway	934	0.03%	temples	617	0.01%
608	performs	933	0.03%	biology	616	0.01%
609	emerging	930	0.03%	dominic	613	0.01%
610	multi	925	0.03%	areas’	30642	0.7%
611	expansivity	913	0.03%	builds	16614	0.38%
612	yes	913	0.03%	northe	14281	0.32%
613	particularly	911	0.03%	exists	13551	0.31%
614	broadways	908	0.03%	lights	13147	0.3%
615	begins	907	0.03%	aligns	12194	0.28%
616	1995	906	0.03%	siting	11464	0.26%
617	sandy	906	0.03%	noises	11107	0.25%
618	commissions’	903	0.03%	within	10476	0.24%
619	january	903	0.03%	tables	10410	0.24%
620	census	901	0.03%	levels	9446	0.21%
621	parklands	901	0.03%	costs’	8536	0.19%
622	trees	900	0.03%	county	8355	0.19%
623	churches	897	0.03%	locals	7798	0.18%
624	casings	895	0.03%	waters	6987	0.16%
625	across	894	0.03%	years’	6320	0.14%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
626	predicts	892	0.03%	rights	6009	0.14%
627	paul	891	0.03%	avings	5966	0.14%
628	applications	891	0.03%	tracks	5931	0.13%
629	storage	891	0.03%	rivers	5407	0.12%
630	subjects	889	0.03%	agency	4988	0.11%
631	applying	889	0.03%	occurs	4641	0.11%
632	springs	888	0.03%	riding	4624	0.1%
633	kings	888	0.03%	totals	4520	0.1%
634	combined	887	0.03%	trips’	4187	0.1%
635	electricity	886	0.03%	creeks	3886	0.09%
636	francisco	884	0.03%	period	3773	0.09%
637	1993	880	0.03%	action	3355	0.08%
638	privatization	879	0.03%	trains	3339	0.08%
639	700	879	0.03%	limits	2966	0.07%
640	assists	879	0.03%	draper	2947	0.07%
641	built	878	0.03%	drafts	2542	0.06%
642	carrollton	877	0.03%	boards	2533	0.06%
643	groves	874	0.03%	safety	2447	0.06%
644	divisions	873	0.02%	policy	2368	0.05%
645	guidelines	871	0.02%	zoning	2358	0.05%
646	blues	871	0.02%	thirds	2313	0.05%
647	partially	869	0.02%	fields	2057	0.05%
648	schedule	868	0.02%	points	2056	0.05%
649	december	868	0.02%	avoids	2055	0.05%
650	harry	866	0.02%	likely	2040	0.05%
651	finds	862	0.02%	singly	2031	0.05%
652	events	860	0.02%	allows	1935	0.04%
653	maximum	860	0.02%	groups	1864	0.04%
654	widens	857	0.02%	jordan	1847	0.04%
655	2003	855	0.02%	sounds	1836	0.04%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
656	canals	854	0.02%	dating	1826	0.04%
657	mesas	852	0.02%	trails	1824	0.04%
658	keyes	850	0.02%	family	1824	0.04%
659	ads	849	0.02%	busing	1814	0.04%
660	1997	848	0.02%	energy	1756	0.04%
661	interstation	847	0.02%	models	1702	0.04%
662	attract	844	0.02%	refers	1658	0.04%
663	autos	844	0.02%	orders	1632	0.04%
664	physics	842	0.02%	making	1617	0.04%
665	committees	839	0.02%	noting	1613	0.04%
666	comparison	838	0.02%	tasman	1612	0.04%
667	adopts	837	0.02%	folsom	1597	0.04%
668	experience	837	0.02%	august	1505	0.03%
669	parallel	836	0.02%	taxing	1493	0.03%
670	contacts	836	0.02%	blocks	1468	0.03%
671	staging	835	0.02%	newark	1461	0.03%
672	without	835	0.02%	unions	1459	0.03%
673	sales	834	0.02%	either	1450	0.03%
674	approach	833	0.02%	higher	1398	0.03%
675	louis	831	0.02%	denver	1392	0.03%
676	reasons	828	0.02%	lowers	1383	0.03%
677	sub	826	0.02%	floods	1370	0.03%
678	footings	822	0.02%	adopts	1364	0.03%
679	barriers	821	0.02%	irving	1350	0.03%
680	given	821	0.02%	median	1339	0.03%
681	security	820	0.02%	speeds	1327	0.03%
682	evenly	817	0.02%	covers	1324	0.03%
683	organizing	816	0.02%	riders	1322	0.03%
684	carrying	816	0.02%	modes’	1315	0.03%
685	2010	815	0.02%	powers	1298	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
686	wastes	815	0.02%	mixing	1281	0.03%
687	western	813	0.02%	oregon	1277	0.03%
688	mtdb	812	0.02%	delays	1220	0.03%
689	expands	810	0.02%	church	1199	0.03%
690	terminus	810	0.02%	legend	1198	0.03%
691	directors	809	0.02%	widely	1186	0.03%
692	records	808	0.02%	across	1148	0.03%
693	minneapolis	806	0.02%	artery	1135	0.03%
694	commons	805	0.02%	alters	1123	0.03%
695	august	804	0.02%	losses	1116	0.03%
696	fairs	803	0.02%	begins	1091	0.02%
697	destination	800	0.02%	hudson	1089	0.02%
698	distributions	800	0.02%	census	1079	0.02%
699	immediately	798	0.02%	coasts	1071	0.02%
700	rapids	796	0.02%	meters	1070	0.02%
701	lynx	795	0.02%	starts	1066	0.02%
702	components	790	0.02%	events	1050	0.02%
703	epa	789	0.02%	jersey	1048	0.02%
704	health	788	0.02%	staffs	1013	0.02%
705	loss	780	0.02%	trucks	1009	0.02%
706	respects	777	0.02%	canals	1008	0.02%
707	fares	777	0.02%	health	1000	0.02%
708	101	773	0.02%	givens	986	0.02%
709	walks	771	0.02%	vacant	947	0.02%
710	prior	770	0.02%	evenly	944	0.02%
711	jurisdictions	769	0.02%	widens	924	0.02%
712	via	767	0.02%	entire	873	0.02%
713	disruptions	766	0.02%	firing	863	0.02%
714	trucks	764	0.02%	trimet	851	0.02%
715	interest	763	0.02%	plazas	848	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
716	coasting	762	0.02%	trying	842	0.02%
717	recent	762	0.02%	hblrts	828	0.02%
718	outside	761	0.02%	broads	828	0.02%
719	leads	760	0.02%	enters	826	0.02%
720	known	760	0.02%	moving	816	0.02%
721	medical	758	0.02%	wastes	814	0.02%
722	ambient	757	0.02%	fronts	810	0.02%
723	rtd	757	0.02%	grants	803	0.02%
724	users’	756	0.02%	steele	803	0.02%
725	northern	756	0.02%	scotts	800	0.02%
726	company	753	0.02%	eights	796	0.02%
727	grants	753	0.02%	storms	792	0.02%
728	scales	752	0.02%	fulton	762	0.02%
729	problems	746	0.02%	corps’	762	0.02%
730	mountains	745	0.02%	humans	755	0.02%
731	geology	739	0.02%	sizing	750	0.02%
732	ensure	739	0.02%	runoff	732	0.02%
733	johns	736	0.02%	status	731	0.02%
734	international	736	0.02%	inputs	721	0.02%
735	2020	735	0.02%	nearby	716	0.02%
736	october	735	0.02%	inches	716	0.02%
737	much	734	0.02%	tracts	706	0.02%
738	complexity	730	0.02%	former	691	0.02%
739	focusing	728	0.02%	become	667	0.02%
740	tracts	727	0.02%	naming	660	0.01%
741	drainage	726	0.02%	better	635	0.01%
742	character	725	0.02%	biking	628	0.01%
743	varying	724	0.02%	greens	627	0.01%
744	frequency	723	0.02%	joints	621	0.01%
745	1996	721	0.02%	bergen	613	0.01%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
746	farmers	721	0.02%	parks	22811	0.52%
747	slightly	721	0.02%	using	22018	0.5%
748	guadalupe	721	0.02%	rails	17469	0.4%
749	starts	718	0.02%	plans	16779	0.38%
750	106	718	0.02%	south	15844	0.36%
751	rocks	717	0.02%	roads	10335	0.23%
752	bwi	716	0.02%	along	10078	0.23%
753	retaining	716	0.02%	lands	9500	0.22%
754	excavators	715	0.02%	lanes	6670	0.15%
755	northbound	714	0.02%	oning	6602	0.15%
756	goods	714	0.02%	hours	5469	0.12%
757	circulators	712	0.02%	bases	5096	0.12%
758	sidewalks	709	0.02%	ofthe	4864	0.11%
759	jersey	709	0.02%	needs	4835	0.11%
760	americans	709	0.02%	miles	4795	0.11%
761	enters	708	0.02%	funds	4669	0.11%
762	loops	707	0.02%	peaks	4664	0.11%
763	endangered	706	0.02%	meets	4558	0.1%
764	parsons	706	0.02%	highs	4432	0.1%
765	southbound	705	0.02%	lists	4386	0.1%
766	highest	704	0.02%	lakes	4170	0.09%
767	participation	702	0.02%	metro	3864	0.09%
768	march	699	0.02%	nears	3655	0.08%
769	channels	698	0.02%	parts	3592	0.08%
770	conforms	695	0.02%	terms	3545	0.08%
771	entire	694	0.02%	three	3372	0.08%
772	institutions	694	0.02%	works	3284	0.07%
773	basis	694	0.02%	wells	2846	0.06%
774	storms	693	0.02%	units	2792	0.06%
775	1994	691	0.02%	mains	2767	0.06%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
776	aesthetics	689	0.02%	soils	2718	0.06%
777	investigator	689	0.02%	texas	2705	0.06%
778	orienting	684	0.02%	diego	2582	0.06%
779	sizing	683	0.02%	views	2559	0.06%
780	methodology	682	0.02%	opens	2494	0.06%
781	sprr	680	0.02%	days'	2294	0.05%
782	decrease	679	0.02%	shown	2241	0.05%
783	225	678	0.02%	malls	2236	0.05%
784	requests	678	0.02%	salts	2174	0.05%
785	shops	678	0.02%	turns	2127	0.05%
786	committed	677	0.02%	acres	2006	0.05%
787	eights	676	0.02%	types	2003	0.05%
788	methods	673	0.02%	first	1995	0.05%
789	sharing	672	0.02%	stops	1820	0.04%
790	socially	671	0.02%	since	1805	0.04%
791	teams	668	0.02%	goals	1791	0.04%
792	rows	668	0.02%	daily	1761	0.04%
793	efficient	665	0.02%	links	1752	0.04%
794	jefferson	665	0.02%	shows	1743	0.04%
795	2030	664	0.02%	inity	1736	0.04%
796	owners	663	0.02%	santa	1704	0.04%
797	reflects	663	0.02%	flows	1618	0.04%
798	scott	662	0.02%	pages	1601	0.04%
799	sugar	659	0.02%	march	1573	0.04%
800	proximity	659	0.02%	small	1551	0.04%
801	indirect	659	0.02%	walls	1546	0.04%
802	headways	658	0.02%	trees	1495	0.03%
803	yard	658	0.02%	april	1467	0.03%
804	cats	657	0.02%	ports	1410	0.03%
805	900	655	0.02%	homes	1400	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
806	eirs	653	0.02%	finds	1356	0.03%
807	fishing	653	0.02%	prior	1325	0.03%
808	fires	652	0.02%	fixed	1296	0.03%
809	humans	652	0.02%	sdeis	1289	0.03%
810	1992	651	0.02%	clara	1280	0.03%
811	occupations	647	0.02%	fills	1275	0.03%
812	example	645	0.02%	ramps	1213	0.03%
813	savings	645	0.02%	towns	1211	0.03%
814	conserving	641	0.02%	forms	1208	0.03%
815	percentages	640	0.02%	hills	1206	0.03%
816	borne	640	0.02%	fairs	1138	0.03%
817	villages	639	0.02%	built	1134	0.03%
818	already	639	0.02%	lefts	1127	0.03%
819	analyzed	639	0.02%	johns	1123	0.03%
820	150’	639	0.02%	autos	1075	0.02%
821	baltimore	638	0.02%	yards	1047	0.02%
822	hospitals	638	0.02%	pauls	1023	0.02%
823	produce	637	0.02%	multi	1022	0.02%
824	architecture	636	0.02%	kings	984	0.02%
825	deir	632	0.02%	sandy	978	0.02%
826	practices	629	0.02%	harry	972	0.02%
827	1980	628	0.02%	fares	958	0.02%
828	gates	628	0.02%	goods	955	0.02%
829	ozone	627	0.02%	known	939	0.02%
830	modifications	627	0.02%	walks	936	0.02%
831	pineville	626	0.02%	leads	933	0.02%
832	thus	626	0.02%	users	925	0.02%
833	letters	626	0.02%	mesas	908	0.02%
834	joints	625	0.02%	helps	893	0.02%
835	cleaning	623	0.02%	keyes	892	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
836	acquired	623	0.02%	banks	879	0.02%
837	february	621	0.02%	early	861	0.02%
838	allegheny	620	0.02%	beste	853	0.02%
839	status	619	0.02%	basis	837	0.02%
840	procedures	616	0.02%	shops	832	0.02%
841	installments	616	0.02%	sales	805	0.02%
842	centre	615	0.02%	boxes	771	0.02%
843	fronts	614	0.02%	rocks	757	0.02%
844	function	614	0.02%	calls	757	0.02%
845	story	613	0.02%	plano	739	0.02%
846	notice	611	0.02%	gates	738	0.02%
847	early	609	0.02%	least	736	0.02%
848	mis	607	0.02%	tests	722	0.02%
849	encouraging	607	0.02%	teams	720	0.02%
850	amends	606	0.02%	means	714	0.02%
851	input	606	0.02%	reach	705	0.02%
852	least	606	0.02%	paste	690	0.02%
853	canyons	606	0.02%	paths	681	0.02%
854	helps	605	0.02%	taken	680	0.02%
855	attains	604	0.02%	loops	679	0.02%
856	accepted	604	0.02%	halls	675	0.02%
857	dollars	603	0.02%	party	665	0.02%
858	appear	600	0.02%	seven	665	0.02%
859	conventions	600	0.02%	codes	662	0.02%
860	employees	599	0.02%	loads	658	0.01%
861	justice	599	0.02%	signs	648	0.01%
862	corners	597	0.02%	borne	632	0.01%
863	september	594	0.02%	edges	624	0.01%
864	masters	592	0.02%	ozone	622	0.01%
865	formerly	591	0.02%	story	608	0.01%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
866	lincoln	590	0.02%	poles	608	0.01%
867	nrhp	589	0.02%	city	14191	0.32%
868	vmt	586	0.02%	west	10436	0.24%
869	calls	586	0.02%	also	7902	0.18%
870	database	586	0.02%	ways	7354	0.17%
871	trinity	585	0.02%	mays	5842	0.13%
872	means	585	0.02%	feis	5362	0.12%
873	boxes	585	0.02%	dart	4891	0.11%
874	extent	583	0.02%	feet	4557	0.1%
875	nearby	581	0.02%	busy	4220	0.1%
876	trolleys	581	0.02%	airs	3955	0.09%
877	library	580	0.02%	lots	3727	0.08%
878	secondary	579	0.02%	deis	3265	0.07%
879	obtained	579	0.02%	lows	3222	0.07%
880	positively	579	0.02%	pers	2962	0.07%
881	agreement	577	0.02%	acts	2836	0.06%
882	runoff	577	0.02%	long	2662	0.06%
883	inch	576	0.02%	100’	2595	0.06%
884	staffs	576	0.02%	sees	2577	0.06%
885	277	575	0.02%	blvd	2576	0.06%
886	apartments	574	0.02%	ends	2328	0.05%
887	nepa	574	0.02%	1999	2182	0.05%
888	spurs	569	0.02%	2000	2180	0.05%
889	elm	568	0.02%	four	2161	0.05%
890	restricts	566	0.02%	made	2125	0.05%
891	plano	566	0.02%	utas	2100	0.05%
892	examining	565	0.02%	data	2016	0.05%
893	eastern	565	0.02%	2002	2003	0.05%
894	codes	565	0.02%	utah	1919	0.04%
895	assumptions	562	0.02%	less	1873	0.04%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
896	fulton	562	0.02%	nons	1767	0.04%
897	stadium	562	0.02%	june	1762	0.04%
898	shpo	561	0.02%	shpo	1716	0.04%
899	influencing	559	0.02%	1990	1707	0.04%
900	2008	558	0.02%	many	1615	0.04%
901	natives	558	0.02%	runs	1601	0.04%
902	apes	557	0.02%	1998	1601	0.04%
903	regulatory	554	0.02%	400’	1558	0.04%
904	account	554	0.02%	full	1554	0.04%
905	research	553	0.02%	200’	1540	0.03%
906	held	552	0.02%	maps	1522	0.03%
907	corps	552	0.02%	must	1520	0.03%
908	threshold	551	0.02%	five	1510	0.03%
909	growing	551	0.02%	oaks	1498	0.03%
910	technology	551	0.02%	none	1472	0.03%
911	elk	550	0.02%	2006	1464	0.03%
912	minnesota	550	0.02%	2005	1461	0.03%
913	fort	550	0.02%	1996	1452	0.03%
914	ports	549	0.02%	500’	1448	0.03%
915	whites	549	0.02%	bays	1401	0.03%
916	seven	548	0.02%	2004	1400	0.03%
917	carbonate	548	0.02%	owns	1299	0.03%
918	nowe	548	0.02%	cars	1261	0.03%
919	exposure	547	0.02%	1995	1258	0.03%
920	exclusively	547	0.02%	2001	1243	0.03%
921	conceptually	547	0.02%	just	1232	0.03%
922	tempe	545	0.02%	eirs	1209	0.03%
923	basins	544	0.02%	1994	1200	0.03%
924	converts	544	0.02%	2009	1193	0.03%
925	1998	543	0.02%	mtdb	1171	0.03%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
926	280	537	0.02%	ince	1170	0.03%
927	substations	536	0.02%	uprr	1167	0.03%
928	supply	536	0.02%	jose	1163	0.03%
929	among	535	0.02%	300’	1151	0.03%
930	weekday	535	0.02%	2010	1150	0.03%
931	calculations	535	0.02%	2007	1146	0.03%
932	gas	533	0.02%	2015	1145	0.03%
933	collectively	533	0.02%	jobs	1141	0.03%
934	threatened	533	0.02%	800’	1120	0.03%
935	policing	532	0.02%	1997	1070	0.02%
936	edges	532	0.02%	2020	996	0.02%
937	offer	532	0.02%	july	969	0.02%
938	strategy	531	0.02%	2003	957	0.02%
939	inventory	531	0.02%	2025	957	0.02%
940	whether	530	0.02%	2030	937	0.02%
941	municipal	529	0.02%	much	927	0.02%
942	cfr	528	0.02%	held	903	0.02%
943	hotels	528	0.02%	600’	883	0.02%
944	adequate	528	0.02%	2008	860	0.02%
945	become	528	0.02%	1992	856	0.02%
946	pleasing	528	0.02%	1993	853	0.02%
947	halls	526	0.02%	apes	825	0.02%
948	moving	526	0.02%	rows	820	0.02%
949	occupying	526	0.02%	hovs	803	0.02%
950	adds	526	0.02%	nrhp	794	0.02%
951	communications	522	0.01%	nowe	787	0.02%
952	loads	522	0.01%	1991	766	0.02%
953	banks	521	0.01%	thus	740	0.02%
954	past	519	0.01%	nepa	703	0.02%
955	connectors	519	0.01%	york	692	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
956	walnuts	519	0.01%	feir	668	0.02%
957	another	517	0.01%	dear	651	0.01%
958	forester	517	0.01%	laws	650	0.01%
959	belts	517	0.01%	half	643	0.01%
960	modifying	516	0.01%	copy	611	0.01%
961	backgrounds	515	0.01%	risk	610	0.01%
962	dominating	515	0.01%	lrt	24852	0.56%
963	metrolink	514	0.01%	bus	8995	0.2%
964	114	513	0.01%	new	8886	0.2%
965	discharge	512	0.01%	two	6111	0.14%
966	officials	510	0.01%	lpa	5547	0.13%
967	clearly	510	0.01%	san	5479	0.12%
968	slopes	510	0.01%	eis	5230	0.12%
969	permanently	509	0.01%	0	4573	0.1%
970	martins	509	0.01%	tsm	4269	0.1%
971	characterized	508	0.01%	fta	3921	0.09%
972	vehicular	508	0.01%	due	2990	0.07%
973	paths	507	0.01%	los	2359	0.05%
974	fuels	506	0.01%	mid	2092	0.05%
975	definitive	506	0.01%	205	1450	0.03%
976	next	506	0.01%	dba	1383	0.03%
977	provisions	505	0.01%	cbd	1371	0.03%
978	reaching	504	0.01%	mos	1178	0.03%
979	monoxide	503	0.01%	six	1176	0.03%
980	ppm	503	0.01%	106	1141	0.03%
981	sufficiently	503	0.01%	old	1123	0.03%
982	better	502	0.01%	ads	1063	0.02%
983	archeology	502	0.01%	met	1051	0.02%
984	minimum	501	0.01%	dfw	1017	0.02%
985	conflicts	500	0.01%	epa	986	0.02%

No.	Draft Environment Statement			Final Environment Statement		
	Word	Count	Weighted %	Word	Count	Weighted %
986	denton	500	0.01%	ios	964	0.02%
987	little	499	0.01%	brt	946	0.02%
988	sdsu	498	0.01%	via	923	0.02%
989	tryons	498	0.01%	cfr	883	0.02%
990	brw	497	0.01%	lps	881	0.02%
991	proceed	496	0.01%	101	766	0.02%
992	achieving	494	0.01%	bwi	745	0.02%
993	products	493	0.01%	yes	743	0.02%
994	refining	493	0.01%	225	693	0.02%
995	presence	491	0.01%	mis	690	0.02%
996	underground	489	0.01%	150	668	0.02%
997	naming	487	0.01%	vmt	664	0.02%
998	beyond	487	0.01%	700	651	0.01%
999	cores	485	0.01%	rtd	646	0.01%
1000	sediments	484	0.01%	max	610	0.01%

A.4 A simulation of the change rate of travel time and access to jobs

Table A.6 An overview of travel time and access to jobs under different testing scenarios

Scenarios	Velocity (km/h)	Travel time (T, in hours)	Access to jobs within 1 hour ($A_{i,Job,T1}$, in the no. of jobs)	ΔT (%)	$\Delta A_{i,Job,T1}$ (%)
Base	10	10.0	487		
Scenario1	11	9.1	535	9.1%	10%
Scenario2	12	8.3	584	16.7%	20%
Scenario3	13	7.7	633	23.1%	30%
Scenario4	14	7.1	681	28.6%	40%
Scenario5	15	6.7	730	33.3%	50%
Scenario6	16	6.3	779	37.5%	60%
Scenario7	17	5.9	827	41.2%	70%
Scenario8	18	5.6	876	44.4%	80%
Scenario9	19	5.3	925	47.4%	90%
Scenario10	20	5.0	973	50.0%	100%
Scenario11	21	4.8	1022	52.4%	110%
Scenario12	22	4.5	1071	54.5%	120%
Scenario13	23	4.3	1120	56.5%	130%
Scenario14	24	4.2	1168	58.3%	140%
Scenario15	25	4.0	1217	60.0%	150%
Scenario16	26	3.8	1266	61.5%	160%
Scenario17	27	3.7	1314	63.0%	170%
Scenario18	28	3.6	1363	64.3%	180%
Scenario19	29	3.4	1412	65.5%	190%
Scenario20	30	3.3	1460	66.7%	200%
Scenario21	31	3.2	1509	67.7%	210%
Scenario22	32	3.1	1558	68.8%	220%
Scenario23	33	3.0	1606	69.7%	230%
Scenario24	34	2.9	1655	70.6%	240%
Scenario25	35	2.9	1704	71.4%	250%
Scenario26	36	2.8	1752	72.2%	260%
Scenario27	37	2.7	1801	73.0%	270%
Scenario28	38	2.6	1850	73.7%	280%
Scenario29	39	2.6	1898	74.4%	290%
Scenario30	40	2.5	1947	75.0%	300%
Scenario31	41	2.4	1996	75.6%	310%
Scenario32	42	2.4	2044	76.2%	320%
Scenario33	43	2.3	2093	76.7%	330%
Scenario34	44	2.3	2142	77.3%	340%
Scenario35	45	2.2	2190	77.8%	350%
Scenario36	46	2.2	2239	78.3%	360%
Scenario37	47	2.1	2288	78.7%	370%
Scenario38	48	2.1	2336	79.2%	380%
Scenario39	49	2.0	2385	79.6%	390%
Scenario40	50	2.0	2434	80.0%	400%

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