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Revealing The Economic Viability of Railway Investments (Case Study: Restoring Your Railway Programme, United Kingdom)

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ABSTRACT The UK's "Restoring Your Railway" (RYR) programme aims to reopen abandoned railway infrastructure to foster local economic growth. However, since 2020, only 30% of RYR proposals have progressed, revealing challenges in the methodological approach, especially for projects introducing rail as a new mode. The current unimodal approach for estimating user benefits in such projects is considered inadequate. To address this, a Cost-Benefit Analysis (CBA) with improved methods for user benefit estimation has been conducted, compared with existing cases to determine if it results in a better Benefit-Cost Ratio (BCR). Historically, early appraisal methods relied on the Strategic Outline Business Case (SOBC), which took six months and incurred costs of approximately Rp. 1.5 billion. To expedite project delivery, sensitivity analysis explores circumstances under which RYR projects are socially justifiable across different Value for Money scenarios. Additionally, a comparative analysis is performed between the UK and Indonesian approaches. This study introduces a new CBA approach, focusing on user benefit estimation and conducting sensitivity analysis on key determinants. The mathematical CBA model, modified for the value of time and diversion factor, forms the basis for sensitivity analysis on BCR, travel time savings, capital and operational costs, diversion factor, and GDP growth. Testing the model against business cases reveals a 17-20% reduction in the required demand for the same BCR compared to conventional CBA approaches, suggesting the new method captures additional benefits related to mode shifts. Sensitivity analysis highlights circumstances under which railway projects are likely to deliver acceptable value for money, considering various BCR values. Total order indices show that operational costs contribute 40% to the model output, followed by capital costs and GDP growth rate at 29% and 25%, respectively. Surprisingly, the In-Vehicle Time (IVT) for trains has only a small contribution, ranging from 1.83% to 4%.

KEYWORDS Rail Appraisal; Restoring Your Railway; User Benefit; Reduced Multi Modal Approach; Sensitivity test

1 INTRODUCTION

The British government's Restoring Your Railway (RYR) programme aims to reopen closed rail lines and stations with a £500 million budget (Department for Transport, 2020). Following RYR, the UK government introduced Rail SPEED, focusing on Swift, Pragmatic, and Efficient Enhancement Delivery, with the goal of halving project delivery time and reducing investment costs for increased efficiency and savings (Network Rail, 2020). Local governments and communities are encouraged to conduct a strategic business case to justify their projects. However, due to high investment costs, not all proposals progress. Out of 170 proposals received since 2020, only 30% have advanced, indicating ongoing evaluations or considerations (Department for Transport, 2020).

The challenge arises from the multitude of potential projects eligible for RYR funding. Limited funds necessitate prioritization, prompting the Department for Transport and Network Rail to quickly evaluate submitted proposals while awaiting the six-month business case process. On the other hand, the current appraisal approach presents practical challenges, especially under RYR programme (House of Lords, 2011; Tyers and Dallas, 2023). In the context of rail appraisal, one widely used and conventional approach is Transport Appraisal Guidance (TAG) guidance. However, the current practice of TAG offers unimodal approaches when estimating the user benefit for schemes that introduce rail as a new mode. The difficulty arises in estimating user benefits that incorporate the quality factor improvement existing between transport modes. The current practice of TAG is not able to provide the benefit factors that stem from the quality improvement arising from mode shift (Ojeda-cabral et al., 2021). In multi-modal schemes where rail is introduced as a new mode, there is the potential for passengers to experience varying levels of journey quality between the existing modes and the new mode. This difference will account for different perceptions in valuing the time spent in both modes.

Several previous studies have been caried out in the context of transport appraisal, particularly on railway project. Foster and Beesley (1963) examine the social benefits of the London Underground railway. They investigate the benefits and losses expected from the introduction of Victoria Line services by comparing the consumer surplus of social benefits over the total costs incurred. Furthermore, Beesley (1965) introduces the concept of value of time (VOT) by providing evidence on the valuation of travel time, it emphasises that the time savings accounted for a significant proportion of the measured gross benefits in studies, with values ranging from 64% to 80% of total benefits at the first year of operation.

Recently, Hensher (2001) provides a method to measure the Value of Time (VOT) incorporating Revealed Preference (RV) and Stated Preference (SP) survey. The results indicate that the SP methods are more accurate than RV in determining the Value of Travel Time. Furthermore, Mackie et al. (2003) examine the difference in VOT savings between transport modes. This paper formulates the differences in the value of time among various transportation modes, using the car as the baseline mode.

In the context of Cost Benefit Analysis, Nash and de Rus (2010) provide an indication of the circumstances in which such proposals might be worthwhile in the context of High Speed Rail utilizing the concept of NPV (Nett Present value > 1). The results are that High-Speed Rail in the UK could only be socially justified with patronage levels below 6 million passengers per year, under the most optimistic scenario characterized by low construction costs and significant time savings.

The current appraisal approach in the UK is not directly applicable in the scenario that introduces rail as a new mode. Therefore, this research aims to overcome these challenges by developing a mathematical model based on the general concept of Benefit-Cost Ratio (BCR) and modifying it to address the challenges that arise in the current appraisal practice in the UK. The CBA model aims to simulate conditions that closely resemble real-world scenarios and perform sensitivity tests on key determinants. By analysing the outcomes of these sensitivity tests, the study aims to identify the key determinants that can generate the required demand to achieve a particular BCR value (1, 1.5, and 2). This research will benefit the Department of Transportation United Kingdom, and Network Rail in the context of quickly estimating the rail project worthiness under the RYR programme by looking at the combination of demand and travel time saving.

2 METHODS

The model developed is based on the current practices of rail appraisal in the United Kingdom (Figure 1), specifically addressing the current approach within the RYR program initiated by the government. The main objective of this research is to understand under what circumstances an investment in the railway industry is socially justifiable based on the required demand. Therefore, to address this objective, a particular appraisal approach is employed to assess the demand needed for a project to yield an acceptable value for money (VfM). The appraisal methods used in this research utilise the basic principle of Benefit-Cost Ratio (BCR), which is part of Cost-Benefit Analysis (CBA) approach. It is considered a quantitative method involving the use of numerical data and mathematical models to analyse and solve problems. The CBA model developed in this research is derived from the original BCR equation with various algebraic manipulations coupled with some simple empirical assumptions to derive a pragmatic mathematical model. This model, later on, is used as a testbed.

The utilization of BCR as a test bed model refers to two main reasons. First, the current practice of transport appraisal in the UK refers to the Greenbook regulation. The Greenbook categorizes project worthiness into different levels of value for money (VfM), which could be low, medium, or high VfM. The categorization of VfM itself is based on the BCR value (HM Treasury, 2022), which produces ratio-type data. Second, the BCR method divides the total benefit by the total cost, hence it produces ratio-type data, which is considered as the highest type of data (Department for Transport, 2023*b*). The ratio types of data can be used to objectively compare across different projects even if on different magnitude, since it represents the percentage value between two different variables. Apart from BCR, there is also another method in CBA, namely Nett Present Value (NPV). The NPV methods subtract the total benefit from the total cost, hence, it produces absolute currency value (De Rus, 2010; Queensland Government, 2011). The NPV is only useful for comparing across different projects if those projects are within a similar magnitude. Therefore, this research utilises BCR as a basic concept to develop the CBA model.

The CBA approach is combined with the sensitivity analysis in order to systematically examine how the outcome of a cost-benefit analysis varies in response to changes in inputs, assumptions, or analysis setup. It is a valuable tool for comparing different alternative scenarios. This approach helps to understand the conditions under which a particular output is likely to occur, considering various key determinants (Hadley, 2011; Rayment et al., 2021). SA is essential to test the sensitivity of results to changes in various parameters or assumptions within the model, it is regarded as a necessary step in model construction for diagnostic or prognostic purposes, as well as in any field that utilises models (Saltelli, 2002). Sensitivity analysis is an important step in determining the resilience and dependability of a mathematical model, particularly in the context of cost-benefit analysis. Sensitivity analyses are often categorised as either local (LSA) or global (GSA). Local sensitivity analysis examines how changes in par-

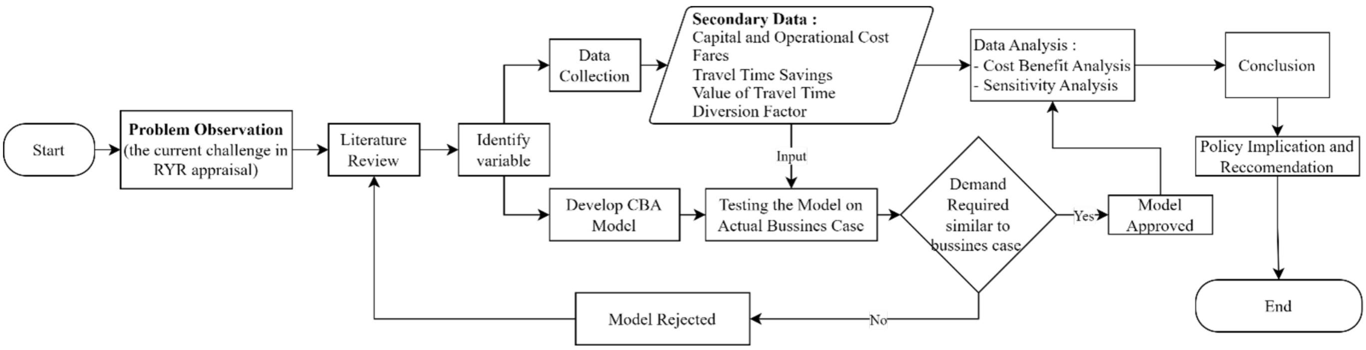

Figure 1 Research Procedures

Table 1. Capital cost per KM without optimism bias

Rail Project Name	Length (km)	Capital Cost per km	Operational Cost per km	Source
Barrow Hill Line	20.7	Rp 81,176,000,000	Rp53,709,600,000	(Sheffield City CA, 2021)
Metro West	14	Rp 70,066,997,802	Rp105,302,907,486	(West of England Combined Authority, 2014)
Waterside Rail	8.3	Rp 93,724,780,871	Rp35,026,332,000	(Hampshire Council, 2021)
Northumberland	24.5	Rp 78,651,792,420	Rp97,828,200,000	(AECOM, 2019)

ticular input parameters influence output around a single point in the parameter space. Global sensitivity analysis, on the other hand, assesses the impact of input parameters throughout the whole parameter space (Saltelli et al., 2008).

This research employs the global sensitivity analysis (GSA). The GSA analysis performed a large number of simulations, similar to Monte Carlo simulations, it requires a tool that is able to calculate it automatically. Therefore, this research utilised Saltelli methods (Saltelli et al., 2010) that are written in Scala on OpenMOLE platform (Reuillon et al., 2013). It is worth noting that the Saltelli methods tend to perform sensitivity analysis on the models not on the data, therefore, it does not require any specific data for the key input. Rather, it takes a data in the form of range, usually the maximum and minimum values.

Since this research utilised secondary data that is widely available, the data collection is solely about finding the correct data that aligns with the research objective. Most of the business cases used as reference in this research are already published for public domain, except for a specific business case, namely Borders railway business case. This requires researchers to request directly from Network Rail, as there are confidential financial and commercial discussions. Additionally, a prompt telephone conversation was conducted with Mike Smith, the Programme Director of Restoring Your Railway, to furnish and authenticate supplementary data necessary for the analysis. Furthermore, another supplementary data was obtained from the manual guidance of transport appraisal extensively utilized in the UK, as well as from the Greenbook, which offers a comprehensive overview of Value for Money classifications.

Before conducting sensitivity analysis, several data and assumptions are needed to define. The data utilised in this research is categorised as secondary data, sourced from various publications, e.g. Business Case studies, journals, reports or working papers. In cases where the required data is unavailable, necessary assumptions are made. It is essential to acknowledge that the baseline assumptions used in the appraisal below have been derived from high-level assumptions and analysis.

2.1 Capital and Operational Cost

Differences in capital costs are subject to variations in construction costs, land acquisition, and the construction methods employed. Additionally, the capital costs mentioned above already include an additional optimism bias. Therefore, Table 1 provide the range of capital cost across different projects

2.2 Expected Travel Time Saving and Fares

Assumes that the average distance covered by a single train journey in the UK is around 29 miles, as reported by Department for Transport (2017). The average speed of trains in the UK falls within the range of 55 to 125 mph, as extracted from various sources (Lancefield et al., 2017; TfN, 2019; Cairns, 2023; Northern Railway, 2023). On the other hand, intercity buses typically achieve an average speed of 30 mph on free-flowing roads (Department for Transport, 2016). Utilising these statistics, the expected time savings from a bus to a train over a 29-mile distance are estimated between 30 to 45 minutes.

Fares can vary based on the level of demand and journey distances. Therefore, it requires data expressed in

Table 2. Railway incomes Revenue 2017 – 2019

Revenues (Billion)			Passenger Km (billion)			Ticket Prices (per passenger per km)		
2017	2018	2019	2017	2018	2019	2017	2018	2019
Rp221,513	Rp219,940	Rp228,764	66.0	66.2	67.7	Rp3,261	Rp3,261	Rp3,453

Source: Office of Rail and Road (2022, 2023)

Table 3. Value of Time

Values of Time by Mode (Rp. per hour, prices)			
Trip Purpose	Factor Cost	Perceived Cost	Market Price
Commuting	176,090.76	209,659.26	209,659.26
Other	80,372.58	95,718.18	95,718.18

Source: Department for Transport (2023*a*)

per passenger per kilometre units. Office of Rail and Road (2022) published financial data that contains income revenues from fares cost for every Train Operating Companies (TOCs) in UK, then this data is divided by passenger kilometres (Office of Rail and Road, 2023) in the UK. The data is shown in Table 2.

The ticket prices seen in Table 2 is obtained by dividing the total revenues from fares by total journey distance by all passengers. In order to avoid bias and uncertainty in the data set, it is selected from the time period preceding the COVID-19 pandemic. According to Table 2, the fare is Rp. 3,325 per passenger per kilometre. This value is the average fares which is potentially differs compared to specific case scenario. However, for simplicity, this research utilized the average fares per passenger per kilometre seen in Table 2.

2.3 Value of Time

Since the appraisal method measures benefit and cost in monetary terms, the Value of Time (VOT) is an important variable to convert the travel time into monetary value. The TAG incorporates several values of times depending on the trip purpose. Table 3 shows the value of time for a particular trip purpose that is used to produce the generalised cost:

The value of time obtained from the TAG Databook does not account for benefits arising from mode shift. Therefore, Mackie et al. (2003) introduce the quality adjustment of VOT between transport modes that is seen in Table 4.

Utilizing the ratio of VOT mentioned in Table 4, the VOT for each mode can be estimated as follows: The Average VOT from commute and leisure journey type is Rp. 159,018 per hours, which same for all modes. Therefore, incorporating Dunkerley et al. (2018) approach, the percentage of Rail and Bus VOT to Car VOT within 25 miles distance is 76.5% and 109%. Furthermore, the VOT for Bus approximately Rp. 2,877 per minute, and VOT for Rail approximately Rp. 2,110 per minutes

2.4 Diversion Factor

The demand expression can be quite complex as demand may originate from various transport modes. In this research, to simplify the analysis, it is assumed that the scenario mirrors the reduced multi-modal approach, where the do-minimum scenario is characterized by the presence of an alternative public transport option, typically represented by buses or other similar modes of transportation. In the do-minimum scenario, the bus diversion factor is used to represent the demand for buses, on the other hand, the car diversion factor is used to calculate the Marginal External Benefit (MEb) because it captures the benefits gained from reducing car usage on the roads.

Dunkerley et al. (2018) conduct a study related to journey time elasticities and diversion factors for all modes in United Kingdom. This report, commissioned by the UK Department for Transport, offers insights into fare and journey time elasticities, as well as diversion factors across all transportation modes. Utilizing a rapid evidence reviews method; the study systematically identifies relevant academic and grey literature through structured database searches and expert inquiries. It presents key findings derived from the analysis of the collected evidence and offers recommendations for values to be utilized in demand forecasting, appraisal, policymaking, while also identifying existing evidence gaps. According to Dunkerley et al. (2018), the diversion factor is seen in Table 5.

2.5 GDP Growth

There is another consideration when determining the present value of total benefits and total costs, which is the annual economic growth rate of a particular country. This annual growth rate indicates growth in national economic conditions. Currently, GDP is the most accurate determinant to represent economic growth, measured in terms of the increase in the aggregated market value of additional goods and services produced (**?**). Considering these facts, the annual growth rates should be taken into account for calculating the present value of total benefits and total costs (Harberger, 1962; Quah et al., 2021). Extracted from Office for National Statistic (2023), for the last 20 years of UK economic development, the average GDP growth is between 0.17% – 1.28%.

Table 4. Quality-adjusted VOT

Trip Purpose and Distance		VOT_{car} Rp. per minute	VOT_{rail} as % of VOT_{car}	VOT_{bus} as % of VOT_{car}
Commute	10 miles	103.58	85	119
	25 miles	132.36	78	109
Leisure	10 miles	93.99	84	118
	50 miles	184.15	75	104

Source: Mackie et al. (2003)

Table 5. Diversion factor

Do-minimum scenario		Do-something scenario
Bus (Q_0^{Bus}) : $0.3Q_1^{Rail}$	To estimate user benefit	Rail (Q_1^{Rail}) : 1
Car (Q_0^{Car}) : $0.4Q_1^{Rail}$	To estimate MEb	
New Generated (Q_0^{New}) : $0.3Q_1^{Rail}$		

Source: Dunkerley et al. (2018)

3 Developing CBA Models

The general concept of BCR is dividing the total benefit by the total cost to gain the ratio between those two variables. The common equation is as follows Equation 1:

$$BCR = \frac{\textit{Total Benefit}}{\textit{Total Cost}} \tag{1}$$

3.1 Total Benefit

The majority of the total benefit is derived from user benefits and marginal external benefits (Nash, 2015). The equation can be expressed in Equation 2. Note that, the integral exponential function indicates that the model is estimated in present value. The *Ub* express as user benefit, and *MEb* expressed as marginal external benefit.

$$\textit{Total Benefit(TB)} = \int_0^t (\textit{Ub+MEB})e^{-rt}dt \tag{2}$$

Rearrange using the principles of exponential integral (Equation 3):

$$\textit{Total Benefit(TB)} = \frac{(Ub + MEb)}{r}(1 - e^{-rt}) \tag{3}$$

According to Nellthorp (2017), the user benefit can be estimated utilizing the concept of rule of half, in which the rule assumes that users will only capture half of the benefits resulting from a reduction in travel time or cost, with the other half being captured by producers or suppliers of transport services (Winkler, 2015; Department for Transport, 2022*a*). The general equation for ROH is seen in Equation 4 and 5.

$$Ub = \frac{(GJC_0 - GJC_1)(Q_0^{Bus} + Q_1^{Rail})}{2} \tag{4}$$

$$Ub = \frac{(IVT_0{*}VTTS_0 - IVT_1{*}VTTS_1)(Q_0^{Rail} + Q_1^{Rail})}{2} \tag{5}$$

The assumption used for user benefit calculation is that the scenario is set to replicate the reduced multi-modal approach. Hence, the demand configuration for calculating user benefit is: $Q_0^{Bus} = 0.3Q_1^{Rail}$

furthermore, the user benefit equation is shown in the Equation 6 and 7:

$$Ub = \frac{(IVT_0{*}VTTS_0 - IVT_1{*}VTTS_1)(0.3Q_1^{Rail} + Q_1^{Rail})}{2} \tag{6}$$

$$Ub = \frac{(IVT_0{*}VTTS_0 - IVT_1{*}VTTS_1}{)}(1.3Q_1^{Rail})2 \tag{7}$$

Marginal External Benefits (*MEb*) are the additional benefits gained by society when the negative cost of externalities related to transportation activities are reduced or eliminated. These costs are not incurred directly by rail passengers but rather by society as a whole. Factors such as congestion, air pollution, noise, infrastructure wear and tear, and accidents are examples of marginal external costs. Therefore, the introduction or improvement of rail transport that reduces the negative externalities becomes an indirect benefit to society (Department for Transport, 2022*b*).

Since most of externalities comes from car usage, the car diversion factor in Table 5 is used to estimate the externalities benefits. The value of 0.475 is used to calculate the MEb to account for car users who would switch to rail improvement, which results in the following:

$$Q_0^{Car} = 0.475Q_1^{Rail} \tag{8}$$

Table 6. Externalities Monetary Value

Marginal External Costs		Indirect Tax - Cars
No	Cost Type	Weighted average (pence per vehicle km)
1	Congestion	14.5
2	Infrastructure	0.1
3	Accident	1.9
4	Local Air Quality	0.2
5	Noise	0.1
6	Greenhouse Gases	2.6
7	Indirect Taxation	-2.2
	Total	17.3

Source: Department for Transport (2023*b*)

The monetary value of road externalities, according to TAG Databook, is seen in Table 6.

According to Table 6., the total monetary value of car benefit externalities is 17.3 pence per 1 km road (Department for Transport, 2022*b*). Additionally, based on data from the National Transport Survey, the average car occupancy in the UK is 1.55 passengers per car, and the average rail journey in the UK is approximately 29 miles (Department for Transport, 2017). Furthermore, the equation to calculate *MEb* is as follow:

$$MEb = \frac{Q_0^{Car}}{1.55} * Distances * 17.3pence \tag{9}$$

$$MEb = \frac{0.475Q_1^{Rail}}{1.55} * S * 17.3pence \tag{10}$$

$$MEb = 0.053S.Q_1^{Rail}pounds \tag{11}$$

The equation for user benefit (7) and marginal external benefit (11) is inputted into the total benefit equation.

$$\textit{Total Benefit(TB)} = \frac{(Ub + MEb)}{r}(1 - e^{-rt}) \tag{12}$$

$$TB = \frac{\frac{(IVT_0 * VTTS_0 - IVT_1 * VTTS_1)(1.3Q_1^{Rail})}{2}}{r} + \frac{0.053SQ_1^{Rail}}{r}(1 - e^{-rt}) \tag{13}$$

To simplify the equation writing, let α=(1-e^{-rt}) and $\Delta = (IVT_0 * VTTS_0 - IVT_1 * VTTS_1)$

$$TotalBenefit = \frac{(\frac{(\Delta)(1.3Q_1^{Rail})}{2} + 0.053SQ_1^{Rail})}{r}(\alpha) \tag{14}$$

3.2 Total Cost

The total cost function is determined by the sum of investment and operational costs, subtracted from the revenue generated. The scenario is mimicking the reduced multi-modal approach, in which there is a fraction of demand in DM that is shifted into rail modes, then Q_1^{Rail} is substracted by Q_0^{Bus}.

This subtraction is important to avoid double counting, i.e. demand from current transport modes that already exist.

Another factor that must be considered in determining the total cost is the total revenue. Like user benefits, these are proportional to the demand for rail. Hence, in new railway initiatives, there is a significant correlation between User Benefits (UB) and fare revenues, which are the primary contributors to overall benefits. It's crucial to emphasize that, within the UK framework, the inclusion of revenues in Benefit-Cost Ratio (BCR) calculations is enabled by the present value of costs (PVC). This approach is adopted because the anticipated revenues are anticipated to alleviate the overall transport budget requirements, aligning with the definition mandated by the Transport Analysis Guidance (TAG) (Ojeda-cabral et al., 2021). Extracted from de Rus and Nash (2007) and minor adjustments, the total cost equation is:

$$\textit{Total Cost} = \textit{(Investment Cost+Operational Cost)-Revenue} \tag{15}$$

$$\textit{Total Cost} = (I + \int_0^t (Op)e^{-rt}dt) - (\int_0^t p(Q_1^{Rail} - Q_0^{Bus})e^{-rt}dt) \tag{16}$$

Investment and operational costs are usually derived from financial analysis, which usually provides per unit cost. Subtracting income revenues from the overall project expenses assists in acknowledging the potential revenue generation of the project and establishing the net cost of the project. This net cost reflects the true expenditure of the project once any generated revenue is considered (Stubbs et al., 2017; Weisbach et al., 2018).

To be noted that the total cost models only assume that the capital cost only occurs in the first year only. On the other hand, the operation cost and income revenue are applied in every year of the time period, hence, the operational cost and income revenue are multiplied by discount factors. Furthermore, incorporating the basic principles of integral exponential function, which is exemplified in the de Rus and Nash (2007) paper, the equation above can be simplified:

$$\textit{Total Cost} = (I + \frac{Op * (1 - e^{-rt})}{r}) - (\frac{(Q_1^{Rail} - Q_0^{Bus})p * (1 - e^{-rt})}{r}) \tag{17}$$

Due to this model utilising the reduced multi-modal approach, then $Q_0^{Bus} = 0.3Q_1^{Rail}$, furthermore the total cost function is:

$$\textit{Total Cost} = (I + \frac{Op(1-e^{-rt})}{r}) - (\frac{(Q_1^{Rail} - 0.3Q_1^{Rail})p*(1-e^{-rt})}{r}) \quad (18)$$

To simplify the equation, let α=(1-e^{-rt}),

$$TotalCost = (I + \frac{Op*(\alpha)}{r}) - (\frac{(Q_1^{Rail} - 0.3Q_1^{Rail})p*(\alpha)}{r}) \quad (19)$$

3.3 CBA Model

The CBA model is constructed using the equation of total benefits and total costs that are inserted into the BCR equation. By substituting the Total Benefit (14) and Total Cost (19) values into the BCR Equation, the model is established.

$$BCR = \frac{\frac{\frac{(\Delta)(1.3Q_1^{Rail})}{2} + 0.053Q_1^{Rail}}{r}(\alpha)}{I + \frac{Op*(\alpha)}{r} - \frac{(Q_1^{Rail} - 0.3Q_1^{Rail})p*(\alpha)}{r}} \quad (20)$$

In order for the model to calculate the required demand, it should be rearranged, simplified and substituting,α=(1-e^{-rt}), and $\Delta = (IVT_0*VTTS_0 - IVT_1*VTTS_1)$

back to the equation. This model is utilized as a basis to conduct CBA and sensitivity analysis, assessing the changes in the required demand in response to uncertainty in key determinants.

$$Q_1^{Rail} = \frac{\frac{(\frac{BCR*I*r}{1-e^{-rt}})BCRR*Op}{IVT_0*VTTS_0 - IVT_1*VTTS_1}}{\frac{1}{0.65 + 0.053S + 0.7*p*BCR}} \quad (21)$$

Op = Operational Cost
I = Capital cost
r = discount rates
t = time
p = ticket prices
S = Distances
IVT_0 = In Vehicle Time (bus)
VOT_1 = Value of Travel Time in Do-Something Scenario (Train)
VOT_0 = Value of Travel time in Do-minimum Scenario (Bus)
Q_1^{Rail} = Demand for DS scenario (rail)
$IVT_1 = InVehicleTime(rail)$

Table 7. Key determinant from Barrow hill and Fleetwood

Key Determinant	Barrow Hill	Fleetwood
Operational Cost / Year	Rp. 79,221,660,000	Rp. 55,627,800,000
Capital cost (year 1)	Rp. 2,100,429,000,000	Rp. 2,321,022,000,000
Ticket Prices	Rp. 68,672	Rp. 68,672

Source: Lancashire County Council (2021); Sheffield City CA (2021)

4 RESULTS

4.1 Testing the CBA model

The model is tested against the actual business case to gain an insight whether the improved approach of will contributes better BCR value. Testing the models is also useful to validate whether the model closely resembles real-world conditions. The business case that is used to test the model are Barrow hill line and Fleetwood line. The time periods used is 60 years with 3.5% discount rates following the standard UK approach (Department for Transport, 2022*b*). The input parameter for both case is seen in Table 7.

Necessary assumptions are: The discount rate is fixed, Investment occurs in year one only, Operational cost is fixed per year, no demand and benefit growth incurred. The result is seen in Table 8.

4.2 Local Sensitivity Analysis (LSA)

This analysis aims to provide insights into the conditions that might lead to achieving acceptable benefit-cost ratio (BCR) values. The key determinant data needed for constructing the model is collected from various actual business cases and publications. This analysis entails systematically varying the model's key determinants and inputs to observe how changes in these factors impact the output. Let's consider a hypothetical scenario of railway reopening initiatives encompassing a distance of 50 KM. The data and assumptions used for this scenario is shown in Table 9.

The baseline scenario is sets that the project would yield a BCR of 1.5 based on a particular combination of key determinants. Furthermore, several key determinants are altered in order to analyse the potential changes in the required demand to yield different levels of BCR (1, and 2). As seen in Table 10, The demand fluctuates depending on changes in the key determinant, ranging from 890,000 to 2.21 million passengers per year.

To gain a comprehensive understanding of how this demand value compares to real scenarios, the model is compared to actual case studies, like the successful Borders railway line in the UK. Covering approximately 50 km, the Borders railway line serves as a benchmark. It attracts around 1.29 million passengers per year (Tra, 2012).

Table 8. CBA Model testing results

Scenario	Barrow hill line				Fleetwood line			
	BCR	VOT_0	VOT_1	Q_1	BCR	VOT_0	VOT_1	Q_1
Business Case	1.5 - 2	Rp. 4147	Rp. 4147	1,464,654	1.5	Rp. 4147	Rp. 4147	1,270,000
without Quality Benefit	1.75	Rp. 4147	Rp. 4147	1,520,603	1.5	Rp. 4147	Rp. 4147	1,348,674
with Quality Benefit	1.75	Rp. 2965	Rp. 4147	1,247,750	1.5	Rp. 2965	Rp. 4147	1,103,305

Table 9. Baseline Scenario

Variables	Value	Unit	Variables	Value	Unit
Ticket prices	Rp. 3,325	Per km	Discount Rates	3.50%	fix for 60 years
Operational Cost	Rp.2.48 – Rp.4.2	Billion per km	GDP Growth	0.07 – 1.28	Percent per years
Capital cost	IDR 70 – 93	Billion per km	Time Periods	60	years

4.3 Global Sensitivity Analysis (GSA)

This subsection aims to measure the relative significance of distinct key determinant parameters and their interactions with another key determinant in influencing the variability of the output. The CBA model is tested utilizing the Saltelli approach (Saltelli et al., 2010) that is based on the Sobol methods and executed it on OpenMOLE platform (Reuillon et al., 2013). The results are seen in Table 11.

5 DISCUSSION

5.1 The expected BCR value of improved approach

Based on Table 8, If the quality improvement benefit is ignored, the model's required demand is slightly higher than that mentioned in the business case. However, utilizing quality improvement benefits, which is indicated by two distinct values of time, the model is able to generate lower demand required compared to the business case. Therefore, if the specific required demand in the business case is aim for, the CBA model is able to generate higher BCR value. Approximately 17 – 20% more than in the business case.

5.2 The circumstances that yield acceptable VfM (Low, Medium, High)

According to Table 10, the required demand practically changes when the value of the key determinant is altered. In line with the increasing in capital cost, the demand that is align with the Borders railway are gradually decreasing, even further when the 30% optimism bias is applied. Furthermore, by looking at Table 10, we can gain an insight that operational costs have higher contributions to the required demand, followed by capital costs. In the context BCR 1.5 and 2, the highest operational cost generate the required demand that far beyond the benchmarked studies, even when it coupled with the highest time saving, the highest GDP growth and diversion factor.

Following the principles of GSA, the value that close to zero indicates that the parameter has no influence on the output variance, and the value that close to 1 indicates that the parameter has a significant influence on the output. As seen in Table 11, In any VfM category, the total-order indices for X1, X2, and X4 remain constant at approximately 29%, 25%, and 40%, respectively. This implies that, across various levels of VfM, these three key determinants consistently hold significance in determining the model output. However, surprisingly, the IVT train, translated into time savings, does not play a significantly influential role in determining the model output. Within the three categories of VfM, X3 only registers between 1.8% and 4.3% in either first-order or total-order indices. The diversion factor also does not play a significant role, as it only occurs between 2.22% and 2.73%.

5.3 Limitations, Strengths, and Weaknesses

This research, rooted in cost-benefit analysis and specific data assumptions, has inherent limitations. Appraisal, as a discipline within the social sciences, depends significantly on these assumptions, which directly impact its accuracy. This study is particularly dependent on assumptions, especially in securing key inputs like capital and operational costs, often relying on average values. Consequently, its relevance to specific case studies may be questioned. Moreover, the detail provided on operational costs is insufficient, with only aggregate expenses listed and lacking specific yearly breakdowns such as rolling stock maintenance and staff salaries.

However, this paper offers intriguing findings and insightful discussions. The model effectively captures the benefits that arise in the context of a mode shift, e.g., quality improvement. The sensitivity analysis pro-

Table 10. Demand required based on various circumstances.

KM				50	No Optimism Bias Cost (*)						30% Optimism Bias Added (*)					
capex/km					Rp70,067		Rp81,176		Rp93,258		Rp70,067		Rp81,176		Rp93,258	
capex total					Rp3,503,350		Rp4,058,800		Rp4,662,919		Rp4,554,355		Rp5,276,440		Rp6,061,794	
					Diversion Factor											
BCR	Opex / KM	Opex Total	θ	TTS	0.16	0.2	0.16	0.2	0.16	0.2	0.16	0.2	0.16	0.2	0.16	0.2
					Demand Required (*)											
1.00	Rp. 2,475	Rp. 123,7553	1.28%	30	0.89	0.91	0.96	0.97	1.03	1.04	1.01	1.03	1.10	1.12	1.19	1.21
				35	0.87	0.88	0.93	0.95	1.00	1.02	0.99	1.01	1.07	1.09	1.16	1.18
				40	0.85	0.86	0.91	0.93	0.98	0.99	0.97	0.98	1.05	1.06	1.14	1.15
				45	0.83	0.84	0.89	0.90	0.96	0.97	0.95	0.96	1.03	1.04	1.11	1.13
			0.07%	30	1.01	1.03	1.10	1.12	1.19	1.21	1.18	1.20	1.29	1.31	1.41	1.43
				35	0.99	1.01	1.07	1.09	1.16	1.18	1.15	1.17	1.26	1.28	1.37	1.40
				40	0.97	0.98	1.05	1.07	1.14	1.16	1.12	1.14	1.23	1.25	1.34	1.36
				45	0.95	0.96	1.03	1.04	1.11	1.13	1.10	1.11	1.20	1.22	1.31	1.33
	Rp. 4,220	Rp. 211,002	1.28%	30	1.23	1.25	1.29	1.32	1.36	1.39	1.35	1.38	1.44	1.46	1.53	1.56
				35	1.20	1.22	1.26	1.29	1.33	1.36	1.32	1.34	1.40	1.43	1.49	1.52
				40	1.17	1.19	1.24	1.25	1.30	1.32	1.29	1.31	1.37	1.39	1.46	1.48
				45	1.15	1.16	1.21	1.23	1.27	1.29	1.26	1.28	1.34	1.36	1.43	1.45
			0.07%	30	1.35	1.38	1.44	1.46	1.53	1.56	1.51	1.54	1.62	1.65	1.74	1.78
				35	1.32	1.34	1.41	1.43	1.50	1.52	1.48	1.50	1.59	1.61	1.70	1.73
				40	1.29	1.31	1.37	1.39	1.46	1.48	1.45	1.47	1.55	1.57	1.67	1.69
				45	1.26	1.28	1.34	1.36	1.43	1.45	1.41	1.43	1.52	1.54	1.63	1.65
1.50	Rp. 2,475	Rp. 123,7553	1.28%	30	1.05	1.07	1.12	1.15	1.21	1.24	1.19	1.22	1.29	1.32	1.40	1.43
				35	1.03	1.05	1.10	1.13	1.18	1.21	1.17	1.20	1.27	1.30	1.37	1.41
				40	1.01	1.03	1.08	1.11	1.16	1.19	1.15	1.17	1.24	1.27	1.35	1.38
				45	0.99	1.01	1.06	1.09	1.14	1.17	1.13	1.15	1.22	1.25	1.33	1.35
			0.07%	30	1.19	1.22	1.29	1.33	1.40	1.44	1.38	1.42	1.51	1.55	1.65	1.69
				35	1.17	1.20	1.27	1.30	1.38	1.41	1.36	1.39	1.48	1.52	1.62	1.66
				40	1.15	1.18	1.25	1.27	1.35	1.38	1.33	1.36	1.46	1.49	1.59	1.63
				45	1.13	1.15	1.23	1.25	1.33	1.36	1.31	1.34	1.43	1.46	1.57	1.60
	Rp. 4,220	Rp. 211,002	1.28%	30	1.45	1.48	1.52	1.56	1.60	1.64	1.59	1.63	1.69	1.73	1.80	1.84
				35	1.42	1.45	1.49	1.53	1.58	1.61	1.56	1.60	1.66	1.70	1.76	1.81
				40	1.39	1.42	1.47	1.50	1.55	1.58	1.53	1.57	1.63	1.67	1.73	1.77
				45	1.37	1.40	1.44	1.47	1.52	1.55	1.51	1.54	1.60	1.63	1.70	1.74
			0.07%	30	1.59	1.63	1.69	1.73	1.80	1.84	1.78	1.82	1.91	1.96	2.05	2.10
				35	1.56	1.60	1.66	1.70	1.77	1.81	1.75	1.79	1.88	1.92	2.01	2.06
				40	1.53	1.57	1.63	1.67	1.74	1.77	1.72	1.76	1.84	1.88	1.98	2.02
				45	1.51	1.54	1.60	1.64	1.70	1.74	1.69	1.72	1.81	1.85	1.94	1.98
2.00	Rp. 2,475	Rp. 123,7553	1.28%	30	1.15	1.18	1.23	1.27	1.32	1.36	1.31	1.34	1.42	1.46	1.53	1.58
				35	1.13	1.16	1.21	1.25	1.30	1.34	1.29	1.32	1.39	1.43	1.51	1.55
				40	1.11	1.14	1.20	1.23	1.28	1.32	1.27	1.30	1.37	1.41	1.49	1.53
				45	1.10	1.13	1.18	1.21	1.27	1.30	1.25	1.28	1.35	1.39	1.47	1.51
			0.07%	30	1.31	1.35	1.42	1.46	1.54	1.58	1.52	1.56	1.66	1.71	1.81	1.86
				35	1.29	1.33	1.40	1.44	1.51	1.56	1.49	1.53	1.63	1.68	1.78	1.83
				40	1.27	1.30	1.38	1.41	1.49	1.53	1.47	1.51	1.61	1.65	1.76	1.81
				45	1.25	1.28	1.36	1.39	1.47	1.51	1.45	1.49	1.59	1.63	1.73	1.78
	Rp. 4,220	Rp. 211,002	1.28%	30	1.58	1.63	1.67	1.72	1.76	1.81	1.74	1.79	1.85	1.91	1.97	2.03
				35	1.56	1.60	1.64	1.69	1.73	1.78	1.72	1.77	1.82	1.88	1.94	2.00
				40	1.54	1.58	1.62	1.66	1.71	1.75	1.69	1.74	1.80	1.85	1.91	1.96
				45	1.52	1.55	1.60	1.64	1.68	1.73	1.67	1.71	1.77	1.82	1.88	1.93
			0.07%	30	1.75	1.80	1.85	1.91	1.97	2.03	1.95	2.01	2.09	2.16	2.25	2.31
				35	1.72	1.77	1.83	1.88	1.94	2.00	1.92	1.98	2.06	2.12	2.21	2.28
				40	1.69	1.74	1.80	1.85	1.92	1.97	1.89	1.95	2.03	2.09	2.18	2.24
				45	1.67	1.71	1.77	1.82	1.89	1.94	1.87	1.92	2.00	2.05	2.15	2.21

*Opex Figures in Million *Demand figure in Million. Capex figure in Million

Abbreviation in Table 10, TTS: Travel Time Savings, Opex: Operational Expense, Capex: Capital Expense.

Note: The grey highlighted cells indicate the demand value aligned with the border's railway scenario.

Table 11. Global Sensitivity Test Indices

BCR	1 (VfM Low)		1.5 (VfM Medium)		2 (VfM High)	
Determinant	First Order	Total Order	First Order	Total Order	First Order	Total Order
Capital Cost (X1)	28.91%	29.00%	29.34%	29.42%	29.54%	29.62%
Growth Factor (X2)	24.90%	25.24%	25.26%	25.61%	25.44%	25.78%
IVT Train (X3)	4.36%	4.33%	2.68%	2.65%	1.81%	1.78%
Operational Cost (X4)	39.68%	39.46%	40.26%	40.03%	40.54%	40.31%
Diversion Factor (X5)	2.19%	2.22%	2.50%	2.53%	2.70%	2.73%
Total	100%	100%	100%	100%	100%	100%

vides deeper insights into which key determinant has the greatest impact on the required demand. Lastly, this paper addresses limitations stemming from the development of the CBA model. Grounded in the UK government's manual and guidance, it embraces a governmental over a corporate perspective. The model focuses solely on user benefits and marginal external benefits, neglecting secondary market impacts like land value uplift, GVA, and job improvements. Additionally, it is specifically designed for the UK appraisal approach, requiring modifications for application in other countries. Furthermore, it is based on a reduced multimodal approach, presuming the "do minimum" scenario is served solely by buses.

6 CONCLUSION

The model developed in this research is able to produce significant improvement in the BCR values. The CBA model show a better grasp of user benefits related to mode shift, such as quality differences and diversion factors. It is proved by testing the models on two business cases. The demand requirement for the improved methods is roughly 21% less than mentioned in the business case. Therefore, the CBA model produce higher BCR value, approximately 17 – 20% more than stated in the business case. The sensitivity analysis shows how demand requirements will shift if the key determinant value varies based on several circumstances. Using the Borders railway as a benchmarked study case, not all combinations of key determinants generate the required demand that aligns with the Borders case. Operational cost is considered to affect the required demand the most, followed by capital cost. Following the GSA, the total order indices for operational cost are the highest, approximately 40%, followed by capital cost and the growth factor with 29% and 25%, respectively. The indices indicate that operational cost, when it interacts with other key determinants, contributes nearly half of the model output. Therefore, it is valid to state that operational cost is the highest contributor to the model output, either as a standalone variable or when interacting with another key determinant. This finding provides insight for stakeholders on what kind of variables need to be pursued to alter the demand, either with the aim to increase or decrease the required demand.

DISCLAIMER

The authors declare no conflict of interest.

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