Erasmus University Rotterdam

MSc in Maritime Economics and Logistics

2018/2019

Appraisal of decision-making on large-scale transportation infrastructure project: Case study of the Hongkong-Zhuhai-Macao Bridge in China

by

Tian Li (Benjamin Li)

Acknowledge

It has been a year since I arrived in Netherland. During this year, I spent a very fulfilling but unforgettable time with my lovely classmates in MEL. At the end of this journey, I would like to present this dissertation as a summary of my master study in MEL.

Throughout the writing of this thesis I have received a lot of help and assistance from many people. Without the recommendation and data offered by them, I cannot finish my thesis in such a short period. Thus, I would like to show my sincere gratitude to them.

First, I would like to thank my supervisor, Prof. M. Dooms, who gives me invaluable suggestions in designing the research structure and methodology. It is my honour to work with such a nice professor with in-depth expertise and experience on the subject as well as a good sense of humour. Second, I would like to thank Wenjun Yang for offering the confidential document related to the project and his kindly participation of the interview. His support plays a very important role in writing this thesis.

Also, I would like to thank Martha Tjhin, Felicia de Jong and Renée Slater from MEL office. Thanks for their help and support during this whole year. They are really helpful and warm-hearted tutors. I would like to say thank you to my friends in the Netherland, who were of great help in providing joyful distraction to rest my mind outside of my thesis.

Last but not the least, I would like to show infinite gratitude my parents. Thank you for your love and support.

Tian Li
Rotterdam, August 2019

Abstract

The dissertation presents an evaluation of the decision-making framework of a large-scale transportation infrastructure project (LSTIP). The study adopts a case study analysis supported by the confidential documents from governments and an interview with one of the project's decision participants. The analysis selects a typical large-scale transportation infrastructure project in China as the principal case and compares its ex-ante decision-making framework to that of two European benchmarking projects. Based on the result of the case study and actual performance in the first-year operation, we conclude that the decision-making framework of the Chinese case is still incomprehensive and overoptimistic at the ex-ante stage although it shows advantages in some respects. Also, to expand the value of the research, we introduce a possible evaluation framework to assess the quality of decision making at the ex-post stage and give some policy recommendations to improve the similar decision-making process in the future.

Keywords: large-scale transportation infrastructure project (LSTIP), Hong Kong-Zhuhai-Macao Bridge (HZMB), Decision making, Case study, Ex-post appraisal

Table of Contents

List of figures and tables

Figures

Tables

1 Introduction

As the foundation of a region or country, large-scale infrastructure projects or megaprojects plays an important role in most Western and non-Western countries in several aspects. Among several types of megaproject, large-scale transportation infrastructure projects (LSTIP) has been gaining substantial attention due to its far-reaching impacts on the transportation pattern and logistics network within a region. In recent years, large amounts of investment have been poured into the construction of transportation infrastructure projects due to the increasing demand for trade and tourism all over the world. However, the huge amount of budget, frequent cost escalation, revenue shortfall, and other uncertainties often pose threat to the success of a transportation project as these problems may seriously peril the project's profitability and sustainability. In order to diminish these problems, high-quality decision-making at the early stage should be attached greater importance.

The decision making of a mega transportation project usually involves strategic choices for major issues such as project planning, feasibility demonstration, investment and financing, environmental protection and management mode. In most transportation projects, the decision-making process becomes complex due to the extensive number and layers of decisions, a wide range of coverage, inadequate information, and incapability of decision-making principal. Mega transportation projects in history like The Channel Tunnel have proved that once the decision making fails or underperforms, it will cause great harm not only to the projects themselves but also to the society, economy, and environment related to the project. Thus, it is crucial for decision makers to conduct a sound ex-ante appraisal of a possible new transportation project to assure the quality of decision making at the planning stage. Also, a systematic ex-post appraisal should be implemented to compare the expected and actual performance and learn from behavioural and methodological elements neglected at the ex-ante stage.

Among the transportation Infrastructure projects built in recent years, the Hong Kong–Zhuhai–Macau Bridge (HZMB) is a very special case due to its unprecedented complexity and difficulties in the decision-making process. HZMB serves as a vital sea-crossing transportation infrastructure project which provides a faster land connection between Hong Kong, Macao, and the Chinese mainland within the Pearl River Delta (PDA). Figure 1.1 map out the old (pink) and new route (red) linking two shores of PDA before and after the construction of HZMB. It is estimated that the bridge could reduce the travel time by 80% from 4 hours to 45 minutes. Meanwhile, the LSTIP is also regarded as an important step to realize the national strategy of forming a Great Bay Area (GBA) on the southern coast of China. As a world-class LSTIP, the bridge not only inherits the common characteristics of LSTIP but also

shows uniqueness in its decision-making process: on the one hand, under the “one country, two systems” policy, the HZMB have to comply with the different legal framework and quality standard in three territories where the government represents the benefit of its own citizen. In order to come to an agreement, conflicts and trade-offs can hardly be avoided from the planning stage of the project. In addition, the HZMB will pass an area where a Chinese white dolphin national nature reserve situates. This conservation issue together with other environmental concerns undoubtfully makes the decision making more sophisticated. Thus, an aggregated analysis and evaluation is necessary to be done from technical, financial, social and environmental perspectives. On the other hand, as a bridge located in the heart of GBA, the HZMB will considerably alter the transport and logistic pattern in the region, especially in maritime sectors as it is surrounded by several important ports and logistic hubs. This effect of HZMB has been initially evidenced by the accelerated development of Zhuhai ports (the port was ranked as the 7th most promising container port with an astonishing 69.7% growth of throughput in 2017). Table 1.1 summarises the basic information (world rank, throughput and growth rate) of major ports in the GBA according to 2018 data.

Port Name	World Rank	Throughput in 2018 (TEU)	Growth rate
Shenzhen	4th	25,740,000	+2.1%
Guangzhou	5th	21,922,100	+7.6%
Hong Kong	7th	19,596,000	-5.7%
Zhuhai	81st	2,310,000	+69.7% (2016- 2017) +1.8% (2017- 2018)

Table 1.1 World top 100 ports in GBA (Source: Lloyd’s list, 2019)

To sum up, the unique and complicated decision-making process of HZMB makes it worthwhile to scrutinize its quality of the decision making through a case study analysis. The analysis will help decision makers better understand and learn the strength and weakness of HZMB’s decision-making process.

In the paper, we are going to assess the quality of the decision making of HZMB by comparing its ex-ante appraisal framework with that of two similar projects in Northern Europe. In this case, the Oresund Fixed Link and Fehmarn Belt Fixed Link are selected as the benchmarking project because they were regarded as either a successful or a promising project in recent decades under the prestigious European standard. Then, according to the results, we will suggest a possible ex-post appraisal framework for HZMB and then make an overall conclusion with some policy recommendations. The study has two add-value: 1) it paves a way to the possible ex-post decision-making appraisal of HZMB in the coming 5 or 10 years; 2) it provides some illuminations on the design and quality control of decision-making appraisal to

similar LSTIPs in China and other countries.

The paper proceeds as follows. In Chapter 2 we review existing literature on the problems and evaluating techniques of decision-making of LSTIP, the necessity of doing an ex-post assessment along with real cases, the study on decision making of HZMB at present, and some in-depth study of decision-making appraisal of LSTIP. Meanwhile, we introduce a brief framework to assess the ex-ante decision-making of HZMB; In Chapter 3 we explain the reason for our choice of methodology and the study cases; Chapter 4 presents a detailed analysis of three projects' appraisal framework and summarizes the pros and cons of the principal project and propose an ex-post appraisal framework; and in Chapter 5 we make a conclusion and offer some recommendations.

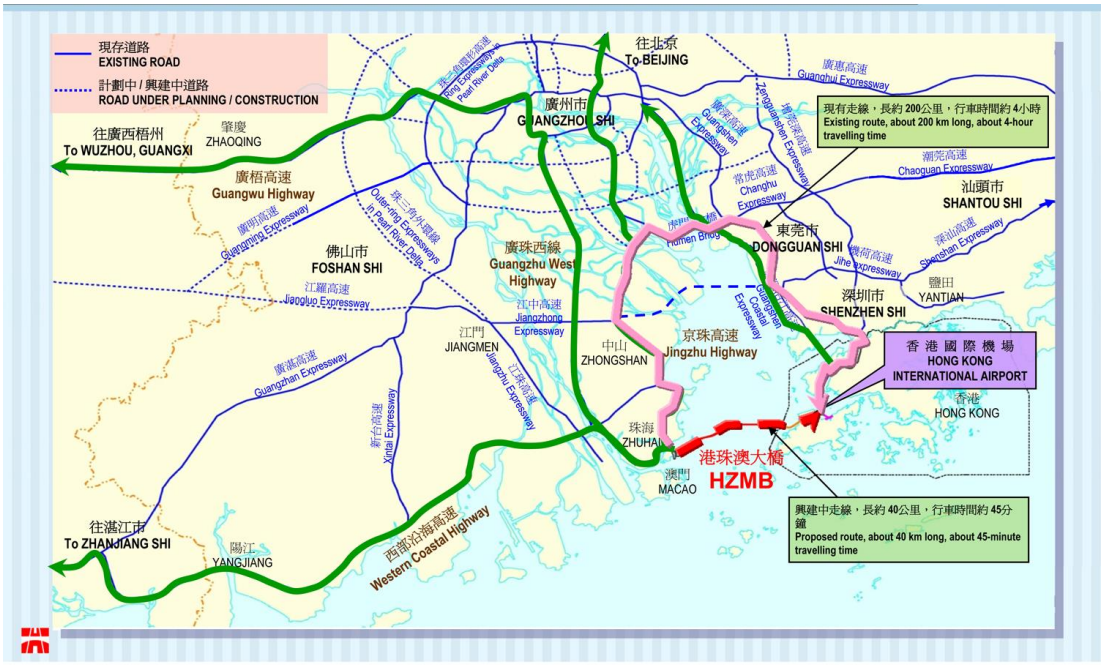


Figure 1.1 Old and new connection between Hong Kong and Zhuhai in the PDA (Source: Highways Department)

2 Literature Review

2.1 Definition of LSTIP and problems of decision-making of LSTIP

Large-scale Transportation Infrastructure Projects, one type of megaprojects or major projects, are defined as the large-scale, complex ventures transportation projects which may take many years to develop and construct with a cost more than 1 billion dollars (Flyvbjerg, 2014; Flyvbjerg et al, 2003a). Apart from the considerable costs of the LSTIP, LSTIP always involves several significant direct and indirect impacts on the community and environment for which a high level of public or political interest are usually attached to these kinds of projects (Capka, 2004). Frick (2005) clearly summarized the main characteristics of Large-scale projects with his '6Cs': colossal, captivating, costly, controversial, complex, and laden with control issues.

In general, decision making is defined as a cognitive process during which individuals make their choices among several alternative possibilities to integrally produce the desired outcome. Decision making is widely adopted nowadays in many fields to direct the resources of an organization towards future goals and narrow the gap between the actual and desired situation through both quantitative and qualitative analysis (BBAmantra, 2019). In recent years, the subject of decision making on large-scale infrastructure projects, especially large-scale transportation infrastructure projects, and the associated appraisal frameworks have gained increasing attention in both academic and professional fields.

Over the years of construction and development of LSTIP, many characteristics-related problems appear at the early stage of decision making and become the impediment of the progress of megaprojects in many countries. Many well-known major transportation infrastructure projects suffer from the budget problem. The Channel tunnel, the only fixed link between the island of Great Britain and the European mainland, had been reported several near-bankruptcies since its opening in 1994 with an 80% overrun in construction costs and a 140% overrun in financing costs but a more-than-50% underestimation of revenues (Flyvbjerg et al, 2003a). The new Jubilee Line extension of London Underground cost £3.5 billion rather than £1.9 billion as planned (84% cost overrun) and gained a substantial loss in revenue due to its six-year lag in the intended date of operation (Joosten, 2005). In the research of large-scale infrastructure projects, Berg, Kilde and Rolstadås (2003) reported that five large Norwegian public infrastructure projects were under cost overruns which range from 10 to 222 percent and Odeck (2004) found an average cost overspend at around 8% among 620 Norwegian public road projects built between 1992 and 1995.

Among the study of megaprojects, a series of research done by Bent Flyvbjerg on decision making of megaprojects are the leading piece in this area and widely

accepted and referenced by many following studies due to the large number of projects, the variety of project categories, the large time span and the extended regional coverage (Cantarelli, 2011). He concluded that overestimation of demand and underestimation of costs are two major pitfalls in the decision making of most of the existing large-scale infrastructure projects, especially the large-scale transportation infrastructure projects (Flyvbjerg, 2008). Cost overruns directly lead to the budget problem of the projects whereas the inaccurate forecasts of traffic demand not only cause revenue shortfall but also mislead the following decision making of LSTIP (Flyvbjerg, 2007). In a research with 70-year duration, Flyvbjerg (2007) studied 258 large-scale project cases globally of which the result shows that 9 out of 10 projects are confronted with cost overruns with average overspends of 44.7% in rail projects, 33.8% in fixed link projects such as tunnels and bridges and 20.4% in road projects. A number of studies get similar conclusion about the cost overrun problem in several types of megaprojects (Priemus, 2010; Magnussen & Samset, 2005; Merewitz, 1973; Morris and Hough, 1987; Nijkamp and Ubbels, 1999; Jong, 2007; Odeck, 2004; Pickrell, 1992; Hall, 1980; and Dantata, 2006).

Problems of cost overruns and lower-than-predicted traffic volumes incurred among large-scale transportation infrastructure projects not only endanger the viability of the projects but also curtail the projects' profitability and effectiveness of boosting the economic growth within the regions. Specifically, there are four reasons making cost overruns and benefit shortfall problematic (Flyvbjerg, 2007). First, the inaccuracy leads to an adverse selection with "Pareto-inefficient allocation of resources, i.e., waste" as the estimation bias influences the ranking of projects in cost-benefit analysis on which decision makers rely. Second, the cost overruns easily incur postponement because the extra investments take time to reach their final spenders. Meanwhile, another negotiation and approval among the decision makers may begin if the overrun and shortfall are too substantial. These delays are very costly. A project with an $8 billion investment could generate $1 million per day or $370 million per year cost of delay (Flyvbjerg, Holm, and Buhl, 2004). In this case, benefit shortfalls not merely come from less-than-expected traffic demand but the later opening day with operational spending but zero revenues. Third, large overruns and shortfalls are likely to "destabilize policy, planning, implementation, and operation" due to the nonstop administrative debates and reapprovals from the Parliament and outside. Finally, the bigger the project, the bigger the problem (Flyvbjerg, Holm, and Buhl, 2004: 12). The cascading impact of the size of megaprojects on cost overruns and benefit shortfalls will become severe if the overruns cause national fiscal distress.

Apart from the cost overruns problem, most of the problems arose from a variety of alternatives and uncertainties in terms of policies (Omar et al., 2009). Niekerk & Voogd (1999, p.28) sorted out these problems from strategic and operational perspectives which align with Grigg's model: in strategic level not only alternatives are too extensive

and abstract but also information about the effects of alternatives as well as the possibilities and effects of mitigating and “flanking policies” is inadequate; Also generating direct feedback from the public and politics is also hard to realize. At the operational level, information is lacking in strategic and politic issues as well; In addition, the involvement of local politics and interest groups brings societal dynamics to societal dynamics which then give rise to the uncertainties.

From many previous studies, it can be concluded that although LSTIP has a long history of development the problems related to them are still difficult to avoid due to the lack-of-accuracy estimation of cost and revenue, the poor foreseeability of the uncertainties, and asymmetric information and different trade-offs among the stakeholders. Thus, ensuring the quality of decision-making for LSTIP is crucial to the success of these kinds of megaproject (Magnussen & Samset, 2005). A study by the World Bank found that the higher the quality and the extent of the front-end investigation conducted, the better the projects will perform in the future (World Bank, 1996). Table 2.1 provides an overview of the main conclusions of the previous study in LSTIP and related decision-making problems.

Factor	Main conclusion	Sources
Definition of LSTIP	LSTIP is one type of LSIP which may take many years to develop and construct with enormous investment.	Flyvbjerg, 2014; Flyvbjerg et al, 2003a
Characteristics of LSTIP	LSTIP often has far-reaching direct and indirect impact on society and environment. The main characteristics could be summarized with '6Cs':colossal, captivating, costly, controversial, complex, and laden with control issues.	Capka, 2004; Frick, 2005
Prevailing budget problems	Many national major transportation infrastructure projects such as the Channel were confronted with the budget and revenue problem during their construction and operation.	Flyvbjerg et al, 2003a; Joosten, 2005; Berg, Kilde and Rolstadås, 2003; Odeck, 2004
Other policitcal problems	These problems include insufficient consideration of alternatives and uncertainties (i.e. risks), lack of stakeholders' feedback and inadequate stakeholder inclusion.	Omar et al., 2009; Niekerk & Voogd, 1999
Inacurrate estimation and forecast	Underestimation of cost and overestimation of demand are two major problems in decision making of LSTIP in which overestimated demand often brings revenue shortfall.	Flyvbjerg, 2007; Flyvbjerg, 2008; Priemus, 2010; Magnussen & Samset, 2005; Merewitz, 1973; Morris and Hough, 1987; Nijkamp and Ubbels, 1999; Jong, 2007; Odeck, 2004; Pickrell, 1992; Hall, 1980; Dantata, 2006
Negative impact of forecast biases	The biases in cost and demand prediction will not only endanger the viability and the profitability of the projects but also curtail the effectivenss of boosting the regional economic growth.	Flyvbjerg, 2007; Flyvbjerg, Holm, and Buhl, 2004
Key factor of megaprojects' success	Ensuring the quality of decision-making, especially the up-front quality at initial phases, plays an important role in the success of the large-scale projects.	Magnussen & Samset, 2005; World Bank 1996

Table 2.1 Summary of major conclusions of previous study

2.2 Overview of techniques and processes on decision-making for LSTIP

In the decision-making for LSTIP, several types of appraisal approaches were applied as techniques to facilitate the decision-making process among various stakeholders. These appraisal methods usually combine qualitative and quantitative analysis to evaluate the projects more comprehensively (Macharis, de Witte and Ampe, 2009). The most prevailing five types of evaluating the method at present are Private Cost Benefit Analysis (CBA), Cost Effectiveness Analysis (CEA), Economic Effect Analysis (EEA), Social Cost Benefit Analysis (SCBA) and Multi Criteria Decision Analysis (MCDA) (Dooms, 2017).

Among the five techniques, CBA is the most popular evaluating methods and decision-making tools for large-scale public infrastructure investments with one actor involved because it monetizes cost and benefit of market and non-market goods and guides the decision maker through direct display of aggregated and pure financial criteria such as Net Present Value (NPV), Internal Rate Return (IRR), Profitability Index (PI), the Benefit-Cost Ratio (BCR) or the net-benefit/investment cost ratio (NBIR) (Dooms, 2019; Jones, Moura and Domingos, 2014). CBA is widely adopted by Japan, America, and several European countries to assess the major transportation infrastructure projects in domestic (Hayashi and Morisugi, 2000). However, CBA is also blamed for many weaknesses shown in practice. Jones et al. (2014) summarized the major weaknesses of CBA in their paper with sufficient theoretical foundation from a number of academic articles and researches: overestimated traffic forecast and underestimated cost (Flyvbjerg, 2005; Rasouli & Timmermans, 2012), unpredictability of long-term discount rate (Florio, 2006a; EC, 2006), divergent standards of value of life (Trottenberg & Rivkin, 2011; Bellavance, Dionne, & Lebeau, 2007), safety concerns for developing countries (Grant-Muller, Mackie, Nellthorp, & Pearman, 2001; World Bank, 2005b), complex variables' structure of value of time (van Wee, 2007; Trottenberg and Rivkin, 2011), ignorance of network or crowding out effects in regional impacts (van Wee, 2007; ITF, 2011), negligence of agglomeration and land use interaction in local impacts (Banister, 2007; Martinez, 2010), exclusion of equity and environmental impacts (Shi & Wu 2010, Martens, 2011, Heinzerling & Ackerman, 2002) and overlook of residual value (Edgerton, 2009; Matria, 2012).

CEA is an appraisal method often used in projects when decision makers emphasize only a single dimension of outcomes and the overall benefits are difficult to obtain and evaluate. In practice, it often applies for the assessment of the technical efficiency but not the allocative efficiency and the optimization of output or cost under given constraints (IAS, 2014). EEA, also known as Economic Impact Analysis (EIA) and Regional Economic Impact Study (REIS), is often used for evaluating macro-economic impacts of a specific project, firm or sector on a certain region or country from the government perspective. This method underlines the use of models with

various inputs and corresponding outputs (e.g. labor and consumption goods for households, public services to business and goods and services for government and capital consumption and investment for capital market) as well as multipliers to calculate indirect impacts (e.g. induced and strategic effects) (Dooms, 2017; Soens, 2019). The definitions and applications of CBA, CEA, and EEA show that these three methodologies assess different projects from a single stakeholder's perspective and usually the outcomes are demonstrated through economic and financial indicators. The major weakness of them is that they neglect or obscure the importance of environmental, social and politic influences which are difficult measured by direct data sources. It is necessary for a decision maker to design a more comprehensive appraisal system taking non-financial or indirect costs and benefits into account.

In order to avoid the aforementioned disadvantages, SCBA and MCDA are introduced as two more wide-ranging and integrated appraisal methods which gradually gain more attention from the decision makers. SCBA was first known to the world in the 1960s when continuous growth of demand for basic infrastructure projects in the United State urgently needs a new technique to control the quality of the decision-making process. Nowadays, SCBA is wining increasingly popularity in assessing the decision making of projects highlighting the environmental factors (Cameron, 2011; Crookes & de Wit, 2002) and especially for large transportation infrastructure projects, SCBA has been advocated for a long time (Macharis, de Witte and Ampe, 2009). In addition, many trends in decision making imply it imperative for decision makers to investigate "social desirability, usefulness, and necessity of the particular investment" (ROYAL HASKONINGDHV, 2019). Unlike CBA, SCBA gains its edge through not only expressing the social and environmental cost and benefits in monetary terms rooted in Welfare theory (principle of compensation) but also making comparisons among different projects viable (Dooms, 2017). These advantages are preferred by the decision makers as well as the stakeholders because the SCBAs are supposed to provide transparent information for the decision-making process and clarify the alternatives' strengthens and weaknesses to stakeholders.

When it comes to MCDA, the approach has been adopted in the transportation sectors in a broader applicable and geographical scope (Macharis, de Witte and Ampe, 2009). The range of the application varies from strategic decisions (Dooms and Macharis, 2006) to assessment of policy measure in passenger transport (Bouwman and Moll, 2002), and various infrastructure projects (De Brucker et al., 1998) whereas the geographical scope includes Austria, Belgium, Greece and the Netherlands (Bristow and Nellthorp, 2000). Those who are in favor of MCDA figure that the monetization in SCBA is immature where the negative influence from pro memory and uncertainty in the analysis will hazard the reliability of the results (Macharis, de Witte and Ampe, 2009; Ferreira and Lake, 2002). In this case, SCBA suffers from uncomprehensive consideration of all externalities and intangible benefits as the results are only

meaningful in the short term but relatively worthless in the long term. Nevertheless, MCDA did well in this aspect as the multi-criteria evaluation makes it possible to consider all effects generating from a policy (Vincke, 1992). In the book published by UK's government, DCLG (2009) concludes that MCDA is one of the best ways to deal with the composite problems characterised by a mixture of monetary and non-monetary factors, to decompose the complex problem into smaller manageable fragments which could be analysed in software and if necessary, to reassemble these pieces into a coherent and one-for-all map which helps decision makers have a clear overview of the projects. Moreover, the institution regards MCDA as a tool aiding cognitive thinking and making the decision rather than taking the decision directly. To some extent, MCDA could be considered as a more comprehensive and computer-friendly evaluating method than SCBA.

2.3 Need for more comprehensive Ex-post evaluation of LSTIP

Large-scale infrastructure projects evaluation in the transport sector is often carried out utilizing ex-ante cost-benefit analysis in the past. However, it is rare for decision makers to follow up on the performance of the projects after their completion and to implement a systematic ex-post appraisal to compare the expected and actual performance of a project. Flyvbjerg et al (2003) investigated three mega-projects in the transport sector among UK, Sweden, and Demark and found that ex-post evaluations are rarely carried out in the case of public procurement because the decision makers show little interest about the results of them.

In generalized definition, ex-post evaluation is to evaluate whether the original objectives, the anticipated influences, estimated costs and benefits of a project or a piece of legislation have realized and what's important, identify the inaccuracy (over- and under-estimation) and unintended outcomes (force majeure) thereof (Republic of Kosovo, 2019). In recent year, ex-post evaluations were often done within a time horizon of five years and seldomly found in long term (De Jong, Vignetti and Pancotti, 2018).

However, many studies still highlight the importance and value of ex-post evaluation. Worsley (2014) regarded ex-post evaluation as an improvement of ex-ante analysis and concluded four advantages of taking ex-post evaluation: 1) providing benchmark to decision maker to identify the optimal projects in given situations; 2) identifying the effect of non-transportation investments and their interaction with transportation investments; 3) helping ex-ante evaluation set proper time frame, cost and demand forecast through retrospective analysis; 4) supporting communication with the public and transparency of the information related to the project. Likewise, Welde & Holst Volden (2017) figured that the ex-post assessment could be used as a tool to validate the ex-ante appraisal, to understand critical relationships and to learn about what

makes a project successful and frustrated. They also suggest that Cost-Benefit analysis (CBA) could be largely used as the basic methodology in the appraisal of transportation projects in both ex-ante and ex-post situations, which provides the decision maker with the economic profitability of the project (Welde & Holst Volden, 2017). In addition, the disadvantages of traditional ex-ante evaluation through CBA mentioned in the prior section not only become incentives for decision makers to find a more comprehensive way to do the evaluation. Dooms (2017) provided five possible solutions to deal with the methodological problems of traditional (S)CBA: appropriate sensitivity analysis, standard methodologies, the inclusion of and dialogue with stakeholders, effective ex-post analysis and best practices (benchmarks) for SCBA.

Some governmental institutions deliver various standards of an optimal comprehensive ex-post evaluation. European Commission recommends to carry out an enhanced ex-ante and ex-post evaluation of major infrastructure projects in transport sectors with a summary of 10 principles: considering the whole project cycle, adopting a dynamic to ex-ante appraisal, using a progressive approach to environmental analysis, performing quantitative risk analysis, monitoring project development, adopting risk management and mitigation strategies, performing ex-post evaluation systematically, using harmonised models and data, making maximum use of evaluation results and establish a dedicated team progressing the whole evaluation (EVATREN, 2019). A comprehensive ex-post evaluation could exist in a goal-oriented appraisal (Volden and Samset, 2013). The OECD DAC (1991) pointed out five evaluation criteria of goal-oriented appraisal of major projects: efficiency, effectiveness, impacts, relevance, and sustainability. Although it is not widely used in evaluating transportation infrastructure in developing countries, it still can be used as a reference for designing a new ex-post and goal-oriented evaluation framework.

Up to now, there are merely a limited number of paradigmatic ex-post evaluation cases done in LSTIP. Among these cases, two of them are well known and presented in many studies: the Post Opening Project Evaluation (POPE) of the UK Highway Agency (HA) is regarded as one of the comprehensive ex-post analyses of transport project and the data shows that this assessment method helps 94% of the projects achieved their objectives. Another successful ex-post evaluation was in Norway where 3 to 5 road projects were assessed yearly through several ex-post CBAs with a standard framework. The results indicate that 15 out of 20 selected projects gain an improvement in NPV when compared to the estimated output in ex-ante evaluations. Further analysis of the 15 profitable projects suggests that the traffic demand was higher than the original estimation and one-half of the projects incur lower construction costs (Welde & Holst Volden, 2017). The common characteristics among these projects offer an insight into the market climate and the willingness to pay in the public in the status quo. Some important financial indicators and project parameters from them could be gathered in a database and used as benchmarks for similar projects

that will be built in the near future.

Even if the ex-post evaluation was already introduced into transportation projects decades ago, some problems still exist and are found in many cases. The foremost one is the lack of standardisation of evaluation methodologies (Nicolaisen and Driscoll, 2016). Apart from standardisation, data availability has been a problem being neglected for a long time (Nicolaisen and Driscoll, 2016; Welde & Holst Volden, 2017). During a study of examing transportation project cost overruns, Siemiatycki (2009) found that both eight systematic ex-post evaluation schemes and ten national audit reports had the same difficulty in collecting data from the earlier ex-ante appraisal. Last but not the least, zero alternatives or no-build alternatives (alternatives that were not implemented), defined as the counterfactual problem, also post a threat on accuracy in ex-post LSTIP evaluation due to overoptimistic political-economic explanations (Næss, 2011; Nicolaisen and Driscoll, 2016).

2.4 Ex-post assessment of cases from the literature and policy

In general, a large part of the decision makers of LSTIP is comprised of government and public investors. Different stakeholders will make different or even opposite trade-offs due to the high uncertainty of the knowledge and inadequate agreement on standards, which could be regarded as untamed political problems with contested information (De Bruijn and Leijten, 2007). Consequently, it is easily ambiguous what appraisal indicators should be selected and what rationales support the choices. Even within a country, the conflicts among stakeholders who come from the same nation were already problematic. There is no doubt that the policy issues will be more sophisticated when it comes to a mega transportation infrastructure project between two different countries or among regions with different policies. Similar to the case study selected in this paper, the assessment of the Oresund Bridge and the Channel tunnel both of which connect two countries could offer a better understanding of decision-making appraisal under this scenario.

Oresund bridge (Øresund or Öresund Bridge), also known as The Oresund Fixed link, was officially open to traffic on 1 July. The bridge, comprised of a railway and a motorway, connects Copenhagen (the capital of Denmark) and Malmo (the second largest city of Sweden). The opening of the bridge has considerably switched the transport pattern in the Oresund region where the commute between two cities was heavily relied on the ferry but has been mainly through the bridge since 2000 (Knudsen and Rich, 2013). After around 20 years' operation, several annual official reports indicated that the bridge is a successful investment of LSTIP from a socio-economic perspective. Although the estimated demand and revenue were perceived too challenging to realize, the actual traffic volumes surpass the number forecasted

one year before the opening of the bridge (Oresund, 1999). Compared to 60 years' pay-back time and 4% interest rate projected by TRM in 2002, a new forecasting profile which estimates 50 years to pay back with a 3.5% interest rate was shown in the 2010 Oresund annual report (Oresund, 2010a; TRM, 2002).

The most comprehensive retrospective analysis of the Oresund bridge was done by Knudsen and Rich in 2013 through ex-post social cost-benefit assessment. One of the highlights of the study is that the authors take counterfactual scenario (i.e. zero alternatives) into account and the transport costs and demand flows in this scenario is projected and compared with actual ones. The assessment results clearly depict the cost profile and the consumer surplus for the bridge from 2000 to 2010. Finally, further analysis summarised three key factors relevant to the success of the Oresund bridge: 1) low exposure to competition from aviation; 2) low degree of border effects after the construction of the bridge was finished; 3) large local labour market agglomeration influences (Knudsen and Rich, 2013).

The Channel Tunnel, nicknamed Chunnel, is the only fixed link below the English Channel which is mainly designed for rail carrying passengers and cargo to shuttle between Folkestone, Kent, in the United Kingdom and Coquelles, Pas-de-Calais, in the hinterland of France in Europe. The idea of building a link like this had already existed in the early 1900s but the tunnel was finally finished almost one century later in 1994 (History of Bridges, 2019).

The Channel Tunnel share a lot of noteworthy similarities with the Oresund bridge project. For example, both two projects are LSTIPs and link two different countries across the sea. In addition, before the projects were completed, the major way to shuttle between two regions is by ferries and after the opening of the projects, identical transportation flow could be found in them (Knudsen and Rich, 2013). However, opposite from the success of the Oresund bridge, the ex-post evaluation of Channel Tunnel reveals that the construction of the project is an unwise decision and encumbered the British economy as the total expenditure dwarfs the benefits created. From a long-term perspective, the project is still considered in poor feasibility of investment in financial and cost-benefit terms (Anguera, 2006). The ex-post evaluation carried by Anguera in 2006 consists of three parts: transport cost-benefit appraisal, Eurotunnel financial appraisal, and long-term appraisal. The further analysis of the results suggests that underestimation of traffic volume, the escalation of construction costs due to unpredicted schedule lag and revenue decrease brought by increased competition are the main reasons for the project’s poor financial performance (Anguera, 2006).

The major determinant of success or failure rooted in the different actual traffic growths of two transnational LSITP. Based on the data collected in Anguera’s and

Knudsen's study, the figures indicate that the passenger flows of the Oresund bridge increased by around 70% from 15,150 to 25,694 while that of the Chunnel only increased by 8% from 14,900 to 16,113. Knudsen and Rich (2013) suggest that on the one hand, "local agglomeration effects" or "border effects" are more crucial for the Chunnel than the Oresund bridge because of the cultural and linguistic differences between Britain and France are larger than that between Demark and Sweden. On the other hand, the Chunnel has been competing with air transport for decades. The competition became more intense after the boom of budget airlines in Europe which shuttle among major European airports several times a day with low fare.

Table 2.2 summarizes and compares the differences between the ex-post appraisal framework of the Chunnel and the Oresund bridge based on Anguera's and Knudsen's study.

Factors	Chunnel	Oresund Bridge
Methodology	CBA with financial and long-term appraisal established by HM Treasury (2003)	SCBA suggested by Danish Ministry of Transportation
Discount rate	3.5% recommended by HM Treasury	3.5% recommended by European Commission
Indicators considered	a) Traffic volume and costs comparison (forecast and actual) b) IRR comparison (ex-ante and ex-post) c) User benefits from travel time saving and fare reduction d) Producers' losses	a) Traffic volume comparison (forecast and actual) b) Cost profile c) NPV and IRR statement at ex-post stage d) Consumer benefit from travel time and costs saving
Conclusion	The ex-ante studies inaccurately forecasted the costs and demand but precisely predicted the market share; The overall losses of the project outweigh the total benefits.	The ex-ante studies did reasonably well in traffic forecasting; The project has generated significant consumer benefits so far.

Table 2.2 Comparison of ex-post appraisal of the Chunnel and the Oresund Bridge

2.5 Existing literature about decision making of HZMB

The proposed project Hong Kong – Zhuhai – Macao Bridge, which straddles the water of Lingding Bay of the Peral River Estuary in southern China, is not merely a mega sea-crossing bridge linking the Hong Kong Special Administrative Region, Zhuhai City of Guangdong Province and the Macao Special Administrative Region, but also an critical transportation infrastructure project under the “National High Speed Road Network Planning” of China (Highways Department, 2009). Noteworthily, existing literature about the ex-ante evaluation of the decision making of HZMB is rarely found on the available academic resources. Most of the assessments were done by the governmental agencies.

The Transport and Housing Bureau (2008) of Hong Kong carried out the evaluation of the Benefits of the HZMB Project based on the traffic volume forecasted through a four-stages modelling approach. The four-stages method consists of a demand projection of cross-boundary passenger trips and cargo volume, distribution pattern analysis, mode choice analysis, and route choice assignment. The results indicate that the direct benefits of HZMB, including saving in transport costs, the value of time saved for travellers and induced traffic volume, is estimated to bring 74.0 billion RMB (around €9.6 billion) economic benefits to the three territories in 2009 prices. In addition, the indirect benefits of HZMB are more far-reaching. The HZMB has substantial strategic value to the local economies especially in Hong Kong: the reduction of travel time not only optimizes the transportation networks and boost the maritime, logistics and other infrastructure development in the Delta Area but also attracts more tourism and passengers travel through Hong Kong international airport. Meanwhile, the increased connectivity of mainland and special administrative regions enhances the development potential of three cities due to better investment and residence distribution. Apart from the economic evaluation, the Highway department of Hong Kong Project Management office (2009) conducted an Environmental Impacts Assessment (EIA) to evaluate the environmental impacts of HZMB. Overall, it is reported that the HZMB project would be environmentally practicable as long as the proposed mitigation measures have been implemented effectively.

One of the most important non-governmental researches was done by Shiyong in 2013, he evaluated the decision making for investment and financing structure of the HZMB on the basis of a comprehensive project evaluation from social, economic, financial and environmental perspectives. According to the project evaluation, he reckons that although the HZMB will have profound social and economic benefits to the Big Bay Area as well as the whole country, and the negative impacts on the environment are modest and controllable, the pessimistic financial performance due to large-scale investment and limited charge standard make it difficult to attract public investors to continuously invest their capital into the project. Thus, he defined HZMB

as a large-scale infrastructure with higher strategic and public significance but lower operational and financial return (Shiyong, 2013). Accordingly, he explains the reasons why HZMB gave up the traditional BOT financing mode and was fully funded by the government. The main conclusion of his study indicates that the decision making for HZMB's investment and financing structure is relatively successful as it perfectly aligns with the project's characteristics.

2.6 Broader studies on decision-making appraisal of LSTIP

Prevailing decision-making appraisals focus on the technical feasibility, political strategy and environmental and social-economic costs and benefits. In recent years, there is a growing understanding of quality control at the front-end phase to achieve cost-effective projects and many relevant researches are carried out (Magnussen & Samset, 2010; Williams and Samset, 2010). Magnussen & Samset (2005) learned from the initiative by the Norwegian government and designed a revised quality assurance framework to guarantee the quality of the decision-making progress at the early stage of a project cycle. Their front-end assessment includes two sub-analyses: quality assurance of the choice of concept and the quality of the basis for control and management which includes cost estimation and uncertainty analysis for the chosen project alternative.

Mackie and Preston (1998) argue that existing appraisals are prone to become worthless and mislead the decision maker due to the biases and errors in the evaluating system. Table 2.3 shows twenty-one errors and biases they found and in transportation projects appraisal. A similar opinion can be found in Dooms's research on societal challenges in transport infrastructure development. He indicated that a number of projects obtain contestability because of the "opaque, black-box, non-inclusive and simply poorly executed ex-ante feasibility and impact analyses" (Dooms, 2017).

Problems	Description
Unclear objectives or conflicts between stated and actual objectives	Sometimes appraisal criteria are hard to choose due to different objectives held by partners.
Prior political commitment	Schemes are hard to alter because of the political commitment made beforehand.
Inaccurate perception of current transport situation	Studies are often based on the historical data which is not consistent with status quo.
Incorrectly defined study area	Tightly defined study area may have negative knock-on effect on wide-scale studies.
Incorrect definition of the base and do-something cases	There is misinterpretation of 'do nothing' scenario and omission of 'do something' scenario.

Gold plating of the “do-something” option/cost over-runs	Some projects are over-engineered and incur over-capacity and over-provision.
Planning assumptions errors	Errors in planning assumptions will hazard the project scheme.
Incorrectly forecasted external factors	Inaccurate external factors forecast will have a negative impact on transport forecast.
Incorrect transport input	Travel speeds, frequencies and fares are not as forecasted.
Model error	Forecasting models may contain measurement, specification and aggregation errors and other problems.
Ignorance of interactions	Interactions among transport markets and within transport market are ignored.
Ignorance of dynamics	Disruption, new product and new technology may bring uncertainties to the project performance.
Incorrectly assessed project life	Technical life of the asset may be misjudged in some cases.
Omission quantifiable impacts	Some important and quantifiable impacts are unreasonably omitted.
Treatment of non-quantifiable impacts	CBA excludes the non-quantifiable impacts from the analysis.
Incorrect values used	No standard valuation is universally used for calculating non-monetized factors.
Double counting	Certain impacts may be counted more than once due to cascading effects.
Transfers	Transfers such as taxes, grants and subsidies are rarely identified.
Treatment of system effects	Some infrastructures only show their value in the whole system.
Rules changes	Political, financial and economic rules’ shifts affect the appraisal criteria.
Appraisal optimism	The Overestimated benefit and underestimated cost are widespread.

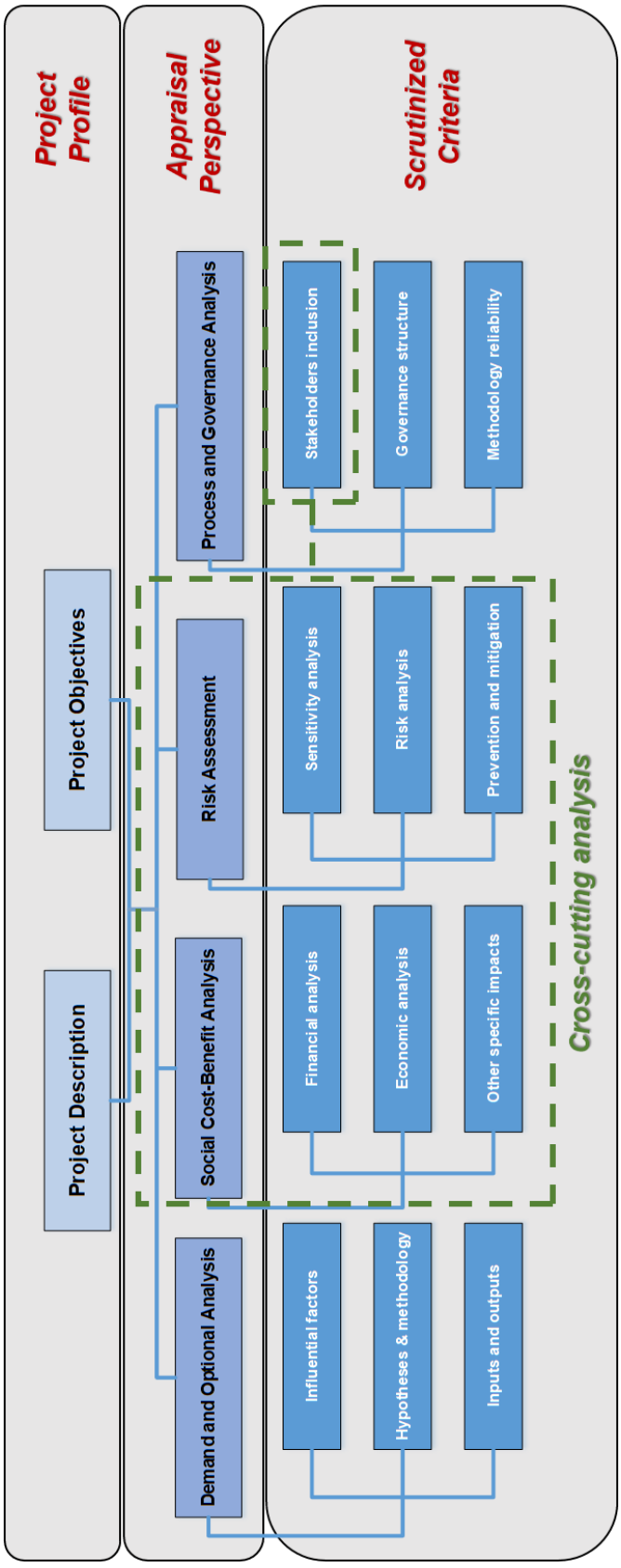
Table 2.3 Twenty-one errors and biases in transportation projects appraisal (Source: Mackie and Preston, 1998)

2.7 Conclusion: framework to assess the ex-ante decision-making of HZMB

Earlier in this chapter, the overview of LSTIP and the problem related the decision making of it indicate that the success of an LSTIP largely depends on the cost and benefit estimation, traffic demand forecast, actual construction time and political issues such as stakeholder inclusion. In order to control the risk, a number of evaluations were carried out before the project construction. However, these ex-ante evaluations often draw overoptimistic conclusions due to subjective and objective bias. This phenomenon is especially severe for the evaluation conducted by the governments which were prone to display positive and beneficial sides of the project while “strategically” adjust or even omit some critical but underperforming factors.

Thus, it is necessary for the non-governmental researchers and stakeholders to scrutinize the reliability and comprehensiveness of some ex-ante evaluations of the decision making of some LSTIP with significant impacts on the nearby regions. According to the recommendations and opinions provided in the literature so far, figure 2.1 shows the SCBA framework designed to assess the ex-ante decision-making based on the proposed case — HZMB. The dashed line in green shows the cross-cutting analysis in which the stakeholders inclusion will be evaluated from the SCBA and risk assessment.

Figure 2.1 The appraisal framework of the ex-ante decision-making of HZMB


Project Profile
Appraisal Perspective
Scrutinized Criteria
Project Description
Project Objectives
Demand and Optional Analysis
Social Cost-Benefit Analysis
Risk Assessment
Process and Governance Analysis
Influential factors
Hypotheses & methodology
Inputs and outputs
Financial analysis
Economic analysis
Other specific impacts
Sensitivity analysis
Risk analysis
Prevention and mitigation
Stakeholders inclusion
Governance structure
Methodology reliability
Cross-cutting analysis

3 Methodology

The purpose of this paper is to evaluate the ex-ante appraisal of the decision making of HZMB and accordingly recommend an ex-post appraisal framework of decision making of HZMB. Based on the existing ex-ante evaluation of the project, a qualitative, case-based research will be conducted to analyze the possible criteria and select critical indicators inside the framework. Specifically, the research will conduct a single case study which not only grounds in secondary data analysis and decision makers interview but also uses similar LSTIP in other countries to benchmark the case project.

Qualitative research usually refers to multimethod research which adopts an interpretive and naturalistic methodology to its research principal and emphasises qualities of entities (e.g. the processes and meanings) (Denzin & Lincoln, 1994; Denzin & Lincoln, 2005) Being one of the most popular research methods in qualitative study, the case study research has been adopted in many fields and this methodology is being implemented in the academic researches more frequently in recent years (Green, 2016).

The reasons for adopting case study research in this paper are closely relevant to the research questions and principal. On the one hand, from the definition, the case study research becomes more relevant to one's questions if these questions seek to "explain some contemporary situation and require an extensive and "in-depth" description of some phenomenon" (Yin, 2018). The main question of this paper perfectly aligns with the definition as the author tries to find out a suitable ex-post appraisal framework to assess the LSTIP like HZMB, for which an exploratory case study could be carried out to find out a possible solution. On the other, case study research is often regarded as a useful technique to study a research project at the preliminary and exploratory stage and to provide the initial basis to conduct a more structured and qualitative research method such as surveys and experiments (Rowley, 2002). The background of the paper suggests that not only the study's appraisal framework of LSTIP especially in ex-post situation could rarely be found so far but also the cases like HZMB which involves cross-regional and political issues were seldomly discussed under the topic of LSTIP. Thus, a case study research is quite appropriate in this scenario to investigate the selected case in depth and find out its uniqueness and possible enlightenment to similar studies.

Like any other research methods, case study research has its own strengths and limitations. Many researchers state their opinions on this method. In a nutshell, the pros and cons of case study research could be roughly summarised in table 3.1. For the single case study used in this dissertation, the major limitations lie in external generalisability and replicability as a unique cross-border LSTIP of China was selected as the principal case. The uniqueness of the project makes it difficult for the

author to find the highly identical projects to which the analysis result can be applied. Also, due to the time limit, the data collection and analysis in this case study is relatively inadequate if compared to the well-performed ones.

Advantages	Disadvantages
a) Providing in-depth analysis to real-life individual case (Flyvbjerg, 2006; Lindvall, 2007; McLeod, 2014)	a) Offering few generalizable conclusions to wider body of “similar” cases (Flyvbjerg, 2006; Stake, 1978: Jacobsen, 2002)
b) Creating hypotheses to guide future research and a field’s knowledge base (Jacobsen, 2002; Merriam, 2009; McLeod, 2014)	b) Drawing invalid conclusion due to the intuitive and subjective responses from external participants. (McLeod, 2014; Miles, 1979)
c) Investigating current events without control over behavioural events (Yin, 2018; Merriam & Nilsson, 1994)	c) Easily falling into researchers’ self-fulfilling prophecy due to their interactive role in the research (Flyvbjerg, 2006; Garger, 2013)
d) Catching information from more holistic perspective than experiments and surveys (Merriam & Nilsson, 1994; Gomm, Hammersley and Foster, 2000)	d) Lacking rigorous standard and giving too much freedom to investigator to get conclusions (Yin, 2018; Gibbert, Ruigrok and Wicki, 2008)
e) Handling and combining various kinds of data collection approaches (Eisenhardt, 1989; Merriam & Nilsson, 1994;)	e) Collecting and analysing the data is a time-consuming and labour-intensive activity (Miles, 1979; Yin, 2018; McLeod, 2014)
f) Enriching existing experience and improving humanistic understanding (Yin, 2018; Stake, 1978)	

Table 3.1 Advantages and disadvantages of case study research (Sources: Case-control studies: advantages and disadvantages (Sedgwick, 2014))

In general, a comprehensive case study research includes five phases. Figure 3.1 shows an overview of the procedure to operationalize a case study research in the author’s paper.

For the first stage, a single case study research will be adopted to find out the suitable ex-post appraisal framework for decision making of HZMB. Being a newly built LSTIP which opened to the public on October 2018, HZMB gains research values from its far-reaching impacts on social and economic benefit and politic uniqueness. First, the

bridge forms a triangular transportation network which completely alters the logistics pattern, especially in the container transport. It will release significant opportunities in Great Bay Area (GBA), boost tourism and expands Hong Kong's economic hinterland (Information Service Department of Hong Kong, 2018). On the other, the bridge was a strategic infrastructure project under the construction of GBA and more important, it involves three different regions with different policies in China. Thus, it is worthwhile to choose HZMB as an interesting case and critical model in the decision making of LSTIP.

In order to strengthen the validity and reliability of the case study research, this paper selects two benchmarking projects — the Oresund Bridge and the Fehmarn Belt Fixed Link. The reasons for choosing them are the high similarities they share with HZMB:

- They are all road links which mainly serve the transportation of automobiles and rail between different regions.
- They are all cross-border or cross-region LSTIPs with high political complexity and cooperative divergence.
- Part of these three projects consists of an underwater tunnel.
- They all influence the major transport pattern for passengers to commute between two shores.

For the second and third stages, the case study evidence and data will be collected from two major sources. First, an interview will be designed to collect opinion and suggestion from a decision participant of HZMB which could provide us with another perspective to judge the pros and cons in ex-ante decision making appraisal and revise the ex-post evaluation framework. The interview (see the Appendices) is a targeted and insightful way to collect case study evidence as it could concentrate on the critical topics of the case study and provide useful explanations and personal views (Yin, 2018). Due to the limited number of interviewees, the interview in this paper serves more like a supplementary source to support the analysis and ex-post appraisal frame design.

First, the documentation will be a significant source to perform secondary data analysis and provide benchmarking criteria. The sources via the documentation are advantageous in its stability, unobtrusiveness, concreteness, and broadness (Yin, 2018). In this case, the governmental documentation such as financial reports, annual performance dashboard, and project feasibility analysis will be collected from the website as well as the decision participants of the project and used as the foundation of analysis. This collection strategy is more suitable for the HZMB as most of the ex-ante studies were carried out on behalf of the government. Noteworthy, according to the interview with Mr. Yang, HZMB, a project 100% funded by the governments of three regions, keeps large part of official documents confidential in order to avoid media hype and intellectual property theft. Through his

help, we successfully collected the vital data and information in the confidential documents to support the analysis. As for the two European projects, due to the better transparency, most of the official documents have open access to the public. Meanwhile, the documents from academic journals, a scientific report from the university team and other non-governmental resources are abundant enough to provide extra information to support and improve the analysis. Table 3.2 depicts a full list of all evidence sources used for each case project.

For the analysis and reporting phase, the main strategy will be developing a case description: the ex-ante appraisal framework of HZMB will be scrutinized under the standard of a comprehensive ex-ante evaluation suggested by the European Commission and compared with that of the benchmarking cases. According to the result, we will summarise the strengths and drawbacks and draw a conclusion towards the quality of decision making of HZMB at the end of the case study. Meanwhile, we will recommend a possible ex-post decision-making appraisal framework for HMZB.

Figure 3.1 Steps to carry out a case study research (Sources: Case study Research and Application: design and methods (Yin, 2018))

Project Name	Official sources	Other sources
HZMB	a) CSHMPRD. (2015). Studies on the comprehensive impact of the HZMB on regional economic development b) Highways Department. (2009). Environmental impact assessment of HZMB c) Transport and Housing Bureau. (2008). Evaluation of the benefits of the HZMB project d) CCCC Highway Consultants CO.,Ltd (2009). Feasibility report of HZMB project (confidential) e) Official website: http://www.hzmb.hk/tchi/	a) Lau, E. (2015). Review of the application of cost-benefit analysis b) Qiu, Y., Chen, H., Sheng, Z. and Cheng, S. (2019). Governance of institutional complexity in megaproject organizations. c) Shiyong, M. (2014). A study on investment & financing mode decision of HZMB based on comprehensive evaluation of projects. d) Huanyu, L. (2010). Study on area development and traffic impact analysis of HZMB e) Zhu, Y., Shi, Q., Li, Q. and Yin, Z. (2018). Decision-making governance for the Hong Kong-Zhuhai-Macao Bridge in China.
The Oresund Bridge	a) Omega Centre. (2014). Project Profile: Sweden, The Oresund Link. b) Öresundsbro Konsortiet. (2019). Annual Report 2018 c) Official website: https://www.oresundsbron.com/en/start	a) Knudsen, M. and Rich, J. (2013). Ex post socio-economic assessment of the Oresund Bridge b) Cerrato, R. (2010). The Oresund Bridge and the commuting trends. c) Sørensen, M., Nielsen, O. and Schauby, J. (2019). The Øresund Traffic Forecast Model.
The Fehmarn Belt Fixed Link	a) CLS Communication A/S. (2014). Traffic forecast for the Fehmarnbelt Fixed Link b) The Danish Ministry of Transport. (2015). Cost–benefit analysis of the Fehmarn Belt Fixed Link c) European Court of Auditors. (2019). Assessment of the assumptions and general methodological quality of the EU Transport Flagship Infrastructure Projects' Cost-Benefit Analyses (CBAs) (confidential) d) Official website: https://femern.com/en	a) TENTacle. (2019). Guidance Paper: "How to use the Fehmarnbelt Fixed Link as impulse for regional growth ". b) FBBC. (2009). Creating Connections: the fixed Fehmarnbelt link.

Table 3.2 List of reference sources for the three projects

4 Case Study Analysis−Hong Kong-Zhuhai-Macau Bridge

4.1 Project Profile

The Hong Kong–Zhuhai–Macau Bridge, officially named as Hong Kong-Zhuhai-Macao Bridge (Chinese:港珠澳大桥), is one of the largest cross-regional major transportation infrastructure projects in China recent years. The HZMB project is regarded as a critical part of China's 13th Five-Year Plan to create an economic hub and promote the economic development of the whole area of the Pearl River Delta, which is also known as Greater Bay Area.

The construction of HZMB started on December 15th in 2009, completed on May 23rd, in 2018 and opened to traffic on October 24th in the same year. The history of the project could be traced to approximately 40 years ago. In the early 1980s, although the land transportation corridor between Hong Kong, Macao and the Chinese mainland continued to improve, the transportation links between Hong Kong and the West Bank of the Pearl River Delta were restricted by the barriers of the ocean. In order to enhance the connectivity and cooperation within Pearl River Delta as well as give full play to regional strengthens, the idea of building a bridge that connects three important cities on the Pearl River Delta had been proposed since the late 1980s. Although Zhuhai had established a bridge-building department since 1988, it was not until 2003 that National Development and Reform Commission (NRDC) together with the government of Hong Kong Special Administrative Region (HKSAR) had finally agreed on the construction of HZMB at initial phases. In 2009, the Chinese State Council authorized the feasibility report of HZMB made by research and consulting institution, which symbolizes the official start of this marvellous LSTIP (Zhang, 2010).

The Y-shape HZMB spans over the Lingding Channel meandering for 55 kilometres consists of three major sections—the dual three-lane Main Bridge with a underwater tunnel across the Pearl River estuary (29.6 km), two artificial islands housing the Hong Kong Boundary Crossing Facilities (HKBCF) and the Boundary Crossing Facilities for both mainland China and Macau, and two link roads connecting three cities to the main bridge (12 km in Hong Kong side and 13.4 km in the Zhuhai and Macau side) (Highway Department, 2019). At both ends of the HZMB, several intra-regional extensions were designed with great strategic significance and completed simultaneously with major sections. For example, on the Hong Kong's side the HKBCF serves more than a clearance facility for goods and passengers. It also becomes a transportation hub in HKSAR due to its convenient location: it not only connects to the Main Bridge through Hong Kong Link Road (HKLR) but also provides the North New Territories (NWNT) with a direct link to Hong Kong Port, North Lantau and the Hong Kong International Airport (HKIA) through Tuen Mun – Chek Lap Kok

Link (TM-CLKL). On the other side, the link in Zhuhai provide extensive connectivity with mainland's road network to the bridge through three major expressways (the Jing-Zhu Expressway, Guang-Zhu West Expressway and Jiang-Zhu Expressway). Consequently, major cities in the hinterland of West Bank of Pearl River Delta such as Guangzhou, the capital of Guangdong Province, can also gain benefits from the enhanced reachability to HKSAR. Figure 1 shows the overall construction structure of HZMB.

According the data provided in the official website, it is estimated that the HZMB will cost around RMB¥72.7 billion (€9.5 billion) in 2009 prices in which 50% of the budget was spent on the bridge-cum-tunnel construction in theoretical calculation and that from 2010 to 2035 the project will generate RMB¥74.0 billion (€9.6 billion) discounted total benefits in 2009 prices discounted at 8% from lower transport cost, saving in time costs and induced traffic volume. It is predicted that the project will take around 36 years to recover the cost with a 120-years technical life. However, the actual total spending of the project reaches at RMB¥127 billion (€16.5 billion) in 2018 prices. Meanwhile, the new report shows that the project needs at least 100 years to get its investment back due to cost overrun and cap on tolls (Yu, 2018).

The project objectives of HZMB can be roughly demonstrated by its direct and indirect benefits. For direct benefit, the link enables the passenger and cargo transportation in Western Pearl River Delta to fall into a three-hour commuting radius of Hong Kong. Travel times from Zhuhai to Hong Kong Kwai Tsing Container Terminal and HKIA are considerably reduced from 3.5 hours to 75 minutes (60% time saved) and from 4 hours to 45 minutes (80% time saved) respectively. For indirect benefit, the cross-sea project helps stimulate economic integration of the GBA while better enabling the competitiveness and complementary function of the cities (Information Service Department of Hong Kong, 2018).

Based on the available documentation of HZMB, the brief technical and financial description as well as major indicators of the project objectives are listed in the following table 4.1:

Technical description	
Component	**Description**
Bridge	3×3 lanes, width 33.1 m, length 22.9 km
Underwater Tunnel	3×3 lanes, width 28.5 m, height 5.1 m, length 5.6 km
Hong Kong Link road	3×3 lanes, length 12.0 km
Zhuhai Link road	3×3 lanes, width 31.5 m, length 13.4 km
Navigation condition	maximum 300,000 tonnage class tanker
Design speed	100 km/hour
Junctions	2 artificial islands in east and west bank
Technical life	120 years
Financial description	
Component	**Description**
Theoretical cost	RMB¥72.7 billion (€9.5 billion) in 2009 prices
Theoretical payback period	36 years
Actual cost	RMB¥127 billion (€16.5 billion) in 2018 prices
Actual payback period	>100 years
Project Objectives	
Indicator	**Target**
Travel time	reduced by 60% to 80%
Traffic volume	increased by around 38% in 2020
Discounted total benefits	RMB¥74.0 billion (€9.6 billion) in 2009 prices

Table 4.1 Project profile of HZMB

The preliminary planning process of the projects lasted for almost 30 years due to the complexity and difficulty of making the decision at the earlier stage: the project not only inherits the characteristics of common LSTIP such as the massive building scale and broad technology coverage but also confronts with inadequate referential experience, special geographic location and difference of judicial and construction system among three cities. The ex-ante decision-making processes of the HZMB were summarised in the feasibility study report, including:

- macroeconomic evaluation
- construction necessity evaluation,
- traffic volume forecast and analysis
- construction scale, bridge location and engineering schemes, environmental impact evaluation
- investment portfolio and financial analysis
- governance structure evaluation

Figure 4.1 Construction structure of the HZMB (Sources: Highways Department)

4.2 Benchmarking Projects Profile

As discussed in the previous chapter, the decision-making process of HZMB is unique and sophisticated. In addition to the lack of academic resources related to the decision-making evaluation of HZMB, the official feasibility report is partly confidential and not available to the public. In order to better evaluate the quality of decision making of HZMB, two European LSTIP are introduced as benchmarking cases. The selecting standard is quite straightforward—the Oresund Fixed Link has been awarded as one of the most successful cross-border projects in the 21st century whereas the Fehmarn Belt Fixed Link is one of the most promising mega transportation projects in the next decade. The decision-making process of these case project will be compared with that of the HZMB to find out the pros and cons in decision making of HZMB.

4.2.1 The Oresund Fixed Link

The Oresund Fixed Link, also known as the Øresund Bridge, is a bridge-cum-tunnel project connecting Copenhagen (the capital of Demark) and Malmö (industrial town and second-largest city in Sweden) across the Øresund Strait, one of the busiest waterways since 20th century. The completion of this sea-crossing corridor connects the central part of continental Europe with the Scandinavian Peninsula of Northern Europe, directly enhancing the regional connectivity in the whole of Europe to a certain extent.

The bridge was officially opened on July 1, 2000, with a total length of 16 kilometers from shore to shore. The whole project comprises three major parts—a cable-stayed bridge, an artificial island, and an immersed tunnel. The bridge at the east side of the link is 7,845 meters in length with a four-lane motorway and two railway lines beneath and has a 200-meter-high central pier with 57-meter-high navigation clearance to ensure the capacity of the ships passing through the strait (Janberg, 2019). The bridge is famous as one of the largest cable-stayed bridge in the world. The underwater tunnel situated at the west side of the bridge is 4050 meters long, 38.8 meters wide and 8.6 meters high. Most of the large-size vessels could pass through the unobstructed sea area above the tunnel. The artificial island in the middle is 4055 meters long and serves as a buffer junction between the bridge and the underwater tunnel at two sides of the project (Øresundsbro Konsortiet, 2006). Figure 4.2 shows the overall construction structure of the Oresund Fixed Link.

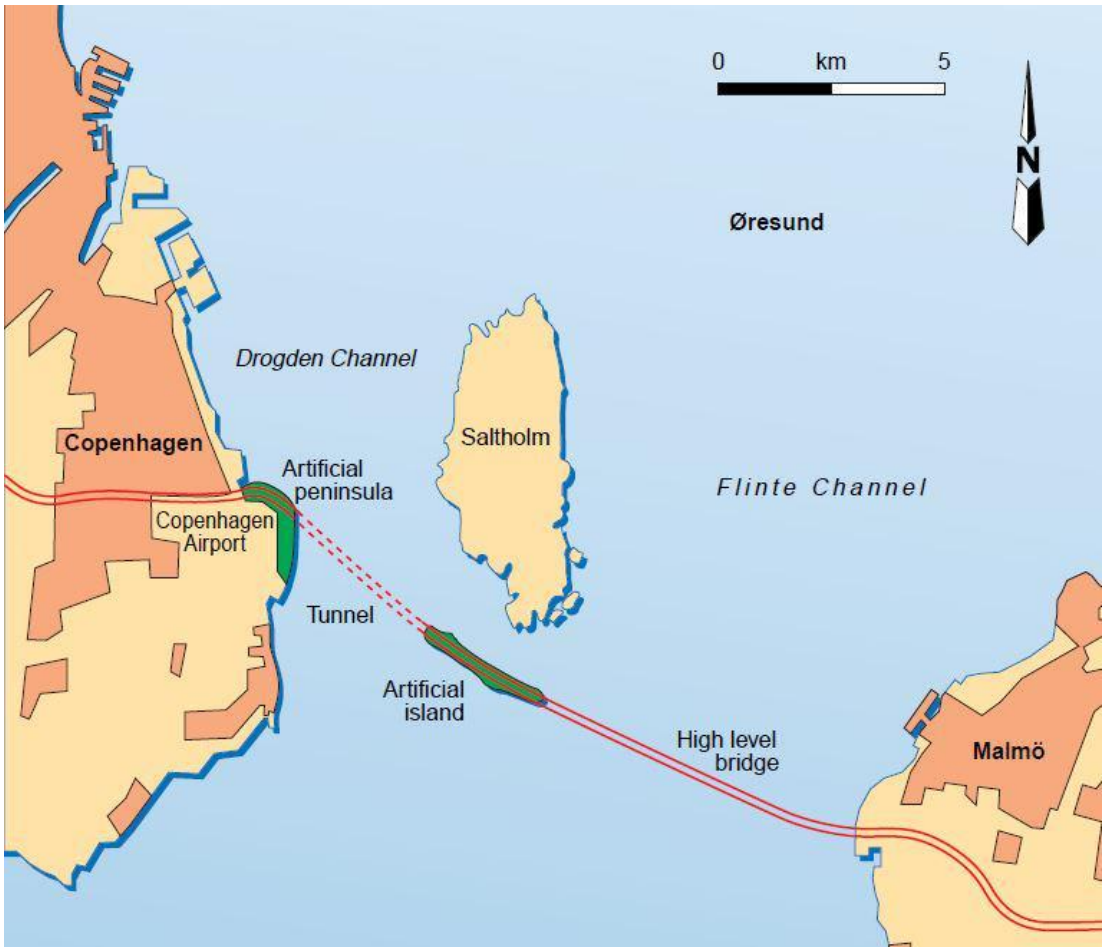


Figure 4.2 Construction structure of the Oresund Fixed Link (Sources: Institution of Civil Engineers, UK)

The reasons for building this bridge are more than a critical connection for northern Europe to access in central Europe. The bridge could also encourage the formation of the so-called 'Oresund Region' which will become the economic centre in Northern Europe. Additionally, with the fast development in both countries, there has been an increasing demand for cheaper houses in Copenhagen and job opportunities in Malmo. The bridge could perfectly alleviate the situation as Danish could buy house in Malmo with more reasonable price whereas Swede could find more opportunity in the capital of Demark.

Since the official operation in 2000, the fixed link has brought a substantial impact on the transport pattern and the traffic volume in the Oresund area. The fixed link not only completely replaced the three southern ferry routes to undertake the transportation tasks but also gradually took away a number of passenger and cargo flow from the northern ferry routes connecting Elsinore and Helsingborg. Meanwhile, the traffic volume of the bridge increased significantly due to the induced traffic flow across the bridge. As shown in figure 4.3, the traffic demand in the following six years

even outnumbered the estimated volume in the ex-ante report (Øresundsbro Konsortiet, 2018).

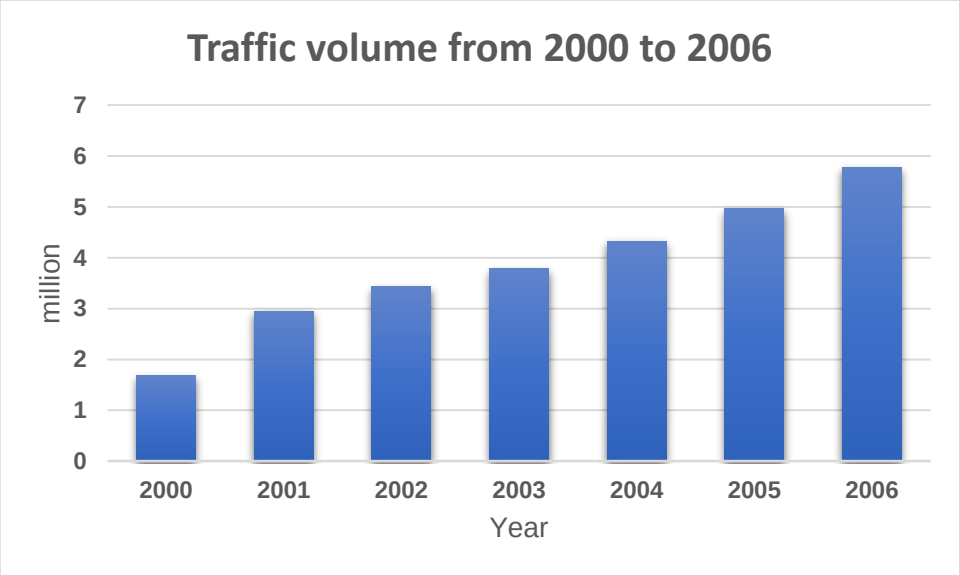


Figure 4.3 Actual traffic volume of the Oresund Fixed Link (Source: Traffic Statistic on Øresundsbron.com)

The total cost for the fixed link was approximately €4 billion under the price index in 2000. The investigation done before the opening of the bridge indicated that under a 4% interest rate it would take 60 years to reach the break-even point of the cost and benefit. However, with significant price reduction policy and the attractive interest rate on loans introduced after 2001, the construction cost of the project was expected to be recouped by 2037 (OECD, 2003). In the 2018 annual report of the bridge, the pay-back period was prolonged to 50 years due to some uncertainties and the debt was expected to be repaid in 2050, which is still less than the estimated 60 years (Øresundsbro Konsortiet, 2019). Obviously, the actual performance of the bridge suggests that this LSTIP can be regarded as a sound investment and benchmarking model from a socio-economic perspective. Also, from an environmental perspective, the bridge project has effectively adopted strict regulations on ensuring that the bridge does not affect the ocean current flowing into the Baltic Sea and cause damage to marine life after careful study and investigation by the two governments.

Table 4.2 lists the technical and financial descriptions as well as the indicators of project objectives.

Component	**Description**
Bridge	2×2 lanes, width 23.5 m, length 7.8 km
Underwater Tunnel	2×2 lanes, width 38.8 m, height 8.6 m, length 4.0 km; 2 tubes for railway, 2 tubes for roads and 1 tube for emergencies
Navigation condition	maximum 300,000 tonnage class tanker
Junctions	1 artificial island in the middle
Technical life	100 years
Financial description	
Component	**Description**
Theoretical cost	€2.4 billion in 1991 prices
Theoretical payback period	60 years
Actual cost	€4.0 billion in 2000 prices
Actual payback period	50 years
Project Objectives	
Indicator	**Target**
Traffic volume	Cars increased by 6% and heavy vehicles by 3% annually
Discounted total benefits	Gained €8.41 billion (US$9.32 billion) in 2015 prices
Expected profit in 2019	€185.1 million (US$205. 2 million) in 2018 prices

Table 4.2 Project profile of The Oresund Fixed Link

4.2.2 The Fehmarn Belt Fixed Link

The Fehmarn Belt Fixed Link (also could be written as Fehmarnbelt Fixed Link) is a new LSTIP in Northern Europe proposed to build an immersed tunnel to connect Lolland island in southern Demark with Fehmarn island in Germany. The underwater tunnel will become the longest immersed concrete tunnel for both road and railway in the world which spans 18 km across the Fehmarn Belt in the Baltic Sea. It is predicted that the tunnel has the potential to be another important connection between Central Europe and Scandinavia after the Oresund Fixed Link as it shortens the travel time between Demark and Germany from around 1 hour to less than 10 minutes by either car or railway (Femern A/S, 2019). Figure 4.4 shows the location of the fixed link on the map.

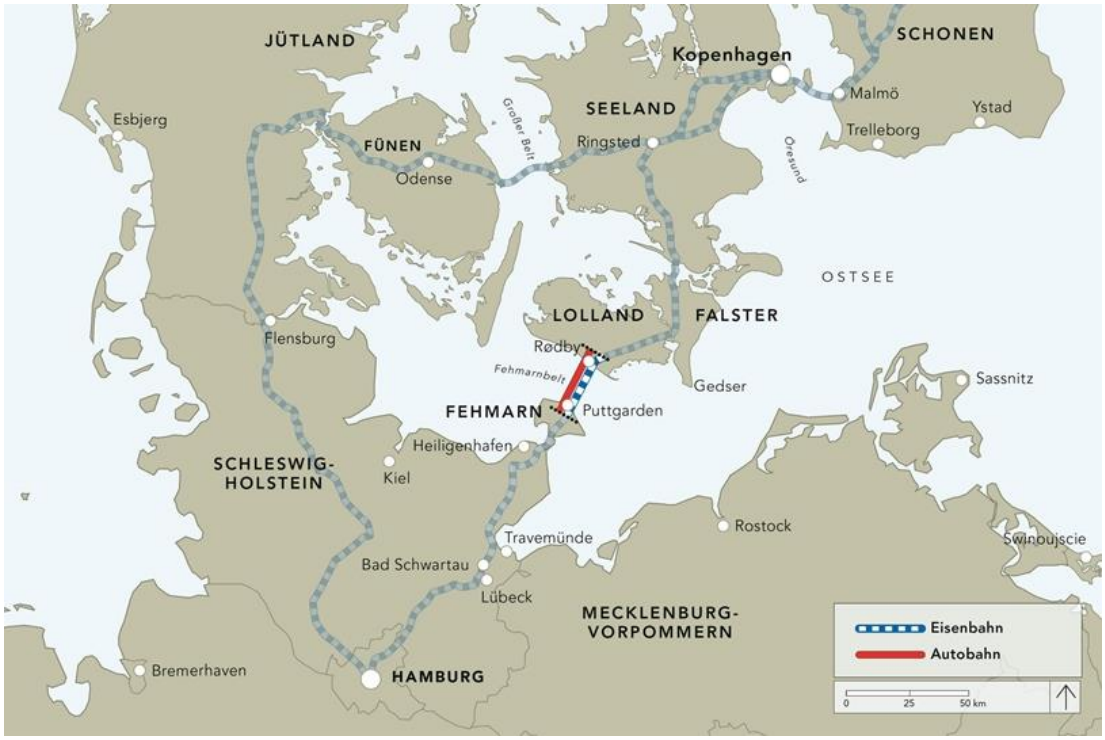


Figure 4.4 Connection of the Fehmarnbelt Fixed Link (Source: Femern A/S)

The tunnel is scheduled to begin construction in 2020 and complete in 2028. In February 2019, the latest progress entered the final approval process for the railway sector by the German national parliament (Femern A/S, 2019). The tunnel is evaluated as a comparable mega project to Oresund Bridge in terms of the project's size and strategic significance. Also, the tunnel will replace a ferry route named "the bird flight line" on which the commuters in both shores heavily depend at present. However, unlike the Oresund Bridge, the Fehmarn Belt Fixed Link is 100% formed by an immersed tunnel which is about five times the tunnel section of the Oresund Fixed Link. The tunnel with a rectangular cross-section (width 40 meters and height 10

meters) will provide two separate motorways to automobiles and two separate tracks to the railway.

The overall construction budget for the project reaches €7 billion included a backup saving of €940 million. In 2015, the European Union Commission has designated this project as one of the 30 prioritized transport infrastructure projects (TEN-T). The Commission has allocated €230 million for the design process and €710 million for the construction process to the project as the initial contribution (Femern A/S, 2019). Sharing the same financial portfolio with The Oresund Fixed Link, the tunnel project was forecasted to pay back its debt in 36 years after the opening. It was estimated that the project will gain €3.8 billion aggregate net benefit (2014 prices discounted at 4% for the first 35 years, then 3% for the rest) over 50 years with a forecasting 3.4 million traffic demand in the opening year.

The Danish state-owned company Femern A/S (2019) summarises 10 reasons for building a direct link between Germany and Scandinavia under the Fehmarn Belt, which can be roughly concluded in the following points:

- Provide a shorter and reliable link between Denmark and Germany, the operation of which will not be influenced by either weather or congestion.
- Strengthen the trade relations among the Nordic countries (Denmark, Sweden, Norway, and Finland) by opening a new gate to the Central European market.
- Upgrade the regional links and boost tourism throughout the entire Fehmarn Belt region.
- Encourage the cross-border business partnerships, the exchange of idea and culture and social co-operation.
- Generate new jobs and educational opportunities from the construction stage to the operating stage.
- Bring a positive CO2 effect by delivering greener transportation modes.
- Close a gap in the whole European transport network

Although there is still a decade to witness the completion of the Fixed Link, the LSTIP has been regarded as a very beneficial and far-reaching project not only for the Germany and Denmark but also for entire Europe. This can be proved by the strong financial support from the European Union. TENTacle (2018) conducted a study to analyze the impact of Fehmarnbelt Fixed Link on regional growth, showing that the project has a relatively higher possibility of bringing positive influence on the region. In addition, key lessons and learned during the construction of the Øresund Fixed Link, which was built in a similar way in 2000 and regarded as one of the most successful LSTIP, will be benchmarked and applied to Fehmarn Belt.

Table 4.3 lists the technical and financial descriptions as well as the indicators of project objectives.

Technical description	
Component	**Description**
Underwater Tunnel	2 tubes for railway and 2 tubes for roads, width 40.0 m, height 10.0 m, length 17.6 km;
Technical life	Around 100 years
Financial description	
Component	**Description**
Theoretical cost	DKK 52.6 billion (€7.0 billion) in 2016 prices
Theoretical payback period	36 years
Actual cost	Unknown
Actual payback period	Unknown
Project Objectives	
Indicator	**Target**
Traffic volume	3.4 million cars in the mid-2028
Aggregate net benefit	DKK 28.0 billion (€3.8 billion) in 2014 prices

Table 4.3 Project profile of the Fehmarnbelt Fixed Link

4.3 Evaluation of Demand and Optional Analysis

In general, demand analysis is adopted in an ex-ante appraisal process to identify the ideal productive capacity and necessary investment for a project by assessing the current demand collected from service suppliers, regulators, ministries, national and regional statistical offices and future demand based on reliable and reasonable forecasting method (European Commission, 2014). The demand analysis always coexists with the optional analysis in which all feasible options in the decision-making process are compared to find out the best scenarios to undertake a project. In the transport sector, the demand analysis usually refers to the traffic volume analysis in which optional analysis is always involved and presented as scenario analysis.

In order to develop a traffic forecasting, factors or critical variables that will lead to the change in traffic volume such as demographic changes, industrial and logistics structure and developments and elasticity with respect to quality, time and price should be considered beforehand to develop three traffic scenarios with different perception of future trend of these variables (high, most likely and low) (European Commission, 2014). Then, hypotheses regarding the project's impact area, degree of complementarity and competition among transport modes, the deviations from historical trends and the sensitivity of demand pattern should be made before the modelling of traffic distribution. Finally, the outputs of the traffic forecast should be indicated by parameters that reflect the passenger and/or cargo traffic as well as the travel times and other network performances.

The most reliable traffic forecast of HZMB was the feasibility report done by China

International Engineering Consulting Corporation (CIECC), whose authoritativeness and authenticity were confirmed by the interview. The traffic volume analysis of HZMB consists of three sections: investigation on existing traffic Origin and Destination (OD) of HZMB, study on impact of Closer Economic Partnership Arrangement (CEPA) and the completion of Hong Kong Disneyland on induced traffic of HZMB, research on the impact of HZMB on important ports in the region. In align with the major function of the bridge, the traffic volume forecast is based on the cross-border traffic demand by road between Hong Kong, Zhuhai, and Macao where the gateways, terminals and control points of the route that have a high possibility to generate traffic flow on HZMB are selected as the investigation sites. In the cross-border investigation conducted by Planning Department of Hong Kong in 2003, a number of investigators are assigned to the selected cross-border facilities and important control point—Humen Bridge, a vital river-crossing link between Zhuhai and Shenzhen Special Economic Zones—to interview a sample of travelers and drivers for two weeks. The 14-days interview is performed for passenger and freight traffic in an hour and direction basis through random sampling to collect the information about:

- travel purposes of travellers
- transport mode chosen by travellers
- origin and destination of travellers and drivers
- socio-economic characteristic of all kinds of travellers
- vehicle type and its drivers' traveling habits
- distribution of different cargo types

After the collection of the raw data, the cross-border traffic volume for passenger and freight were forecasted through Four-Stage Modelling Approach, a combination of time series and qualitative analysis under three predetermined charging schemes of HZMB. The time series analysis provided a solid quantitative estimation of the growth tendency whereas the qualitative analysis was conducted in different period of time in the future as an complementary study in which the impact of the important policies such as CEPA, the growth in interregional trade and the completion of tourist attraction such as Disneyland on the future traffic demand was taken into account to revise the final forecasting results of the traffic volume. As for the premise of the forecast, a floating annual passenger and freight growth rate was applied separately on a yearly basis. In addition, due to the variety of transport modes between Hong Kong and mainland China, the traffic forecast made another prediction of the distribution of the transport modes by using the Logit model. Based on the initial forecasting results, four scenarios were tested according to the possible variation in the social environment, economic development level, traffic policy, and integrated transport planning. Unlike the different charging scenarios, these scenarios offered a further aggregate analysis of the fluctuation of the future traffic volume. Table 4.4 summarized the description and the underlying dimensions of the scenarios.

Scenario Name	Description	Underlying Dimensions
Quota system	The quota system poses caps on the cross-border traffic volume on each side and the deregulation could bring around 20% more traffic demand to the HZMB.	a) No quota system b) Quota as usual (control group) c) Only quota the traffic inflow of Hong Kong
Construction of Nansha bridge	The construction of the bridge will reduce the traffic volume 40% at most with same price level of Humen Bridge.	a) With Nansha Bridge (subdivision of high/low toll level) b) Without Nansha Bridge
Toll level	Different price portfolios of toll system will have different traffic demand and toll revenue, lead to a trade-off between traffic volume and financial benefit.	Each type of vehicle has 10 toll level scenarios: private car, general and container truck pricing from RMB¥100 to ¥280; tour bus from RMB¥200 to ¥650;
Economic projection	The uncertainty of economic projection will influence the cross-border traffic demand and distribution in the future	a) Neutral forecast (control group) b) Conservative forecast (5% increase in growth rate) c) Optimistic forecast: (10% decrease in growth rate)

Table 4.4 Scenarios in traffic forecast of HZMB

Regarding two benchmarking projects, the traffic forecast of Oresund Bridge was briefly introduced and evaluated in an ex-post study conducted by Knudsen and Rich in 2013. The Oresund traffic forecast model is a utility-based model that contains several sub-models for estimation of short- and long trips, and different travel purposes in passenger and freight traffic. Two parallel scenarios including the bridge and the hypothetical if no bridge had been built were considered in the model to stimulate and forecast the traffic flow of all relevant modes of travel between two territories. The Knudsen and Rich's study depicts that the traffic forecast of Oresund Bridge from the Oresund Consortium forecasting model is relatively successful through a superficial time-series model although overestimation happened during the first years, but the losses were compensated by the additional traffic volume in the following years. were However, the traffic forecast was being criticized by Sørensen, Nielsen, and Schauby (2019) for the omission of the competition between fast ferries and the railway and the scale of social and economic barriers for short-distance traffic.

For the Fehmarnbelt Tunnel, the latest forecast was a traffic forecast report based on the FTC and Trans-Tool model from Femern A/S in 2014 and the new forecast updated the forecast data and optimized the methodology used in the 2003 forecast report. As the premise of the forecast, the traffic trends together with their relationship with the economy for the Feharnbelt over the past 40 years was introduced. Based on the relationship, the economic development with a possible recession in the following years was predicted to provide some important macro-economic parameters in the traffic forecasts. Then, the traffic volume was forecasted in two different levels: from a geopolitics perspective, the traffic demand between Scandinavia and Continental Europe was estimated by Trans-Tools trans-European traffic network model including three scenarios based on the scenarios for the development of the other transport infrastructures in Europe. From a regional perspective, the specific traffic demand in the Fehmarnbelt corridor was projected under two different scenarios by the tailored FTC model. Two scenarios in this forecast model were based on different growth expectations in which the main scenario (Case A) refers to the growth expectations from the OECD and the sensitivity scenarios from the German government.

Table 4.5 shows and compares the traffic forecast frameworks of the three projects.

	HZMB	The Oresund Bridge	The Fehmarn Belt Fixed Link
Forecast model	Four-stage Modelling Approach (time-series revised by qualitative analysis)	Oresund Traffic Model by COMVIN J/V	FTC Model and Trans-Tools Model
Scope of the model	Long-term traffic volume for passenger and freight transport from 2010 to 2035	Long-distance and short-distance passenger trips and freight transport	FTC: The traffic trends in the Fehmarnbelt corridor in the medium and long term Trans-Tools: The overall traffic trends between Scandinavia and Continental Europe through Fehmarnbelt corridor
Influential factors	a) Different charging schemes on the bridge b) Impact of the important policies c) The growth of interregional trade d) Macro-economic development e) Completion of tourist attraction and other infrastructures f) Capacity of the boundary crossing facilities g) Traffic volume quota system	a) Different fare policies on the bridge b) Competition of other transport services offered for both private and public users c) Macro-economic development d) Changed restrictions on land use e) Different transport policy options e.g. fuel taxes g) Price elasticities	a) Influence of other infrastructures b) Transport cost structure c) Socio-economic assumptions d) Marco-economic development e) Changed restrictions on land use f) Demographic development
Compound annual growth rate	Different growth rate under different scenarios	General growth rate (determined by GDP) plus a trip-generation growth rate (determined by population, employment and income)	FTC: 2% from 2022 to 2026; 1.5% from 2026 to 2035; 1% from 2035 to 2047; and 0% after 2047 Trans-Tools: 4.0% for passenger and 3.4% for freight from 2005 to 2030
Alternative scenarios (optional analysis)	See table 4.4	Bridge and no bridge	FTC: The main scenarios (OECD growth expectation) and sensitivity scenarios (German growth expectation) Trans-Tools: Three scenarios based on the scenarios for the development of the other transport infrastructures in Europe
Consideration of ferry competition and losses	No consideration of ferry competition and losses	No comprehensive enough due to the omission of the competition between fast ferries and the railway and the scale of social and economic barriers for short-distance traffic	Sufficient consideration and analysis of ferry competition conducted by German Intraplan and BVU

Table 4.5 Traffic forecast frameworks of the three projects

Compared with that of benchmarking cases, traffic forecast of the HZMB have main advantages as following:

- **Combining scenarios analysis with the sensitivity analysis:** In the traffic forecast of Fehmarnbelt Tunnel, the final step of the traffic forecast was a regular sensitivity analysis separated from the scenarios under two criteria, i.e., the German growth expectations and continued ferry service. However, in the HZMB case, the scenario analysis was mixed with sensitivity analysis. In the four-stage forecast, the initial outcomes are based on the default scenarios (Normal quota system, without Nansha Bridge, neutral economic forecast, three presumed toll portfolios). Then, in the final chapter, each criterion in the default scenarios was changed while kept the rest as default and the new forecast outcomes were presented to find out its relative significance. By doing so, the combining analysis not only serves as a sensitivity analysis but also enriches the forecast outcomes through a different combination of scenarios.

- **Further classification of induced traffic volume:** In the benchmarking projects, there is not a clear statement about the induced traffic in the forecasting model but often an overall traffic trend in the region. In the HZMB case, the induced traffic of HZMB is classified into three parts: 1) the traffic generated from the improvement of transport condition 2) the traffic generated from the economic structure change in three regions 3) the traffic generated from the external projects like Disneyland. Compared to the general consideration of inducing traffic, this dismantling classification of induced traffic created a clearer guideline to the following forecast.

- **Improved time-series forecast:** The forecast of HZMB shares more similarity with that of the Oresund Bridge as they both adopt the time-series approach to forecast the passenger and freight traffic. However, unlike the superficial one done in the Oresund case, the time-series forecast in the HZMB case was an upgraded one which not only conducts a qualitative analysis to revise the growth rate in passenger forecasts but also forecasts the freight traffic under different categories rather than as a whole.

However, some drawbacks also can be found in the traffic forecast procedure of HZMB:

- **Insufficient official traffic forecast and severe overestimation at initial stage:** In the Oresund case, six forecasts of traffic volume in 2000 have been done by different authorities before the completion of the link since 1985. Also, in the Fehmarnbelt case, an enhanced traffic forecast report was published in 2014. However, the HZMB traffic forecast was largely based on the feasibility

report done by CIECC in 2009 after which no other follow-up forecast could be found on the official reports. Also, compared to the average 30% deviation (underestimated or overestimated) to the actual traffic flow in Oresund's forecast in the first year's operation, the average deviation of the HZMB reached 73.5% at the first 6 months and 100% of them were an overestimation.

- **Insufficient consideration of alternative routes:** Although the existing report considers the completion of Nansha Bridge, it neglects the possibility of the construction of the fixed link between Zhongshan and Shenzhen. The new fixed link will be located in the middle of HZMB and Nansha Bridge and serve as a new connection between two shores in 2024. This fixed link will undoubtfully become a serious competitor to HZMB without cross-border inconvenience. This omission can also be found in the benchmarking cases as their forecast only took existing or almost-finished alternative routes into account but ignore the potential alternative routes. The insufficient consideration of a possible route may hazard the reliability of the forecast.

- **Lack of consideration of the ferry competition:** In the Fehmarnbelt case, the ferry competition was considered in the sensitivity analysis where the traffic loss of the tunnel generated from continued ferry service was calculated and analyzed. On the contrary, the traffic forecast of HZMB did not involve any impact brought by the ferry service which had been operated for decades. According to the government report, 52.1% of the transboundary freight transport was accomplished by ferry or barge which shuttles between the mainland and Hong Kong. Also, the ferry has been the fastest way for those who live in the western bank of the PRD to travel to Hong Kong since 1997. Thus, the exclusion of ferry competition will weaken the quality of the freight and passenger forecast to certain extent.

4.4 Evaluation of Social Cost-Benefit Analysis

As discussed in chapter 2.2, Social Cost-Benefit Analysis is a prevailing methodology built on the basic Cost-Benefit Analysis and designed to evaluate public investment projects from the social perspective. The highlight of SCBA is that the method considers and evaluates all intangible benefits after turning them into monetary forms. A comprehensive SCBA should have a framework which consists of two major sections—financial analysis and economic analysis. In the transport sector, the financial analysis uses the investment costs, operation, and maintenance (O&M) costs and projected revenue to compute the financial performance indicators and then assess the financial profitability and sustainability of the project. Although the financial analysis of SCBA is similar to that of CBA, the economic analysis is more sophisticated in SCBA. The economic analysis is based on three types of economic

effects: direct effects such as operating cost for road users and service carriers, indirect effects such as travel time reduction and external effects on environment and society such as accidents, noise, air pollution, climate change, and congestion. A good SCBA will help the project find an optimal equilibrium between its financial components and social and environmental consequences.

The interview with decision participants of HZMB has proved that no detailed social cost-benefit analysis report could be found for the HZMB in the available sources as the decision makers of HZMB focus more on the project's strategic and welfare benefit instead of its direct financial gains. However, a brief review of CBA conducted by Lau (2015) from the Hong Kong Institute of Surveyors as well as some government reports provides some useful information about the CBA of the HZMB—a traditional CBA was done by several transport experts within an international framework recommended by OECD in the Hong Kong side. For the financial part, it is estimated that the net economic benefits at discounted present value, also known as Expected Net Present Value (ENPV) will be approximately RMB¥40 billion (€5.2 billion, 2009 prices) in total over 20 years. In addition, the project is projected to have an Economic Internal Rate of Return (EIRR) of 8.8% for 20 years or 12% for 40 years. According to the report, the results prove the financial viability of HZMB when compared to contemporary LSTIPs such as Shatin to Central Link and Hong Kong section of Guangzhou-Shenzhen-Hong Kong express rail link. Two scenarios, i.e. with and without the HZMB, was used for the economic analysis. It is expected that Zhuhai and Zhongshan, two closest cities to the HZMB, will have achieved 10 to 11% GDP growth as the indirect benefit over a 20-year period since the opening year. Also, it is estimated that the total discounted direct benefits in 2009 prices including savings in transport costs, value of time saved for passenger and freight and induce traffic volume will be RMB¥74.0 billion in total which are allocated to three regions according to the traffic flows generated from each city (57.8% for HK, 32.6% for Mainland and 9.6% for Macao). As a supplementary of the CBA, a separate Environmental Impact Analysis (EIA) was conducted by the Hong Kong Highways Department to scrutinize the project's influence on the environment.

In the Oresund fixed link case, although the ex-ante cost-benefit evaluation of the project cannot be accessed from the public, the ex-post social-economic evaluation done by Knudsen and Rich (2013) could be regarded as an improved SCBA framework which includes all elements at the ex-ante stage. The highlight of its financial analysis is that all relevant Danish and Swedish cash flows are included in the calculation of the NPV and other indicators and that a discount rate recommended by the European Commission rather than the Danish Ministry of Transport was applied. The aggregated evaluating method strengthens the framework from an international perspective. However, it is notable that both external impacts such as

accidents, emissions and noise, and air traffic were excluded due to the offset effect. For the economic analysis, most efforts are spent on projecting the consumer benefit for transport. The consumer surplus follows the ‘rule-of-the-half’ approximation from Kidokoro (2004) which represents passenger and freight benefits as a whole and in several transport markets.

The cost-benefit analysis of the Fehmarnbelt tunnel learns the experience not only from the Oresund fixed link but also from German LSTIP. In the cost-benefit analysis, an improved CBA was carried out with a harmonised Danish/German evaluation approach based on German principles which roughly covers total investment cost, O&M cost, saving transportation cost and time cost, external cost and consumer surplus. A synthesizing table showing all financial performance indicators was presented under the financial analysis section whereas detailed subdivisions are included in the economic analysis. For example, the time cost savings are computed separately in road and rail traffic, and the value of time within the road traffic is distinguished from business and leisure trips. In addition to the basic and no-build scenarios, three principal scenarios together with eight technical solution models were taken into account. Noteworthy, the so-called CBA of the Fehmarnbelt tunnel encompasses the intangible social benefit of employment and converts it into monetary value. Thus, the improved CBA can be regarded as a simplified SCBA which takes certain social impacts into consideration.

Table 4.6 summarizes the three projects’ assumptions, cost-benefit categories and the monetized methods used for calculating the value of time.

	HZMB	The Oresund Bridge	The Fehmarn Belt Fixed Link
Analysis period	2010 to 2035	2000 to 2050	2022 to 2071
Discount rate	8%	3.5%	4% for the first 35 years, then 3%
Cost categories	a) Constructions cost b) Operational cost c) Maintenance cost d) Overhaul cost	a) Constructions cost b) Operational cost	a) Constructions cost b) Operational, maintenance and reinvestments cost c) Taxes and tax corrections d) External costs e) Labour supply impact f) Correction, earning from ferries
Benefit categories	a) Revenues b) Transport cost reduction c) Time saving benefit d) Induced traffic benefit e) Benefit from less port facilities and lower handling costs	a) Revenues b) Consumer surplus (Time saving and transport cost reduction)	a) Revenues b) Time saving benefit for road c) Time saving benefit for rail d) Transport cost reduction for road e) Transport cost reduction for rail
Classification of value of time for passengers	a) Business and work travel b) Leisure travel	a) Business travel (rail and car) b) Commuting travel (rail and car) c) Other travel (rail and car)	a) Passenger cars and buses (road) b) Lorries (road) c) International passengers (rail) d) National travellers in Demark and Germany (rail)
Values of time saving	a) For business and work travel, value of time saving equals to % of salary plus other employment-related expenses; b) For leisure travel, value of time saving equals to the willingness to pay. Value of walking and waiting time equals to 150% of time saving c) Value of walking and waiting time equals to 150% of the value of time saving in two kinds of travellers.	The value of time follows the standard estimates derived from Fosgerau (2006) and available in TERESA	a) For road traffic: value of time (passenger car and buses & lorries) is calculated differently under the "rule of half"; shadow waiting time equals to the 80% the time value for journey time while waiting time equals to the value of delay time b) For rail traffic: value of time (international and national passengers) is calculated under the "rule of half";

Table 4.6 Social cost-benefit analysis profile of three projects

Compared with that of benchmarking cases, the cost-benefit analysis framework of the HZMB have main advantages as following:

- **Elaborated cost and benefit split:** In the benchmarking cases, the costs and benefits of the cross-border LSTIP were calculated from the project's perspective but not subsequent analysis was done to find out a reasonable allocation of the costs and benefits to the countries participating in the construction of the project. In contrast, the cost-benefit analysis of HZMB clearly indicates the split of costs and benefit on a slightly different basis with logical reasoning and calculations. The project's benefits were split proportionally with the total traffic volume generated from each territory which was later found to be 57.8%, 32.6% and 9.6% for Hong Kong, Mainland, and Macao respectively. Taking into account the benefit allocation and costs spent on respective connecting roads, the costs of the main construction were apportioned accordingly to 50.2%, 35.1% and 14.7% for three regions. The merit of coherent allocation is that it provides a dependable reference to the unilateral cost-benefit or other relevant analyses which will be independently conducted in the three territories.

- **Horizontal comparison in financial analysis:** The financial analysis of two European projects proved the project's financial viability through a very simple comparison between computed EIRR and a presupposed standard discount rate. However, this comparison itself seems hardly sufficient to evidence the remarkable financial profitability of the projects. By listing EIRR of other infrastructure projects which were undertaking with the same discount rate, the financial analysis of HZMB enhanced the persuasion of cost-benefit analysis by providing a horizontal comparison of contemporary projects. The result indicates that the HZMB, with an EIRR of 12% over 40 years, performed the highest financial viability and profitability among five LSTIPs of Hong Kong in the same period.

However, the weaknesses of the HZMB's framework are obvious and improvement should be made in following aspects:

- **Lack of an aggregated cost-benefit analysis:** Compared to that of benchmarking cases, the CBA of HZMB is less aggregated in both its criteria coverage and applicable region. First, the CBA of HZMB was performed very much close to a purely financial analysis because it did not cover the environmental criteria in its framework even though following the OECD standard. As a complementary study, an isolated EIA was used for evaluating the environmental influences of the project. However, the separation is not an

ideal strategy but possibly hazard the quality of project evaluation because the EIA can't be viewed as the same level evaluation to CBA without enough quantifying analysis. On the other hand, most of the outcomes in the CBA were depicted from Hong Kong's standpoint and measured under Hong Kong's standard. Thus, the applicable region of the CBA is limited as the results are less meaningful for decisions made in Mainland and Macao.

- **Insufficient evaluation of intangible impact:** Unlike the Oresund and Fehmarnbelt case in which most of the social and environmental impacts were either offset by certain externalities or quantified in an improved CBA, the HZMB did not evaluate the project from a social perspective according to the existing governmental report. Also, the project's environmental impacts were not monetized and computed in the CBA conducted by transport experts but merely evaluated through a very qualitatively analysis approach. In this case, the CBA of HZMB may be vulnerable due to incomprehensive economic analysis which does include the basic indicators such as travel time and transportation cost savings but ignores the significance of intangible indicators such as air pollution, noise, and employment, etc.

- **Insufficient alternative scenarios:** Although several scenarios were analyzed in the traffic forecast of HZMB, the scenarios used in CBA were simplified to two base cases adopted in most of the CBA framework, i.e., with and without the project. In the benchmarking projects, the analysis framework of the Fehmarnbelt tunnel provided three extra options with eight technical solution models other than two base cases. The extensive scenario analysis of CBA demonstrates the project's financial and economic performance under various situations, the results of which will suggest a broader financial and economic feasibility of the projects if the results are positive under most scenarios. As a cross-border LSTIP with three territories involved, HZMB has a more complex politic and social background than Fehmarnbelt tunnel. Thus, the scenarios considered in the CBA of HZMB at present are insufficient to support the decision making at this stage whereas more alternative scenarios should be added to validate the financial and economic feasibility of HZMB.

4.5 Evaluation of Risk Analysis

In a comprehensive ex-ante project evaluation, a risk assessment must be carried out in the final section to figure out the major uncertainties that may seriously impede the project's success. A recommended framework for assessing the risk of a project provided by European Commission (2015) consists of three stages: at first stage, a sensitivity analysis will be conducted with a scenarios analysis to classify the impacts

of internal fluctuation of some critical variables on project's financial and/or economic performance. The critical variables refer to the independent and uncorrelated variables in which a 1% variation of their value will lead to a larger variation (>1%) in the value of the chosen indicator, usually NPV or IRR. After the sensitivity analysis, a qualitative risk analysis will be applied to rate the possibility of occurrence of the risk as well as the severity of its negative impact. In some cases of sufficient data or significant residual risk, a probabilistic risk analysis will also be carried out to further investigate the project risk profile. According to the results of the aforementioned analyses, corresponding risk prevention and mitigation strategies will be made for the identified risks at the final stage of the assessment.

In the LSTIP, most of the risk assessment attaches great importance to the sensitivity analysis of the money values of time savings and accident reduction as these two factors usually account for more than 70% of the total benefit. Recommended variables included in the sensitivity analysis are:

- Value of time
- Costs of accident
- Growth rate of GDP and other economic indicators
- Growth rate of traffic volume
- Construction time (years spent on realizing the infrastructure)
- Toll
- Discount rate and residual value

In this case, the following risk assessment of LSTIP should include 8 types of risk: regulatory risks, demand analysis risks, design risks, administrative risks, land acquisition risks, procurement risks, construction risks, operation & financial risks and other.

The risk assessment of HZMB follows neither the EU assessment framework nor the common assessment framework in China. Due to its unique investment and financing portfolio, the sensitivity and risk analysis is executed within certain sections. In other words, no isolated and intact risk assessment can be found in the ex-ante evaluation framework of HZMB. In the HZMB case, one sensitivity analysis was found in the traffic forecast section where four scenarios were selected as the critical variables whose maximum impact on future traffic volume was quantified in percentage; Also, one sensitivity analysis was included in the financial analysis where the percentage variation of the project's EIRR was calculated under three different toll portfolios with a maximum 20% fluctuation in costs and benefits. Another sensitivity analysis, together with a risk analysis, was performed under the economic analysis. Likewise, the sensitivity analysis examines the percentage change of EIRR in each territory when the aggregated costs and benefits fluctuate by ±10% and ±20%. Then, without a qualitative risk analysis in advance, a probabilistic risk analysis was performed using

Monte-Carlo simulations with different weights assigned to each kind of risk. According to the simulation results, brief suggestions for mitigation and prevention were given from the project's planning phases to operating phases.

When it comes to benchmarking cases, both of them perform an independent risk assessment. For the Oresund case, the project management team identified uncertainties and quantify their impact on project cost based on the Successive Principle. Then, they listed 10 largest uncertainty factors and prioritized the most significant one—the opening date—for which contingency plans such as efficient scheduling were established to mitigate the adverse effect. For Fehmarnbelt case, a more comprehensive sensitivity analysis was performed: it includes overall 19 scenarios predicted under three major critical variables (investment costs, traffic volume, and other assumptions) whose impacts are illustrated by the change of IRR. Instead of standard qualitative risk analysis, the risk analysis, in this case, is conducted through enumerating 8 non-valued impacts and simply showing their correlation to the results. However, no clear risk prevention and mitigation can be found in the analysis.

Compared with that of benchmarking cases, the risk assessment of the HZMB has one major advantage as following:

- **Multiple sensitivity analysis:** Although there is not an isolated part assigned to risk assessment, three separate sensitivity analyses were implemented under demand, financial and economic analysis. Multiple sensitivity analysis implements different levels of sensitivity analysis to serve different purposes. The sensitivity analysis of demand has a similar function to the risk assessment of the Oresund case which identifies the critical uncertainties and quantifies its maximum impact to the performance indicators (the traffic demand in HZMB case and the project cost in Oresund case). Although using the same critical variable to observe the variation of EIRR, the financial and economic sensitivity analysis shows dissimilar emphases: the financial one compares the EIRR under different toll portfolios to evaluate the project's anti-risk capability while the economic one seeks to find out whether the bridge always remain beneficial to three territories when there is a fluctuation in costs and benefits. With specific purposes, the multiple sensitivity analysis of HZMB would effectively enhance the decision-making quality by providing the decision makers with a more detailed relation between critical variables and performance indicators.

Nevertheless, the risk assessment of the HZMB also has following deficiencies, part of which are consistent with the interview results (see the Appendices):

- **Lack of specific risk prevention and mitigation strategy:** According to the result of risk analysis based on the Monte-Carlo simulations, the risk prevention and mitigation of HZMB was summarized in three stages. Although there is a clear differentiation between the stage, the prevention and mitigation strategies are relatively vague as only general suggestions rather than specific schemes are proposed in each stage. Compared to the detailed contingency plans of the Oresund case, the brief suggestions of HZMB lack in practical and reference value from which the decision makers could establish corresponding measures to mitigate or prevent the specific risk. In other words, the content of the suggestions does not really provide useful information for the decision makers to improve their decision-making process with regards to risk prevention and mitigation.

- **Too general critical variables in sensitivity analysis:** In Fehmarnbelt case, a total of 19 critical variables were divided into three categories, each of which includes at least 5 critical variables. The ample consideration and classification of the critical variables clearly illustrate the significances of different uncertainties and thus strengthens the reliability of the sensitivity analysis. Compared to the benchmarking case, HZMB only shows the consideration of disaggregated critical variables in the sensitivity analysis of demand while the other two sensitivity analyses under financial and economic parts merely apply costs and benefits as the critical variables to observe the change of EIRR. Although a sophisticated sensitivity analysis in risk assessment does not necessarily lead to a better decision making, a simplified analysis without sufficient classification of critical variables may hardly help decision makers to distinguish the vital uncertainties and easily fall into the ‘double-counting’ problem in which many correlated variables are calculated repeatedly under different classifications.

4.6 Evaluation of Process and Governance Analysis

Although the CBA framework of the EU does not include the analysis of process and governance, Flyvbjerg (2014) points out the importance of stakeholder involvement in decision making process of megaprojects. Same attention was emphasized by Dooms in his study which assesses the quality of the EU transport flagship infrastructure projects’ CBA. He also claimed in his presentation that the project’s stakeholders should be treated as a resource of opportunities rather than threats (Dooms, 2017). According to Dooms’s report, a process and governance analysis should be applied in the quality appraisal of decision making due to the increasing social activism of local communities and inconsistencies in the management of impact assessment (Dooms, 2019). The recommended structure of a process and governance analysis consists of an integrated evaluation of stakeholder involvement,

governance structure, and methodology reliability. In the decision making of a LSTIP, especially cross-border LSTIP in this case, it is more important for a decision maker to carry out a process and governance analysis due to the additional stakeholders' involvement and political sensitivities brought by the participation of different regions.

In this case, the inclusion of stakeholders should be clarified both internally and externally. First, internal stakeholders such as leading governments, project's constructors and operators should be listed to find out whether significant stakeholders are missing. Then, more attention should be attached to the external stakeholders like local communities because their inclusion will not only lead to a multiple benefit conflict but also influence the attitude of political decision makers to non-acceptances. For governance structure, not only the overall organization of the decision-making process but also the membership of steering committee in ex-ante stage, validation committee in ex-post stage and the possible public consulting team should be studied to map out the complex relationship among stakeholders listed in the previous steps. When it comes to the methodology reliability, the evaluation criterion includes whether the decision-making process considers sufficient review of the methodologies, calculations, and analysis from independent experts outside the project and whether the duration and major elements of the methodology are well described. In addition, the stakeholder feedback and expert review should be transparent enough to the general public who can have direct access to this information.

The process and governance analysis of HZMB can be found at the beginning of the ex-ante decision-making analysis. First, the duration of the work plan along with the historical decision-making results was well explained before the introduction of methodology elements used in each analysis. Then, followed by a brief description of the membership of the steering committee, the governance structure is indicated by an organization chart that clearly reflects the relationship between governmental stakeholders of HZMB. However, although it is believed that public stakeholder engagement was held in parallel with the investigation according to the official report, neither stakeholder feedback nor expert opinions toward the methodology and governance structure are illustrated in the section.

Regarding the process and governance analysis, both two benchmarking cases have a clear explanation of the choice of methodology and a concise timeline of the work plan. However, they neither embrace any internal or external stakeholders in the SCBA process nor describe the hierarchy and relation of different organizations. In addition, their methodology reliability also remains questionable without the recognition of external experts. Thus, it can be concluded that two European cases have similar drawbacks with HZMB and should be improved in several aspects based on the past experience from several cases which implemented full transparency of

information and the stakeholder management (e.g. container expansion project in Antwerp).

Compared to benchmarking cases, the process and governance analysis of HZMB has obvious advantages as following:

- **Better demonstration of stakeholder involvement:** In the benchmarking cases, there is no information with regard to consideration of the stakeholder involvement in the ex-ante decision-making process. The vague stakeholder involvement of the European projects could be attributed to the prevailing individualist culture where massive participation of private stakeholders makes it difficult for decision makers to prioritize their significance. On the contrary, the similar projects in China are usually government-led and follow a more collectivist trait which focuses more on principal stakeholders, especially those from the government. Thus, although there is not an elaborated and in-depth analysis of the stakeholders, HZMB provides at least a better demonstration of stakeholder involvement than European cases at governmental level—the analysis explained main duty of the local governments involved in the decision-making process and introduced some important members in the steering committee who will directly influence the process from governments' perspective.

- **Clear structure of the organization at the governmental level:** As two cross-border projects, the benchmarking cases do not provide any governance structure of regional governments involved in this project. Apart from a better demonstration of stakeholders, the study of HZMB also designs an organization chart of the three regional governments to show the governance structure of the project. The clear structure of the organization at the governmental level offers important information about the hierarchy and relation of different governmental stakeholders to decision makers who may use the information to coordinate the decision-making process between governments.

Meanwhile, the process and governance analysis of HZMB may still have several demerits if it is evaluated under a higher standard:

- **Lack of methodological reliability:** The poor methodological reliability is a prevailing deficiency in both HZMB and benchmarking cases. Although standard methodologies are recommended by the European Commission in its official document, the European cases do not strictly follow the original methodology and sometimes apply their own framework. However, the rationale for adopting the new framework often remains unexplained and vague without theoretical support. In the HZMB case, several authorities and consulting

companies participated in the supporting study of the ex-ante decision-making process. These researchers adopt their own methodology to execute the demand forecast, impact analysis and benefit estimation, etc. In this case, the methodological reliability may be seriously weakened without experts' evaluation as there is no guarantee for these supporting studies using appropriate methodologies. In addition, without coordination between various methodologies, the outcomes of these supporting studies may become mutually inapplicable due to the methodological difference.

- **Lack of transparent account of the stakeholder comments on the study:** Without a clear stakeholder involvement, there is no doubt that the analysis of the Oresund and Fehmarnbelt case ignores the stakeholder's comments in their decision-making process. On the contrary, it is clearly announced on the official website that the decision makers of HZMB have launched a series of public engagement activities to maintain the communication with public stakeholders on their opinions and concerns with regards to the LSTIP. However, as the stakeholder comments remain non-transparent to the public, it may give rise to distrustfulness to the quality of these engagement activities. Also, the decision-making analysis of HZMB did not show a conspicuous consideration of the comments from the public and even the governmental stakeholder.

4.7 Summary

In order to assess the quality of ex-ante decision making of HZMB, we carry out a 'short-cut' cross-case analysis by comparing HZMB with two benchmarking cases from the perspectives of demand, social-economic, risk management, and governance. Additionally, the latest European standards on major project CBA appraisals together with some information collected from the decision participants of HZMB in the interview are applied as a supplementary standard to reflects specific requirements in each perspective. According to the analysis, we can conclude that the decision making of HZMB does show its advantage in some respects, but it still cannot be regarded as an ideal ex-ante decision-making evaluation due to its inconclusiveness when compared to the EU standard and benchmarking cases, and worrying performance in the first-year operation. Specifically, the ex-ante decision making of HZMB has a better performance in demand and optional analysis as well as the social cost-benefit analysis although there is still room for improvement. However, it shows critical deficiencies which pose more threat to the quality of decision making in the rest of two analysis. Table 4.5 summarises the strengths and weaknesses we found in the ex-ante decision making of HZMB.

Appraisal perspective	Strengths	Weaknesses
Demand and optional analysis	a) Combining scenarios analysis with the sensitivity analysis b) Further classification of induced traffic volume c) Improved time-series forecast	a) Insufficient official traffic forecast and severe overestimation at initial stage b) Insufficient consideration of alternative routes c) Lack of consideration of ferry competition
Social cost-benefit analysis	a) Elaborated cost and benefit split b) Horizontal comparison in financial analysis	a) Lack of an aggregated cost-benefit analysis b) Insufficient evaluation of intangible impact c) Insufficient alternative scenarios
Risk analysis	a) Multiple sensitivity analysis	a) Lack of specific risk prevention and mitigation strategy b) Too general critical variables in sensitivity analysis
Process and governance analysis	a) Better demonstration of stakeholder involvement b) Clear structure of the organization at the governmental level	a) Lack of methodological reliability b) Lack of transparent account of the stakeholder comments on the study

Table 4.7 Pros and cons of decision-making framework of HZMB

4.8 Recommended Ex-post appraisal framework for HZMB

According to the analysis in chapter 2.3, we have proved the importance and value of executing an ex-post evaluation for decision making of LSTIP. As one of the most pivotal LSTIP of China in recent years, it is necessary to implement a well-designed ex-post evaluation for the decision-making process of HZMB. The major aim of the ex-post evaluation is to discuss whether the HZMB is a successful LSTIP through comparing the actual performance of the project with the performance predicted in the ex-ante stage, and to offer a retrospective analysis helping similar projects which are likely to be built in the near future set proper ex-ante appraisal framework of decision making.

The design of the recommended Ex-post appraisal framework of HZMB refers to the related academic literature, the European Commission standard and the suggestions provided in the interview of the decision-making participants of HZMB (de Jong, Vignetti and Pancotti, 2018; European Commission, 2014). As the HZMB was open to the public almost a year, the timeframe to apply this ex-post appraisal framework is no more than 5 years until 2023. The ex-post appraisal will assess the performance of the project under a new framework which not only inherits most indicators in old ex-ante appraisal but also reorganizes them into a new classification. In the recommended ex-post appraisal framework, we will assess the project from seven perspectives: implementation, relevance, effectiveness, efficiency, sustainability, consistency and special add value.

Table 4.6 summarises the necessary description of these perspectives. Figure 4.5 depicts the logic for placing the ex-post appraisal framework based on the ex-ante appraisal.

Evaluation criteria	Definition	Corresponding elements in ex-ante framework	Evaluation strategy
Implementation	Whether and to what extent the authorities and consulting companies applied the provisions and requirements stipulated by the relevant national and academic documents in their ex-ante study.	Governance structure; methodology reliability;	Mostly qualitative explaination
Relevance	Whether and to what extent the HZMB reach its strategic aims and address the identified conflicts and appeals of the intended stakeholders.	Strategic aims; key policy objectives;	Mostly qualitative explaination
Effectiveness	Whether and to what extent the technical improvements such as actual traffic volume, time saving, and accident reduction reach their estimated level in ex-ante stage	Technical performance indicators; Demand and optional analysis;	Quantitive calculation supported by qualitative analysis
Efficiency	Whether and to what extent the actual financial and economic inputs realize reasonable outcomes.	Financial analysis; Economic analysis;	Mostly quantitive in montery form
Sustainability	Whether and to what extent the LSTIP could last for a long period with sustainable financial performance and environmental viability?	Environmental and social impacts analysis; Financial performance;	Combination of quantitve and qualitative analysis
Consistency	Whether and to what extent the socio-economic value of HZMB may not be seriouly weaken with the interventions of major uncertainties?	Risk analysis; Sensitivity analysis;	Combination of quantitive and qualitative analysis
Special add value	Whether and to what extent the HZMB influences the transport pattern especially in maritime and logistic structure wihthin the GBA?	Non-valued or intangible impacts analysis;	Qualitative analysis supported by quantitive data

Table 4.8 Evaluation criteria in ex-post appraisal framework

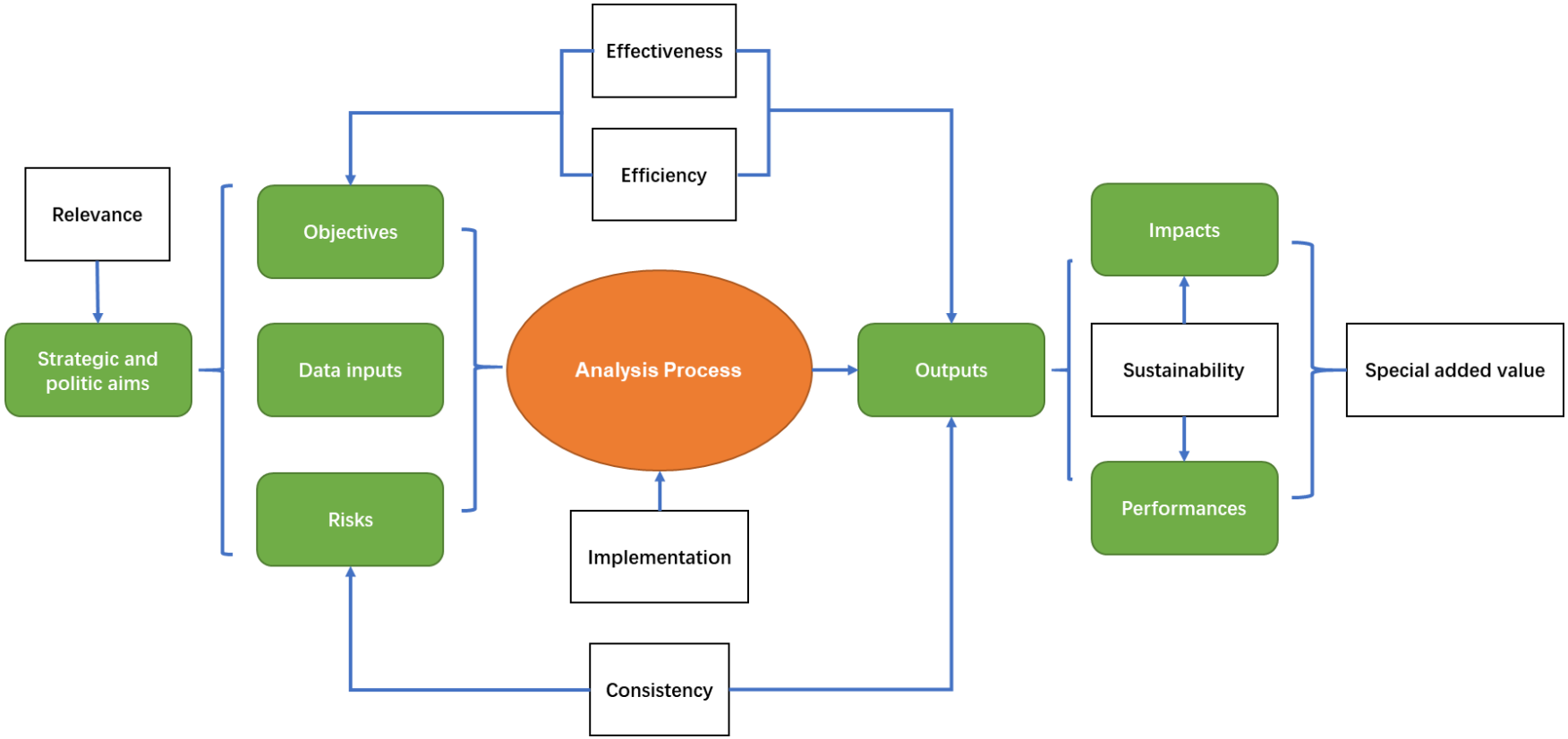


Figure 4.5 The logic flows for arranging the ex-post appraisal framework

5 Conclusion and policy recommendations

The decision making of LSTIP plays an important role in determining the success of these capital-intensive and time-consuming projects. In order to make good decisions at the ex-ante stage, governments and authorities should austerely control the quality of the decision-making process by optimizing their own methodological standard and analysis framework to evaluate the projects in several respects. Although many countries have recognized the importance of the ex-ante decision making and issued an official document guiding the appraisal process, many problems such as cost overruns, demand shortfall, and benefit overestimation still exist in many LSTIPs built in recent decades. In order to find out the reasons behind these problems, it is necessary for decision makers to learn from the successful experience in the past by comparing their decision-making process to the prototype.

The paper presents a single case study of HZMB, a cross-border LSTIP with great strategic significance built in the PRD of southern China. By referencing the appraisal framework of two typical projects under the European standard, the analysis evaluates the quality of the ex-ante decision-making process of HZMB and proposes an ex-post appraisal framework to evaluate the actual performance of HZMB in the coming five years. Based on the case study analysis, we reckon that the ex-ante decision making of HZMB cannot be regarded as a comprehensive one because it still remains relatively problematic in some processes. The result implies that quality control of HZMB's decision making still has room for perfection and could seek a breakthrough by absorbing the essence of the European prototypes. Additionally, due to the remarkable deviation between predicted and actual performance in the first year of operation, we emphasize the necessity and importance for HZMB to carry out an ex-post appraisal to better distinguish the project's strengths and weaknesses in decision making.

In line with the paper's finding, we make some policy recommendation for LSTIP, especially those similar to HZMB, to improve the quality of decision making as follows:

- **Improve the transparency of the decision-making process:** The transparency of the decision-making process could not only increases the project's ability to attract private capital and external surveillance from the public but also enrich the external validity through enabling non-governmental experts and researchers to carry out relevant studies with sufficient information and data.

- **Improve stakeholder inclusion and effectively solve the conflicts of benefit:** Better stakeholder inclusion improves the comprehensiveness of the scenarios and benefits consideration in the decision-making process. The potential consequences of the project, either positive or negative, should be acceptable

among most of the beneficiaries and the decision makers are capable to solve the interest conflicts that may arise.

- **Standardize the methodology and data used in supporting studies of decision making:** If several supporting studies via different authorities are conducted before the decision-making process, the governments (or private decision makers in BOT) should have a methodology and data standard to guarantee the quality and mutual readability of these supporting studies.

- **Establish national and international database of benchmarking LSTIP:** Apart from the standard and provision offered in the official document, a database containing the detailed technical and financial information as well as the decision-making process of some well-performed LSTIPs should be set up and regarded as a vital supplementary resource.

- **Optimize the governance structure of cross-border LSTIP:** The decision makers of cross-border LSTIP should have an effective governance structure which fully considers the legislative and strategic difference between countries or territories and clearly distinguish when the decision-making process should be centralized or decentralized.

- **Adopt ex-post appraisal after 5- and 10-years operation of the LSTIP:** Many ex-post appraisals were conducted within five years after the operation of the project. However, as some LSTIPs have more strategic aim than financial aims, the value of the LSTIP maybe not obvious in such a short time. Thus, we advise conducting a mid-term and a final (or definitive) ex-post appraisals after 5- and 10- years operation.

- **Attach importance to some specific added value:** Some added values generated from the characteristics of the LSTIP are often easily ignored in a general appraisal framework. For example, most LSTIP often serves as a fast connection or link which will considerably influence the transport pattern and logistic network in the area while the ex-ante researches seldomly study these impacts comprehensively. Thus, it is necessary for decision makers to attach more importance to the specific added values of their projects and may execute an independent analysis for them.

The strength of the study includes its representative case choice, reliable information from some confidential documents, transnational evaluation of China project under European standard. However, some limitations should be considered. On the one hand, the paper designs the ex-post appraisal framework merely from the ex-ante framework and the European standard but does not take into account the difficulties

that may appear in practice. For example, data availability may become one of the most serious impediments if the project operators do not keep a continuous data collection work after they take over the project from decision makers. On the other hand, the data and information collection, especially for HZMB, suffers from the difficulty of accessing the confidential resource and the inadequate number of interviewees. These factors may have periled the external reliability of the case study analysis. In addition, the case selection ignores the influence of financing models of different LSTIPs. For example, the non-transparency and insufficient CBA in decision making of HZMB could be largely attributed to its 100% government-sponsored capital while the decision making of European projects have to become transparent and require CBA to guarantee profitability under the BOT framework.

According to the limitations, the future research of this topic could delve into the design of the ex-post appraisal framework and a synthetic study tracking the decision making from ex-ante to the ex-post stage: first, the practicability of the ex-post appraisal should be further discussed in following studies. The design of the framework should not only base on the theoretical knowledge but also consider its practical feasibility. Second, the ex-ante and ex-post appraisal of decision making is often studied separately. A synthetic study of these two appraisals may provide an interesting demonstration of their different emphases.

Reference

Anguera, R. (2006). The Channel Tunnel—an ex post economic evaluation. Transportation Research Part A: Policy and Practice, 40(4), pp.291-315.

Banister, D. (2007). Quantification of the non-transport benefits resulting from rail investment. 2nd International Seminar on Railway Planning, Seoul

BBA|mantra. (2019). Decision Making - Types, Process, Techniques, Importance - BBA|mantra. [online] Available at: https://bbamantra.com/decision-making-process/ [Accessed 16 Jul. 2019].

Bellavance, F., Dionne, G., & Lebeau, M. (2007). The value of a statistical life: A meta-analysis with a mixed effects regression model. Canada Research Chair in Risk Management, Working Paper 06-12.

Berg, P., Halvard, Kilde. and Rolstadås, A. (2003). 'Large Norwegian Governemental Projects. Any Lessons Learnt?', NORDNET 2003 - International Project Management Conference, Oslo, Norway, 24-26 September 2003

Bouwman, M. and Moll, H. (2002). Environmental analyses of land transportation systems in The Netherlands. Transportation Research Part D: Transport and Environment, 7(5), pp.331-345.

Bristow A.L. and Nellthorp, J. (2000). “Transport project appraisal in the European Union”, Transport policy, 7, pp: 51-60.

Cameron, J. (2011). Valuing water, valuing livelihoods. [Geneve]: World Health Organization, pp.200-205.

Cantarelli, C. (2011). Cost Overruns in Large-Scale Transport Infrastructure Projects: A theoretical and empirical exploration for the Netherlands and worldwide. Ph.D. Delft University of Technology.

Capka, J.R. (2004), Megaprojects – they are a different breed, Public Roads, 68(1).

Crookes D, de Wit M (2002). Environmental economic valuation and its application in environmental assessment: an evaluation of the status quo with reference to South Africa. Impact Assessment and Project Appraisal, 20: 127–134

Dantata, N.A., A. Touran, and D.C. Schneck. (2006) Trends in US Rail Transit Project Cost Overrun. Paper presented at the 85th meeting of the Transportation Research Board, Washington,D.C.

De Brucker, K., Verbeke, A. and Winkelmans, W. (1998). “Sociaal- economische evaluatie van overheidsinvesteringen in transportinfrastructuur”, Garant, Leuven.

De Bruijn, H. and Leijten, M. (2007). Megaprojects and Contested Information. Transportation Planning and Technology, 30(1), pp.49-69.

De Jong, G., Vignetti, S. and Pancotti, C. (2018). EX POST EVALUATION OF MAJOR TRANSPORT INFRASTRUCTURE PROJECTS. In: European Transport

Conference 2018.
de Jong, G., Vignetti, S. and Pancotti, C. (2018). EX POST EVALUATION OF MAJOR TRANSPORT INFRASTRUCTURE PROJECTS. In: European Transport Conference 2018.
Denzin, N. K., & Lincoln, Y. S. (2005). Introduction: The Discipline and Practice of Qualitative Research. In N. K. Denzin & Y. S. Lincoln (Eds.), The Sage handbook of qualitative research (pp. 1-32). Thousand Oaks, CA, : Sage Publications Ltd.
Denzin, N., & Lincoln, Y. (1994). Introduction: Entering the Field of Qualitative Research. In N. K. Denzin, & Y. S. Lincoln (Eds.), Handbook of Qualitative Research (pp. 1-17). California, CA: Sage Publication, Inc.
Department for Communities and Local Government (DCLG) (2009), Multi-criteria analysis: a manual. Communities and Local Government Publications, London. Retrieved from: http://www.communities.gov.uk/documents/corporate/pdf/1132618.pdf
Dooms, M. (2017). Societal challenges in (transport) infrastructure development.
Dooms, M. (2019). Assessment of the assumptions and general methodological quality of the EU Transport Flagship Infrastructure Projects' Cost-Benefit Analyses (CBAs). Unpublished.
Dooms, M. (2019). Overview of socio-economic evaluation techniques.
Dooms, M. and Macharis C. (2006). "Multi-Actor, Multi-Criteria Analysis of the DHL-project", In: Institutional aspects in transport project evaluation, Ed: Haezendonck, E., Edward Elgar, Aldershot.
Edgerton, D. (2009). Depreciation of infrastructure assets technical information paper. South Australia Local Government. Brisbane.
Eisenhardt, K. M. (1989). Building theories from case study research. The Academy of Management Review, 14(4), 532-550.
European Commission (2006). Guidance on the methodology for carrying out cost-benefit analysis. Brussels: European Commission.
European Commission (2014). Guide to Cost-Benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020. Belgium: European Union, pp.20-101.
European Commission (2014). Study on the effectiveness and on the improvement of the EU legislative framework on road infrastructure safety management (Directive 2008/96/EC) Ex-Post Evaluation. Belgium.
EVATREN (2019). Guidelines for ex-ante and ex-post evaluation. [ebook] European Commission. Available at: https://trimis.ec.europa.eu/sites/default/files/project/documents/20121215_150809_37259_Deliberable_5.pdf [Accessed 17 Jul. 2019].
Faizal, O. M., Bambang, T. and Johnny, W. (2009) 'Infrastructure project planning decision making: challenges for decision support system applications Infrastructure Project Planning: Progress in Contemporary Decision Support Tools', (January).
Femern A/S (2019). 10 good reasons for a direct link between Germany and

Scandinavia under the Fehmarnbelt. [ebook] Available at: https://femern.com/en/Benefits/Why-we-are-building-a-fixed-link [Accessed 2 Aug. 2019].

Femern A/S (2019). The tunnel | Femern A/S - The tunnel across Fehmarnbelt. [online] Femern.com. Available at: https://femern.com/en/Tunnel [Accessed 2 Aug. 2019].

Ferreira L. and Lake M. (2002). “Towards a methodology to evaluate public transport projects”. Physical Infrastructure Centre Research Report 02-03, School of Civil Engineering, Queensland University of Technology, Brisbane.

Florio, M. (2006a). Cost-benefit analysis and incentives in infrastructure planning and evaluation: A research agenda for the EU cohesion policy. 5th Milan European Economy Workshop, Milan

Flyvbjerg, B. (2005). Policy and planning for large Infrastructure projects: problems, causes, cures. World Bank Policy Research Working Paper 3781.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. Qualitative Inquiry, 12(2), 219-245.

Flyvbjerg, B. (2007) Policy and planning for large-infrastructure projects: problems, causes, cures. Environment and Planning B, in: Planning and Design, 34 (4), pp. 578-597.

Flyvbjerg, B. (2008), Public planning of mega- projects: overestimation of demand and underestimation of costs, in H. Priemus, B. Flyvbjerg and B. van Wee (eds), Decision- making on Mega- Projects: Cost- Benefit Analysis, Planning and Innovation, Cheltenham, UK and Northampton, MA: Edward Elgar.

Flyvbjerg, B. (2014). What you Should Know about Megaprojects and Why: An Overview. Project Management Journal, 45(2), pp.6-19.

Flyvbjerg, B., Bruzelius, N. and Rothengatter, W. (2003a), Megaprojects and Risk: An Anatomy of Ambition, Cambridge: Cambridge University Press

Flyvbjerg, B., Skamris Holm, M. and Buhl, S. (2004). What Causes Cost Overrun in Transport Infrastructure Projects?. Transport Reviews, 24(1), pp.3-18.

Fosgerau, M. (2006). Investigating the distribution of the value of travel time savings. Transportation Research Part B 40 (8),688–707.

Frick, K.T. (2005), The Making and Un- making of the San Francisco–Oakland Bay Bridge: A Case in Megaproject Planning and Decision- making, unpublished doctoral dissertation, University of California, Berkeley.

Garger, J. (2013). Using the Case Study Method in PhD Research. [Website]. Available at: http://www.brighthub.com/education/postgraduate/articles/77789.aspx [Accessed 22 Jul. 2019]

Gibbert, M., Ruigrok, W. and Wicki, B. (2008). What passes as a rigorous case study?. Strategic Management Journal, 29(13), pp.1465-1474.

Gomm, R., Hammersley, M., & Foster, P. (2000). Case study method: Key issues, key texts. London: SAGE.

Grant-Muller, S.M., Mackie, P., Nellthorp, J., & Pearman, A. (2001). Economic appraisal of European transport projects: the state-of-the-art revisited. Transport Reviews: A Transnational Transdisciplinary Journal.

Green, E. (2016). What are the most-cited publications in the social sciences (according to Google Scholar)? London School of Economics. Retrieved from https://blogs.lse.ac.uk/impactofsocialsciences/2016/05/12/what-are-the-most-cited-publications-in-the-social-sciences-according-to-google-scholar/ [Accessed 22 Jul. 2019]

Hall, P. (1980) Great Planning Disasters, Penguin Books, Harmondsworth.

Hayashi, Y. and H. Morisugi (2000), 'International comparison of background concept and methodology of transportation project appraisal', Transport Policy, 7: 73–88.

Heinzerling, L., & Ackerman, F. (2002). Pricing the priceless. Cost-Benefit Analysis of environmental protection. Georgetown Environmental Law and Policy Institute, Georgetown University Law Center.

Hickman, R., Givoni, M., Bonilla, D. & Banister, D. (2015) 'Decision-making and major transport infrastructure projects: the role of project ownership', Handbook on Transport and Development, pp. 380–393.

Highway Department (2009). Hong Kong-Zhuhai-Macao Bridge: Hong Kong Boundary Crossing Facilities - Investigation. Hong Kong.

Highway Department. (2019). HongKong-Zhuhai-Macao Bridge (HZMB): About HZMB. [online] Available at: http://www.hzmb.hk/eng/about.html [Accessed 31 Jul. 2019].

History of Bridges (2019). Channel Tunnel Facts - History of Rail Tunnel. [online] Historyofbridges.com. Available at: http://www.historyofbridges.com/facts-about-bridges/channel-tunnel/ [Accessed 18 Jul. 2019].

HM Treasury (2003). The Green Book. Appraisal and Evaluation in Central Government. Treasury Guidance, TSO, London.

Information Service Department of Hong Kong. (2018). Hong Kong-Zhuhai-Macao Bridge The world's longest bridge-cum-tunnel sea crossing.

Institute for Advanced Studies (IAS) (2014). Guidelines for Cost-Benefit-Analysis of infrastructure projects. Vienna: Institute for Advanced Studies, pp.22-23. Available at: http://www.southeast-europe.net/document.cmt?id=690 [Accessed 16 Jul. 2019].

International Transport Forum (ITF) (2011). Improving the practice of cost benefit analysis in transport. Discussion Paper No. 2011-1.

Jacobsen, D. I. (2002). Vad hur och varför: Om metodval i företagsekonomi och andra samhällsvetenskapliga ämnen. Lund: Studentlitteratur.

Janberg, N. (2019). Øresund Bridge (Malmö/Copenhagen, 2000) | Structurae. [online] Structurae. Available at: https://structurae.net/structures/oresund-bridge [Accessed 2 Aug. 2019].

Jones, H., Moura, F. and Domingos, T. (2014). Transport Infrastructure Project Evaluation Using Cost-benefit Analysis. Procedia - Social and Behavioral

Sciences, 111, pp.400-409.
Jong, M. De (2009) ‘Success in Major Transport Infrastructure Projects’.
Joosten, W. (2005), ‘London Underground Limited. Een casusstudie van de groot- ste PPS van het Verenigd Koninkrijk’, Delft Thesis, Faculty of Technology, Policy and Management, Delft University of Technology (in Dutch).
Knudsen, M. and Rich, J. (2013). Ex post socio-economic assessment of the Oresund Bridge. Transport Policy, 27, pp.53-65.
Koppenjan, J. (2008). Public-private partnership and mega-projects. In: Decision-Making on Mega-Projects. Eds. H. Priemus, B. Flyvbjerg & B. van Wee. Cheltenham: Edward Elgar.
Lau, E. (2015). Review of the application of cost-benefit analysis.
Lindvall, J. (2007). Fallstudiestrategier. Statsvetenskaplig Tidsskrift, 109(3), 270-278
Lloyd’s List (2019). One Hundred Ports 2019. [online] Available at: https://lloydslist.maritimeintelligence.informa.com/one-hundred-container-ports-2019/Digital%20edition [Accessed 5 Sep. 2019].
Macharis, C., de Witte, A. and Ampe, J. (2009). The multi-actor, multi-criteria analysis methodology (MAMCA) for the evaluation of transport projects: Theory and practice. Journal of Advanced Transportation, 43(2), pp.183-202.
Mackie, P. and Preston, J. (1998). Twenty-one sources of error and bias in transport project appraisal. Transport Policy, 5(1), pp.1-7.
Martinez, L.M. (2010) – Financing public transport infrastructure using the value capture concept. PhD Thesis, Transportes, Universidade Tecnica de Lisboa, Instituto Superior Tecnico.
Matria, T. (2012). Cost benefit analysis and ex-post evaluation of railway upgrade projects Ex-post economic evaluation, evaluation of traffic disturbance during construction and evaluation of travel time variability. MsC Thesis, Transportes, Universidade Tecnica de Lisboa, Instituto Superior Tecnico.
Mcleod, S. (2019). Case Study Method in Psychology | Simply Psychology. [online] Simplypsychology.org. Available at: https://www.simplypsychology.org/case-study.html [Accessed 22 Jul. 2019].
Merewitz, L. (1973) How do urban rapid transit projects compare in cost estimating experience? Proceedings of the International Conference on Transportation Research. First Conference. Reprint no. 104, pp. 483-493, Bruges, Belgium.
Merriam, S. B. (2009). Qualitative research: A guide to design and implementation. San Francisco, California: Jossey-Bass.
Merriam, S. B., & Nilsson, B. (1994). Fallstudien som forskningsmetod. Lund:
Miles, M. B. (1979). Qualitative data as an attractive nuisance: The problem of analysis. Administrative Science Quarterly, 24(4), 590-601.
Morris, P. and G.H. Hough (1987) The Anatomy of Major Projects: A Study of the Reality of Project Management, John Wiley and Sons, New York.
Næss, P (2011). The third limfjord crossing: A case of pessimism bias and knowledge filtering. Transport Reviews, 31(2), 231–249.

Nicolaisen, M. and Driscoll, P. (2016). An International Review of Ex-Post Project Evaluation Schemes in the Transport Sector. Journal of Environmental Assessment Policy and Management, 18(01), p.1650008.

Niekerk, F., & Voogd, H. (1999). Impact assessment for infrastructure planning: some Dutch dilemmas. Environmental Impact Assessment Review, 19(1), 21-36.

Nijkamp, P. and B. Ubbels (1999) How Reliable are Estimates of Infrastructure Costs? A Comparative Analysis, in: International Journal of Transport Economics, 26(1), pp. 23-53.

Odeck, J. (2004). “Cost overruns in road construction—what are their sizes and determinants?”. Transport Policy, 11(1), pp.43-53.

OECD (2003). OECD Territorial Reviews OECD Territorial Reviews: Oresund, Denmark/Sweden 2003 OECD Territorial Reviews Series. OECD Publishing. p. 38.

Ole Morten Magnussen and Samset, K. (2005) ‘Successful Megaprojects: Ensuring Quality at Entry Ole’.Overview," Project Management Journal, vol. 45, no. 2, April-May, pp. 6-19

Øresundsbro Konsortiet (2006). WELCOME TO THE ØRESUND BRIDGE. [online] Available at: https://web.archive.org/web/20070607013250/http://osb.oeresundsbron.dk/library/?obj=3755 [Accessed 2 Aug. 2019].

Øresundsbro Konsortiet (2018). The Øresund Bridge and its Region: 18 years. [online] Available at: https://data.oresundsbron.com/cms/download/Bron%202018%20final%20EN_komp.pdf [Accessed 2 Aug. 2019].

Øresundsbro Konsortiet (2019). Annual Report 2018. [online] Available at: https://data.oresundsbron.com/cms/download/%C3%85rsrapport%202018_EN.pdf [Accessed 2 Aug. 2019].

Pickrell, D. (1992) A Desire Named Streetcar: Fantasy and Fact in Rail Transit Planning, in: Journal of the American Planning Association, 58(2), pp. 158-176

Priemus, H. (2010) ‘2010 Decision-making on Megaprojects Drifting on Political Discontinuity and Market Dynamics.pdf’, Ejtir, 10(10(1)), pp. 19–29.

Priemus, H., Flyvbjerg, B. and Wee, B. (2013). ‘Public Planning of Mega-Projects: Overestimation of Demand and Underestimation of Costs’, Decision-Making on Mega-Projects, (February 2008).

Rasouli, S., & Timmermans, H. (2012). Uncertainty in travel demand forecasting models: literature review and research agenda. Transportation Letters: The International Journal of Transportation Research, 4, 55-73.

Republic of Kosovo (2019). Guidelines on Ex-post evaluation of legislation in the Republic of Kosovo. Kosovo, pp.5-15.

Rowley, J. (2002). Using case studies in research. Management Research News, 25(1), pp.16-27.

ROYAL HASKONINGDHV (2019). Social Cost-Benefit Analysis. [online] Available at:

https://www.royalhaskoningdhv.com/en-gb/services/a-z-services/social-cost-benefit-analysis/983 [Accessed 17 Jul. 2019].
Sedgwick, P. (2014). Case-control studies: advantages and disadvantages. BMJ, 348(jan03 1), pp.f7707-f7707.
Shi, J., & Wu, Z. (2010). A quantitative transportation project investment evaluation approach with both equity and efficiency aspects. 12th WCTR, Lisbon.
Shiyong, M. (2013). A Study On Investment & Financing Mode Decision Of Hong Kong-Zhuhai-Macao Bridge Based On Comprehensive Evaluation of projects. Master. Nanjing University.
Soens, D. (2019). Economic Impact Analysis. [online] Economic Development Research Group, Inc. Available at: https://www.edrgroup.com/services/economic-impact-analysis.html [Accessed 17 Jul. 2019].
Sørensen, M., Nielsen, O. and Schauby, J. (2019). The Øresund Traffic Forecast Model. [ebook] Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.531.7839&rep=rep1&type=pdf [Accessed 6 Aug. 2019].
Stake, R. E. (1978). The case study method in social inquiry. Educational Researcher, 7(2), 5-8.
Studentlitteratur
The Transport and Housing Bureau (THB) (2008). Evaluation of the Benefits of the HZMB Project. Hong Kong.
Trottenberg, P., & Rivkin, R. (2011). Treatment of the economic value of a statistical life in departmental analyses-2011 Interim Adjustment. U.S. Department of Transportation, Office of the Assistant Secretary for Transportation Policy.
van Wee, B. (2007). Rail infrastructure: challenges for cost-benefit analysis and other ex ante evaluations. Transportation Planning and Technology, 30(1),31-48.
Vincke, Ph. (1992). “Multicriteria Decision-Aid”, John Wiley&Sons, New York.
Volden, G.H. and Samset, K. (2013). Evaluating Public Investment Projects. Lessons and Advice from a Meta- Evaluation of Four Projects. Concept report no. 30. Trondheim: Norwegian University of Science and Technology.
Welde, M. and Holst Volden, G. (2017). Ex post evaluation of transport projects – experiences from Norway. [ebook] Techno Luddites. Available at: https://editorialexpress.com/cgi-bin/conference/download.cgi?db_name=ITEA2015&paper_id=3 [Accessed 19 Jul. 2019].
Williams, T. and Samset, K. (2010). Issues in Front-End Decision Making on Projects. Project Management Journal, 41(2), pp.38-49.
World Bank (2005b). Valuation of accident reduction. Transport Note No. TRN-16.
World Bank. (1996). Evaluation results 1994. The international Bank for Reconstruction and Development. Washington D.C.
Worsley, T. (2014). Ex-post Assessment of Transport Interventions and Policy Interventions. Roundtable Summary and Conclusions. OECD ITF Discussion

paper 2014 /19.
Yin, R. (2018). Case study research and applications. 6th ed. Los Angeles [etc.]: Sage.
Yu, R. (2018). World's longest cross-sea bridge opens, integrating China's Greater Bay Area - Xinhua | English.news.cn. [online] Xinhuanet.com. Available at: http://www.xinhuanet.com/english/2018-10/23/c_137553194.htm [Accessed 31 Jul. 2019].
Zhang, Y. (2010). Road Planning Research of the Hong Kong-Macau-Zhuhai Bridge's Integrated Transportation System. Master. Tianjin University.

Appendices

Interview with decision participants of HZMB

Interview Template for decision making of HZMB
Interviewee Name: Wenjun Yang (Mr.)
Position: Decision participant of HZMB
Date of interview: August 4th, 2019
Remark: The interview was conducted through WeChat voice call. Mr. Yang is one of the administrators who join in the feasibility study of HZMB and offers suggestion to the decision makers in the HZMB joint office. Our question will focus on the decision-making background and Yang's opinion to ex-ante and ex-post decision making of HZMB. Respecting interviewee's privacy, we won't provide exact position and other private information of Mr. Yang in the interview.
Interview questions and answers: **1) What's the basis of the decision-making process of HZMB?** **Answer:** The decision making of HZMB is built on the feasibility report established by the joint office of HZMB. A number of consulting companies and authorities participated in writing of the report. The report served as an initial guidance of decision makers and if necessary, other studies supporting the following decision-making process will be conducted during the construction of the HZMB. **2) Do you think the feasibility report is sufficient to support ex-ante evaluation?** **Answer:** I think it is enough from government's perspective. The large-scale infrastructure in China like HZMB is usually 100% funded by government due to its significant strategic meaning. Thus, the report could provide adequate technical viability and necessary financial and economic evaluation to the support the decision-making process. Also, the feasibility report is a government-led study, so it is relatively reliable. **3) Why is there not an independent CBA for HZMB?** **Answer:** Like what I said in the last question, the strategic meaning of HZMB is more important than its financial benefit. Due to the financing pattern, the government could fund the project with negative return in certain period. This phenomenon could also be found in the highspeed railway of China. In a word,

without private investment, it is unnecessary for the project to conduct an independent CBA to guarantee the positive return to its shareholders. They attach more importance to its strategic value and social welfare benefit.

4) Why is the document related to decision-making process kept highly non-transparent?

Answer: I think the non-transparency of the decision making could also attribute to the 100% government fund. The governmental decision makers don't need to be responsible to the external shareholders so they could keep their internal data and document confidential to protect the intellectual property right. Besides, some data like the monthly traffic flow has been available to the public since the open of the bridge but it is always released with a four months lag in order to avoid media hype.

5) What's your opinion toward the risk management of the project?

Answer: I did not directly join the study of risk management so I cannot give you very in-depth opinion. From my perspective, the risks of such a sophisticated project are uncountable so the decision makers simplify the risk management with some general sensitivity analysis rather than analyze the risk under detailed scenarios. I think they had their reasons to do so but if condition permitted, a specific risk assessment should be added.

6) How does you perceive the bad performance of HZMB at first-year operation?

Answer: Well, I have to say we cannot evaluate HZMB as a failure and stupid decision through the first-year performance. Although the cost overrun, construction delay and traffic demand shortage existed, the real value of HZMB will be proved gradually in the following decade because the shift of the old pattern takes time. I think we should be moderately optimistic to the future performance of HZMB as it considerably reduces the commute time between two shores in PDA.

7) How would you evaluate the quality of ex-ante decision making of HZMB?

Answer: In my opinion, I think the ex-ante decision making of HZMB is not very effective. First, this is the very first time for Chinese government to build a project connecting the mainland with two Special Administrative Regions. Thus, the lack of experience makes the ex-ante decision making immature. Second, the

complex governance structure weakens the responsiveness of the decision-making process, which could be one of the origins of the delay problem.

8) What elements do you think should be attach great importance into ex-post evaluation of HZMB?

Answer: From my perspective, I think we should focus more on the strategic target of HZMB so the elements in ex-post evaluation should not only include the basic elements to check the financial and technical performance but also study the change of the transport pattern. The bridge is surrounded by several important ports in the regions so it would be interesting to find out its impact on container shipping and logistic network in the PDA.