SAVi Sustainable Asset Valuation

Sustainable Asset Valuation of a Bus Rapid Transit System in Bandung, Indonesia

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July 2023

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Acknowledgements

The International Institute for Sustainable Development would like to thank the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH/Transformative Urban Mobility Initiative team—and Frederic Tesfay, in particular—for collaborating on this project. The authors of this report are also grateful to Achmad Zacky Amdabar from GIZ Indonesia and Fiyat Irawan from the transportation division of the Bandung Basin Metropolitan Area Management Authority (BP Cekban) for their support and engagement.

This report is part of a series of Sustainable Asset Valuation (SAVi) assessments on sustainable transportation and mobility projects to raise awareness and inform decision-makers on the use of systemic approaches and simulation to support the transformation toward sustainable mobility.

For more information about the project, see: https://www.iisd.org/savi/using-systemic-approaches-and-simulation-to-support-transformation-toward-sustainable-mobility/

We are grateful for the financial support of the German Federal Ministry for Economic Cooperation and Development (BMZ).

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Executive Summary

Purpose of This Assessment and the Sustainable Asset Valuation Methodology

This Sustainable Asset Valuation (SAVi) assessment of the bus rapid transit (BRT) system in Bandung City, Indonesia, is part of a series of SAVi assessments on sustainable transportation and mobility projects.

The assessments aim to raise awareness of sustainable transportation infrastructure investments and inform decision-makers on the use of systemic approaches in supporting the transformation toward sustainable mobility. The assessments also integrate the economic valuation of social and environmental impacts such as health and carbon dioxide (CO_2) emissions and aim to highlight their importance for the transportation investment decision-making processes.

The SAVi methodology provides policy-makers and investors with a comprehensive and customized analysis of how much their infrastructure projects and portfolios will cost throughout their life cycles, taking into account risks and externalities that are overlooked in a traditional valuation. SAVi is

- A combination of systems thinking and different modelling methodologies, spatial modelling, economic multiplier/multicriteria assessments, system dynamics, and financial models.
- Customized to each individual infrastructure project, portfolio, or policy.
- Co-created with the decision-makers and stakeholders. The multi-stakeholder approach enables stakeholders to identify the material risks and opportunities that are unique to the projects or alternatives. This strengthens the capacity of decision-makers and stakeholders to take a systemic approach to investments and increases the likelihood of the uptake, use, and impact of the results of the analysis.
- Based on project-level data (where available), the SAVi database (based on literature reviews and data from previous SAVi applications), and best-in-class climate data from the European Union Copernicus Climate Data Store (built into all SAVi models).

BRT in Bandung

Bandung is West Java province's capital city and Indonesia's third-largest city, located about 180 km southeast of Jakarta. The city covers an area of approximately 167 km^2 and has a density of 14,834 people per km^2. The city has a population of approximately 2.5 million.

Motorcycles are the predominant transportation mode in Bandung, accounting for around 75% of all personal movement in the main transportation corridors and two thirds of all vehicle movement. Four-wheelers account for around 20% of trips, and public transport, which consists of large bus services such as the TransMetro Bandung and DAMRI, accounts for only 5% of trips, even less outside these main corridors. The latter account for only around 10% of public transit ridership.

Bandung City in Indonesia has been facing significant urban mobility and transportation challenges as it is constrained by a dense and congested urban road network that is over-reliant on individual motorized transportation modes, predominantly motorcycles. This unsustainable mobility pattern results in high traffic volumes and congestion, health and safety concerns, and CO_2 emissions. These problems are projected to worsen with climate change and continued urban development, which centres around private transportation modes.

To address these challenges, the Bandung City, together with the Indonesian Ministry of Transport and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), explored the option of a city-wide BRT system. The BRT could increase mobility options through public transportation and provide a safe and sustainable transportation mode for current and future users. A comprehensive BRT system could lead to a shift from individual motorized transportation modes to BRT and meet sustainable, low-carbon mobility targets. The BRT system is projected to be 27.4 km long, and it is expected to transfer 204,000 passengers per day after its fourth year of operation in a vehicle fleet of 357 buses. The estimated cost of the BRT infrastructure is IDR 939.119 billion (USD 65.941 million).

This report discusses the value of the economic, social, and environmental outcomes of the BRT and how they impact the financial performance of the project. We used a variety of models to provide estimates of the investment costs (capital, operation and maintenance costs) and the environmental, social, and economic added benefits and avoided costs. We estimated these under low- and high-demand scenarios. The project period used in the assessment starts in 2022 and ends in 2050.

Findings

According to the analysis, the BRT system in Bandung has a wide range of economic, social, and environmental benefits that are typically overlooked in traditional infrastructure assessments. We show that the BRT system will have significant economic benefits related to the value of time saved, positive changes in retail revenues, and health benefits from increased physical activity and reduced levels of air pollution. The SAVi assessment also shows the resulting fuel use savings and CO_2 emissions reductions.

Table ES1 summarizes the results of the integrated cost-benefit analysis (CBA). In addition, we divided the SAVi results into two BRT scenarios: a current BRT scenario based on data from the existing BRT feasibility studies and a high-ambition BRT scenario that assumes growing BRT demand that doubles in 2035 and triples in 2045.

According to the SAVi BRT model, the total net value of both BRT scenarios is positive, and therefore the project is profitable from both macroeconomic and societal perspectives. The integrated CBA shows cumulative, discounted net values of IDR 31,181 billion for the current BRT scenario and IDR 66,75 billion for the high-ambition BRT scenario. The cumulative net benefit takes the wider economic, social, and environmental costs and benefits into account and thus provides information on the benefits to society at large. The SAVi BRT model considers a project period of 28 years from 2022 to 2050.

Table ES1. Integrated CBA (discounted values at 3.5%, for the BRT scenario based on a project period of 28 years)

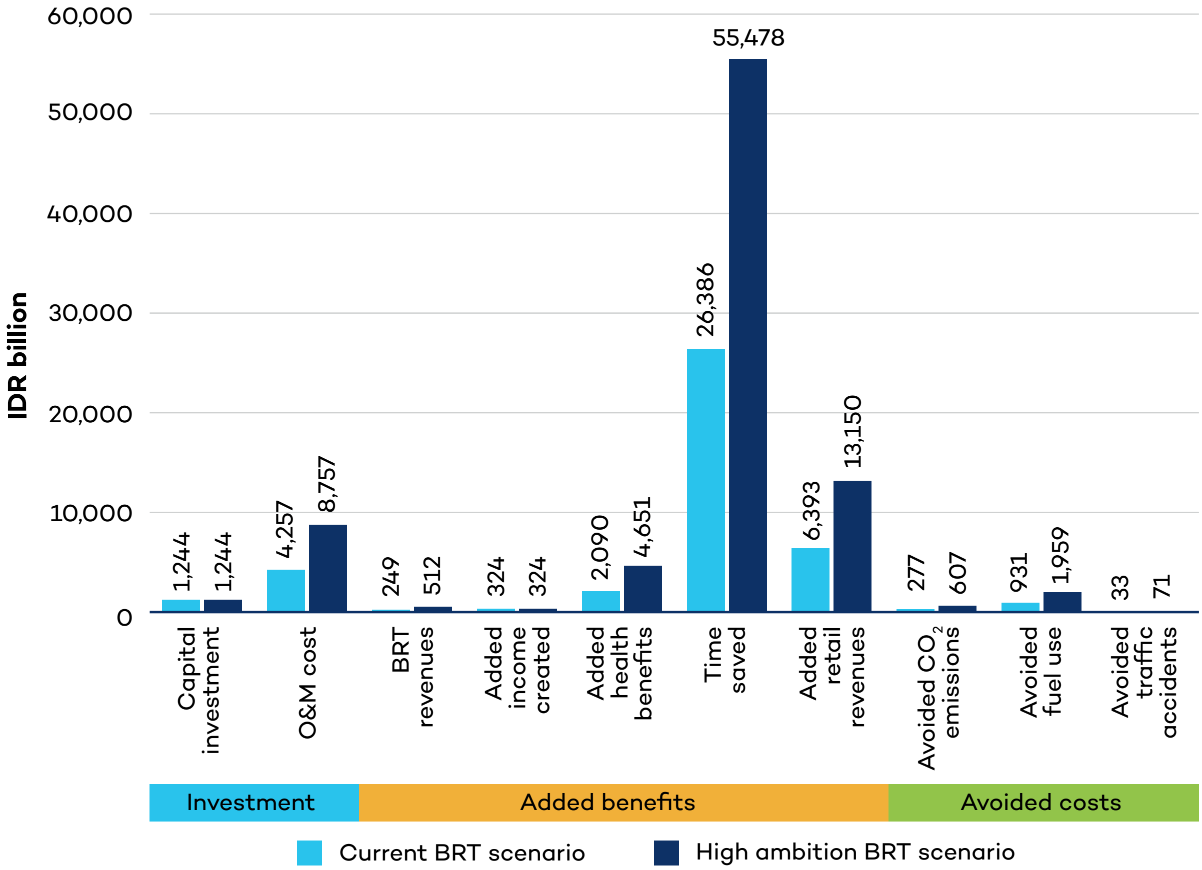
	BRT scenarios (2022–2050) (IDR billion)	
Integrated CBA (discounted[1] at 3.5%)	**Current BRT scenario**	**High-ambition BRT scenario**
Total investment	**5,501.38**	**10,001.55**
Capital costs	1,244.34	1,244.34
Operation and maintenance (O&M) costs	4,257.04	8,757.21
Total added benefits	**35,441.02**	**74,114.93**
Revenues from BRT use	248.95	512.12
Income creation from employment	323.94	323.94
Health impacts	2,089.81	4,651.08
Value of time saved	26,385.79	55,477.63
Retail revenues	6,392.53	13,150.16
Total avoided costs	**1,241.76**	**2,637.18**
CO_2 emissions	277.43	607.07
Fuel use	931.24	1,959.39
Accidents	33.09	70.72
Cumulative net benefits (discounted)	**31,181.39**	**66,750.56**
Benefit–cost ratio (BCR)	0.27	0.28
Sustainable benefit–cost ratio (S-BCR)	**6.67**	**7.67**

As Table ES1 demonstrates, the added benefits related to the value of time saved resulting from the shift from motorized transportation modes to the BRT show the largest values with IDR 26,385 billion in the current BRT scenario and IDR 55,477 billion in the high-ambition BRT scenario. This is followed by the added benefit of increased retail revenues around BRT stations, valued at IDR 6,392 billion and IDR 13,150 billion in the current BRT and high-ambition BRT scenarios, respectively. The BRT system also has the potential to greatly improve public health through increased physical activity and diminishing air pollution levels

[1] The process of converting a value received in a future time period to an equivalent value received today.

in the city, valued at IDR 2,089 billion in the current BRT scenario and IDR 4,651 billion in the high-ambition BRT scenario. In addition, cumulatively over the project period, the BRT system is estimated to create over 670 jobs; lead to nearly 650 avoided traffic accidents, including over 200 avoided fatalities; and reduce between 1.2 million and 2.7 million tonnes of CO_2 emissions from the atmosphere. Overall, the successful implementation of the BRT system in Bandung has the potential to address some of the challenges that keep the city in a car-oriented, high-carbon mobility pathway and transform Bandung into a pilot area for BRT systems and sustainable mobility more generally. The full range of investment costs, revenues, added benefits, and avoided costs is clearly demonstrated in Figure ES1.

Figure ES1. Investment costs, revenues, added benefits, and avoided costs of the BRT system in Bandung



In addition, Table ES2 shows the conventional BCR and S-BCR of the BRT system. The BCR determines the overall value for money of a project. It illustrates the return for every unit (USD or IDR) invested by comparing the project's total benefits with the total costs. The conventional BCR only considers tangible parameters such as capital costs, O&M costs, revenues from BRT use, income creation from employment, and avoided costs of fuel use. In contrast, the S-BCR considers the full range of economic, social, and environmental added benefits and avoided costs. When the full range of added benefits and avoided costs is considered, the S-BCR ranges between 6.67 and 7.67 for every USD/IDR invested compared to 0.27 and 0.28 under the conventional BCR. This reflects more than a 20-fold increase in the BCR when all benefits and costs are considered.

Table ES2. Conventional BCR vs. S-BCR (discounted at 3.5%)

	BCR		S-BCR	
Parameters considered	Investment and costs, revenues from BRT, income creation from employment, avoided cost of fuel use		Investment and costs; full range of economic, social, and environmental added benefits and avoided costs	
Scenario	Current BRT scenario	High-ambition BRT scenario	Current BRT scenario	High-ambition BRT scenario
BCR	**0.27**	**0.28**	**6.67**	**7.67**

Moreover, the SAVi assessment of the BRT system in Bandung demonstrates that the project's benefits outweigh the investment costs by almost seven times. Even under conservative assumptions, the calculated added benefits and avoided costs of the BRT system (IDR 36,682 billion) greatly exceed the projected investment costs (IDR 5,501 billion). In addition, the comparison of the BCR and the S-BCR demonstrates that when only tangible impacts are considered in the analysis, the project is not economically viable, but when social and environmental non-tangible impacts are also considered, the benefits are significantly higher. All of the above show that the BRT system in Bandung is highly profitable from both macroeconomic and societal perspectives.

The SAVi assessment can act as a benchmark study for policy-makers and public infrastructure planners when it comes to valuing the societal benefits and costs of BRT. Table ES3 shows how different stakeholders and decision-makers can use the results of the BRT assessment to make more informed decisions.

Table ES3. How different stakeholders and decision-makers use the results of the BRT SAVi assessment

Stakeholder	Role in the project	How can the stakeholder use the results of the assessment?
Government	Design, implementation, and finance of the BRT system in Bandung	Urban and regional governments can use the assessment results to raise awareness for sustainable transportation projects and to justify investments in BRT, as well as make these assessments a standard and a requirement for investment decisions. Overall, the results of the assessment provide an integrated perspective on BRT systems and the wide range of economic, social, and environmental benefits that they deliver. This can help urban authorities and governments to provide funding and support for such projects, tapping into different capital sources. Policy-makers can use the assessment results to make decisions on sustainable transportation projects and BRT systems in particular, as well as on potential additional investments that may be required to realize additional benefits.

Stakeholder	Role in the project	How can the stakeholder use the results of the assessment?
Private sector/ industry	Project developers	Businesses and private sector entities can use the assessment results for additional advocacy for sustainable transportation projects and BRT systems.
Donors and funders	Funding of BRT projects	Donors can include the assessment results in their reporting processes to show the impacts of their investments. The assessment results can also be used for raising awareness about the benefits of BRT projects, including health benefits, the avoided costs of air pollution, CO_2 emissions, and accidents. This can help to make the case for further sustainable transportation projects and active transportation schemes.
Civil society organizations	Consultation with government on BRT projects	Civil society organizations can use the assessment results and the valuation of the added benefits and the avoided costs of BRT projects to conduct more targeted advocacy for sustainable transportation projects. Civil society organizations can also use the assessment results to promote integrated solutions for sustainable transportation and raise awareness of their value to society.

Integrated assessments, such as this one conducted using the SAVi methodology, can help to make a stronger case for BRT infrastructure. Altogether, this assessment has shown that the BRT system advances the realization of sustainable mobility targets in Bandung and improves the quality of life of its residents by encouraging more sustainable transportation and increasing access to employment opportunities.

Abbreviations and Acronyms

BRT	bus rapid transit
BCR	benefit-cost ratio
BUMP	Bandung Urban Mobility Project
capex	capital expenditure
CBA	cost-benefit analysis
CLD	causal loop diagram
CO_2	carbon dioxide
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IDSUN	Indonesia Sustainable Urbanization Multi-Donor Trust Fund
NO_x	nitrogen oxides
O&M	operation and maintenance
opex	operating expenditures
$PM_{2.5}$	particulate matter with a diameter of less than 2.5 micrometres
PV	present value
RPJMD	Regional Medium-Term Development Plan
SAVi	Sustainable Asset Valuation tool
SO_2	sulphur dioxide
S-BCR	sustainable benefit-cost ratio
UNEP	United Nations Environment Programme

Glossary

Benefit-cost ratio: A ratio that determines the overall value for money of a project. It illustrates the return for every unit (USD or IDR) invested by comparing a project's total benefits with the total costs.

Causal loop diagram: A schematic representation of key indicators and variables of the system under evaluation that shows the causal connections between them and contributes to the identification of feedback loops and policy entry points.

Discounting: A finance process to determine the present value of a future cash value.

Indicator: Parameters of interest to one or several stakeholders that provide information about the development of key variables in the system over time and trends that unfold under specific conditions (United Nations Environment Program [UNEP], 2014).

Methodology: The theoretical approach(es) used for the development of different types of analysis tools and simulation models. This body of knowledge describes both the underlying assumptions used as well as qualitative and quantitative instruments for data collection and parameter estimation (UNEP, 2014).

Model validation: The process of assessing the degree to which model behaviour (i.e., numerical results) is consistent with behaviour observed in reality (i.e., national statistics, established databases) and the evaluation of whether the developed model structure (i.e., equations) is acceptable for capturing the mechanisms underlying the system under study (UNEP, 2014).

Net benefits: The cumulative amount of monetary benefits accrued across all sectors and actors over the lifetime of investments compared to the baseline, reported by the intervention scenario.

Scenarios: Expectations about possible future events used to analyze potential responses to these new and upcoming developments. Consequently, scenario analysis is a speculative exercise in which several future development alternatives are identified, explained, and analyzed for discussion on what may cause them and the consequences these future paths may have on our system (e.g., a country or a business).

Simulation model: Models can be regarded as systemic maps in that they are simplifications of reality that help to reduce complexity and describe, at their core, how the system works. Simulation models are quantitative by nature and can be built using one or several methodologies (UNEP, 2014).

System dynamics (SD): A methodology developed by Forrester (1961) in the late 1950s to create descriptive models that represent the causal interconnections between key indicators and indicate their contribution to the dynamics exhibited by the system as well as to the issues being investigated. The core pillars of the system dynamics method are feedback loops, delays, and non-linearity emerging from the explicit capturing of stocks and flows (UNEP, 2014).

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1.0 Introduction

1.1 Mobility Challenges and Transportation Strategies in Bandung

Bandung City in Indonesia has been facing significant urban mobility and transportation challenges, as it is constrained by a dense and congested urban road network. The core area of the city has narrow roadways and extensive one-way streets that result in many circuitous trips. In addition, many older and historical buildings in the city centre do not accommodate densification or new development. This leads to many transportation issues, including long commuting times and rising numbers of private motorized vehicles, mainly motorcycles, which result in high traffic volumes and congestion, safety concerns, and air pollution. Continued urban development will aggravate these problems in the future. Economic inefficiencies and negative health impacts are some of the many negative consequences of urban transportation planning that are centred around private transportation modes.

Bandung's pattern of development, which is reliant on private modes of transportation combined with congestion and the declining attractiveness of public transportation, is clearly unsustainable. Urban and regional governments are aware of the rising need to improve the situation and ensure the provision of a more reliable, safe, and attractive public transportation system.

The Regional Spatial Plan for West Java (RTRWP) is a guide to the Regional Medium-Term Development Plan (RPJMD). One of the strategies contained in the latter plan is the development of a mass transportation system in the Bandung metropolitan area and its accompanying infrastructure development (Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH [GIZ], 2020a, 2020b, 2020c). The system's objective is to "provide road and transportation infrastructure that is reliable and integrated to support the growth of the centre" (GIZ, 2020a), both in the city and between activity centres. Transportation infrastructure development is to include the development of urban mass transit and the improvement of road traffic and transportation infrastructure. For the Bandung Basin,[2] the infrastructure development plan includes

- building the Soreang-Pasirkoja inner toll road,
- increasing the capacity and condition of strategic roads,
- developing a mass urban public transportation system, and
- increasing traffic infrastructure and road transportation.

[2] Bandung Basin includes the city's greater metropolitan area.

The RPJMD sets out the 5-year vision, strategy, key performance indicators, and infrastructure investment plans. Bandung's 2018–2023 RPJMD is legalized as Regional Regulation (Peraturan Daerah or Perda) No. 3 Year 2019. The RPJMD develops Bandung City's Transport Policy to address key challenges, which include

- the decline in public transportation users from 9 million users in 2013 to 5.5 million users in 2017,
- public transportation services' poor coverage of the city area at only 25%,
- the poor integration of public transportation, and
- online ride-hailing transportation services, which have emerged as more reliable options compared to existing public transportation services.

Also, in the 2018–2023 Bandung City RPJMD, one of the targets reflects the mayor's vision for public transportation development, namely "to improve the public transport level of service" (GIZ, 2020a, 2020b, 2020c). This indicates that bus rapid transit (BRT) development is a relevant issue in the RPJMD. Discussions with the relevant stakeholders suggested several points to complement Bandung BRT's future key performance indicators, including to

- increase public transportation coverage area;
- increase the provision of segregated lanes for bus services;
- implement bus priority measures at selected locations; and
- implement BRT integration with other modes, such as angkots, walking, and cycling.

The above could be considered in the planning of the bus infrastructure for this project.

In addition, the Bandung Urban Mobility Project (BUMP) 2012–2031 outlines the vision for Bandung's transportation and infrastructure projects until 2031. Bandung is experiencing rapid urbanization and, to meet housing demand and balance open space requirements, the city government supports higher-density development and redevelopment. These factors cause significant transportation and congestion problems due to vehicle growth (9.34%) increasing at a faster pace than road development (1.29%). The BUMP consists of five principles:

- an integrated strategy to fulfill human needs (life, work, and play) through the creation of a traffic demand management system (the most appropriate design in transit-oriented development will be the redevelopment of existing terminals and stations);
- the improvement of road networks as links between activity centres, not as a base for district development;
- public transportation development (mass rapid transportation) to include monorails, BRT, cable cars, pedestrian lanes, bike sharing, school buses, etc.;
- improved traffic management using technology, including an automatic tracking control system to control traffic patterns and a mass public transportation performance support system; and
- Technopolis Gedebage, a large-scale investment that aims to function as a technology and service centre as well as a new city centre for Bandung.

The BUMP promotes public transportation improvement to achieve a sustainable environment and good air quality. Several modes were considered, including light rail transit, BRT, and cable cars. With regard to BRT development, the city targets include

- developing up to 13 BRT corridors that are integrated with other transportation modes;
- implementing electric buses, as well as other types of low-emission buses; and
- implementing a smart payment system using advanced technology.

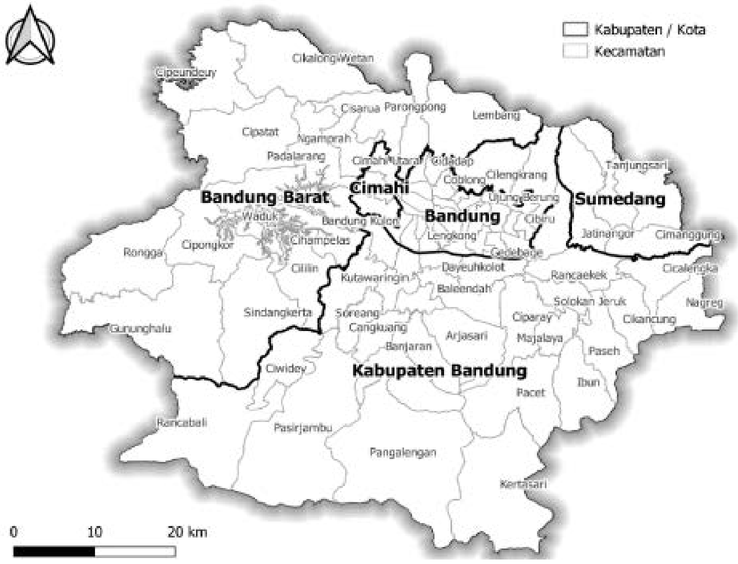
Developing BRT infrastructure has the potential to meet some of these objectives and avoid keeping Bandung on a car-oriented, high-carbon mobility pathway. An efficient and accessible city-wide BRT system can encourage a shift from motorized transportation modes to public transportation and accommodate future transportation demands. In addition, BRT infrastructure could meet sustainable, low-carbon mobility targets.

1.2 The Purpose of a Sustainable Asset Valuation for Bandung's BRT Network

Bandung, West Java Province's capital city and Indonesia's third-largest city, is located about 180 km southeast of Jakarta. The city covers an area of approximately 167 km^2 and has a density of 14,834 people per km^2. The city is divided into 30 *kecamatan* (districts) covering 151 *kelurahan* (sub-districts). Based on 2017 population projections, the city has a population of approximately 2.5 million people (GIZ, 2020a, 2020b, 2020c).

Motorcycles are the predominant mode of transportation in Bandung, accounting for around 75% of all movement in the main transportation corridors and two thirds of all vehicle movement. Four-wheelers account for around 20% of trips, and public transportation accounts for only 5% of trips, even less outside these main corridors. The public transportation sector, comprised of large bus services provided by TransMetro Bandung and DAMRI, accounts only for a strikingly low 1% of trips, even on the main corridors. The large buses account for around 10% of transit ridership, with the remaining 95% in various forms of angkots/minibuses that generally come frequently but are increasingly unattractive compared to private motorcycles, online motorcycle service providers, and cars (GIZ, 2020a, 2020b, 2020c).

Figure 1. Map of Bandung Basin



Source: Indonesia Sustainable Urbanization Multi-donor Trust Fund (IDSUN), 2020a.

The BRT system is a new public transportation project that is set up to improve mobility in Bandung. The BRT project is expected to improve economic performance, making the labour market more accessible to citizens living on the outskirts of Bandung. At the same time, the public transportation system will make a positive environmental contribution by reducing the use of polluting transportation modes, diminishing Indonesia's CO_2 emissions from the transportation sector.

Several studies have been carried out to develop proposals for transit improvements in Bandung. Subsequently, there was a collaboration between the Bandung BRT project and the Global Future Cities Programme, which completed a number of surveys and assessment analyses in Bandung in 2020. Also, the World Bank Indonesian Mass Transit Program Support Project aims to provide technical assistance and financing support for the first implementation phase of the Indonesian Mass Transit Program in selected cities, including Bandung. For Bandung, this project follows from the earlier BUMP. The project was approved in late 2020, and its scope will include BRT.

Moreover, in 2019 and 2020, GIZ conducted surveys to collect data on Bandung's transportation system that expand or build on the earlier surveys and analyses that were carried out. The surveys include data on bus routes, bus terminal conditions, traffic conditions, travel speeds, parking, travel characteristics of public transportation passengers, and modal split, as well as the potential for motorcyclists to shift to BRT once the project is completed (GIZ, 2020a, 2020b, 2020c).

Despite the above, an analysis that clearly demonstrates the multiple benefits of a well-implemented BRT system and to what extent such a system can yield mobility improvements has not been developed. Currently, environmental, social, and economic benefits and costs associated with a successfully implemented BRT system in Bandung are merely anecdotal, based on evaluations of BRT systems implemented in other cities around the world. To strengthen the business case for the BRT system in Bandung and encourage public authorities to invest in providing the baseline BRT infrastructure, it is vital to estimate and value the added benefits and avoided costs expected from this particular BRT system.

The total cost of the project is estimated at IDR 939,119 billion. The total length of the proposed BRT system is 27.4 km, combining 18.2 km of segregated lanes with 9.2 km of route to be operated in mixed traffic (GIZ, 2020a, 2020b, 2020c). The total fleet of buses proposed is 357 and includes small (6 m–8 m), medium (9 m–10.5 m), and large (11.5 m–12 m) buses. The total cost of the buses is estimated to be IDR 596.872 billion. The BRT system is expected to be able to transfer approximately 204,000 passengers per day after its fourth year of operation.

The Sustainable Asset Valuation (SAVi) BRT model serves to estimate and value the environmental, social, and economic added benefits and avoided costs generated by a successfully implemented BRT system, as its use implies a shift from other transportation modes to public transportation. The SAVi assessment of the BRT system is used to provide the added value of two BRT scenarios that are compared to a baseline scenario where the BRT would not be implemented. The wide range of economic, social, and environmental impacts that are quantified in this study and generated by changing mobility patterns can be termed the added benefits and avoided costs of the BRT project. As part of this assessment, their monetary values will be integrated into a cost-benefit analysis (CBA) of the BRT project. The SAVi assessment includes the final results for the two BRT demand scenarios that are compared to the baseline scenario.

This SAVi assessment of the BRT system in Bandung, Indonesia, is part of a series of nine SAVi assessments on sustainable transportation and mobility projects that aim to raise awareness of sustainable transportation infrastructure and inform decision-makers on the use of systemic approaches in supporting the transformation toward sustainable mobility.

1.3 Structure

Section 2 of the report presents the methodology, including an overview of the causal loop diagram (CLD) (system dynamics model) that was created for this SAVi assessment and a summary of the value-added benefits and avoided costs. Section 3 describes the scenarios and assumptions. It summarizes demand figures and shifting mobility patterns associated with the BRT demand scenarios and then presents the valuation methodologies and data sources used for each added benefit and avoided cost. Section 4 of the report presents the results. The section starts with the integrated CBA table that demonstrates the total cumulative monetary values generated by the BRT demand scenarios. The values of the added benefits and avoided costs are integrated into the CBA, which includes the capital and operation and maintenance (O&M) expenditures in order to better represent the societal value of the BRT systemin Bandung. Both parameters are also summarized separately. The last part of Section 4 includes the valuation results for each added benefit and avoided cost. Section 5 concludes by illustrating how the results of the SAVi assessment make a stronger case for the BRT system by highlighting the added value of integrating economic, social, and environmental parameters into transportation infrastructure assessments.

2.0 Methodology

This section introduces the system dynamics methodology used for this SAVi assessment. It provides an overview of the CLD, as well as a summary of the impacts of the BRT system in Bandung from a system dynamics perspective. The second part of this section summarizes the added benefits and avoided costs used in the assessment. A more elaborate description and valuation process of the added benefits and avoided costs is included in Section 3. Some of the limitations of the methodology used are discussed in the concluding Section 5.

2.1 System Mapping

2.1.1 SYSTEMS THINKING AND SYSTEM DYNAMICS

The underlying dynamics of the BRT system in Bandung, including driving forces and key indicators, are summarized in the CLD displayed in Figure 2. The CLD includes the main indicators analyzed during this SAVi assessment, their interconnections with other relevant variables, and the feedback loops they form. The CLD illustrates the interconnections of the economy with a wide range of social and environmental parameters while highlighting key dynamics and potential trade-offs emerging from different development strategies envisaged for the BRT system. The CLD is the starting point for the development of the mathematical stock and flow model.

2.1.2 READING A CLD

CLDs aim to capture causal relationships within a system accurately in order to increase the effectiveness of relevant solutions and interventions. Therefore, CLDs establish causal links between variables. CLDs include variables and arrows, with the latter linking the variables together with a sign (either + or –) on each link, indicating a positive or negative causal relation (see Table 1):

- A causal link from variable A to variable B is positive if a change in A produces a change in B in the same direction.
- A causal link from variable A to variable B is negative if a change in A produces a change in B in the opposite direction.

Table 1. Causal relations and causality

Variable A	Variable B	Sign
⬆	⬆	+
⬇	⬇	+
⬆	⬆	–
⬇	⬇	–

Circular causal relations between variables form causal, or feedback, loops. These can be positive or negative. A negative feedback loop tends toward a goal or equilibrium, balancing the forces in the system (Forrester, 1961). A positive feedback loop can be found when an intervention triggers other changes that amplify the effect of that initial intervention, thus reinforcing it (Forrester, 1961). CLDs also capture delays and non-linearity. In addition, reinforcing loops tend to increase and amplify everything happening in the system (i.e., action–reaction), whereas balancing loops represent a self-limiting process that aims to find balance and equilibrium. A detailed description of all the reinforcing and balancing loops for the BRT system in Bandung is included in Appendix A.

2.1.3 CAUSAL LOOP DIAGRAM FOR THE BRT IN BANDUNG

The impacts of the BRT system in Bandung are presented through a CLD—or more simply, a system map—shown in Figure 2. The impacts cover three main dimensions: social, environmental, and economic.

One of the main dynamics of the system is the shift from private vehicles to BRT and vice versa, which is represented by a reinforcing loop (R1) that is strengthened or weakened by the rest of the loops. Historically, it has been observed that as GDP grows, demand for transportation and mobility increases. As disposable income and affordability grow, motorized transportation demand grows, and the number of vehicles increases. This leads to a wide range of undesirable outcomes, such as traffic congestion, higher fuel use, increased air pollution, an increased number of road accidents, and growing CO_2 emissions. These outcomes impact individual transportation demand in different ways, by either reinforcing it, increasing or reducing it, or balancing the trend by counteracting it.

While increased investment in BRT infrastructure (R3) and employment (R7 and R9) reinforce individual transportation demand, other impacts create a balance in the system, such as traffic congestion (B1), CO_2 emissions (B2 & B8), accidents (B4 & B9), positive health impacts from increased physical activity (B5), employment from BRT (B7), noise pollution (B11), and retail revenues (B10).

However, there is an alternative scenario where investment in BRT can address many of these negative effects. BRT infrastructure is expected to result in numerous economic, social, and environmental benefits. The factors that reinforce the dynamics of the BRT infrastructure are positive health impacts from physical activity (R6), accidents from motorized transportation (R5), CO_2 emissions from fuel use (R3), traffic congestion (R2), employment (R8), changes in property values (R10), and changes in retail revenues from improved walkability (R11). The only loop that can counteract the reinforcing dynamics for the BRT infrastructure is the one representing the accidents resulting from an increase in the use of BRT modes (B5).

Overall, investment in BRT stimulates economic growth, either directly through employment creation or indirectly through stimulating retail and property value increases. From the perspective of the public sector, higher GDP has led to government revenues, allowing the allocation of more resources to BRT infrastructure.

The majority of these identified impacts are quantified in the SAVi BRT model. However, where evidence was not available or effects were negligible, impacts were not included in the SAVi assessment results. The impacts that were not quantified include changes in property value, noise pollution, and access to health, education, and workplaces.

Figure 2. CLD for the BRT system in Bandung

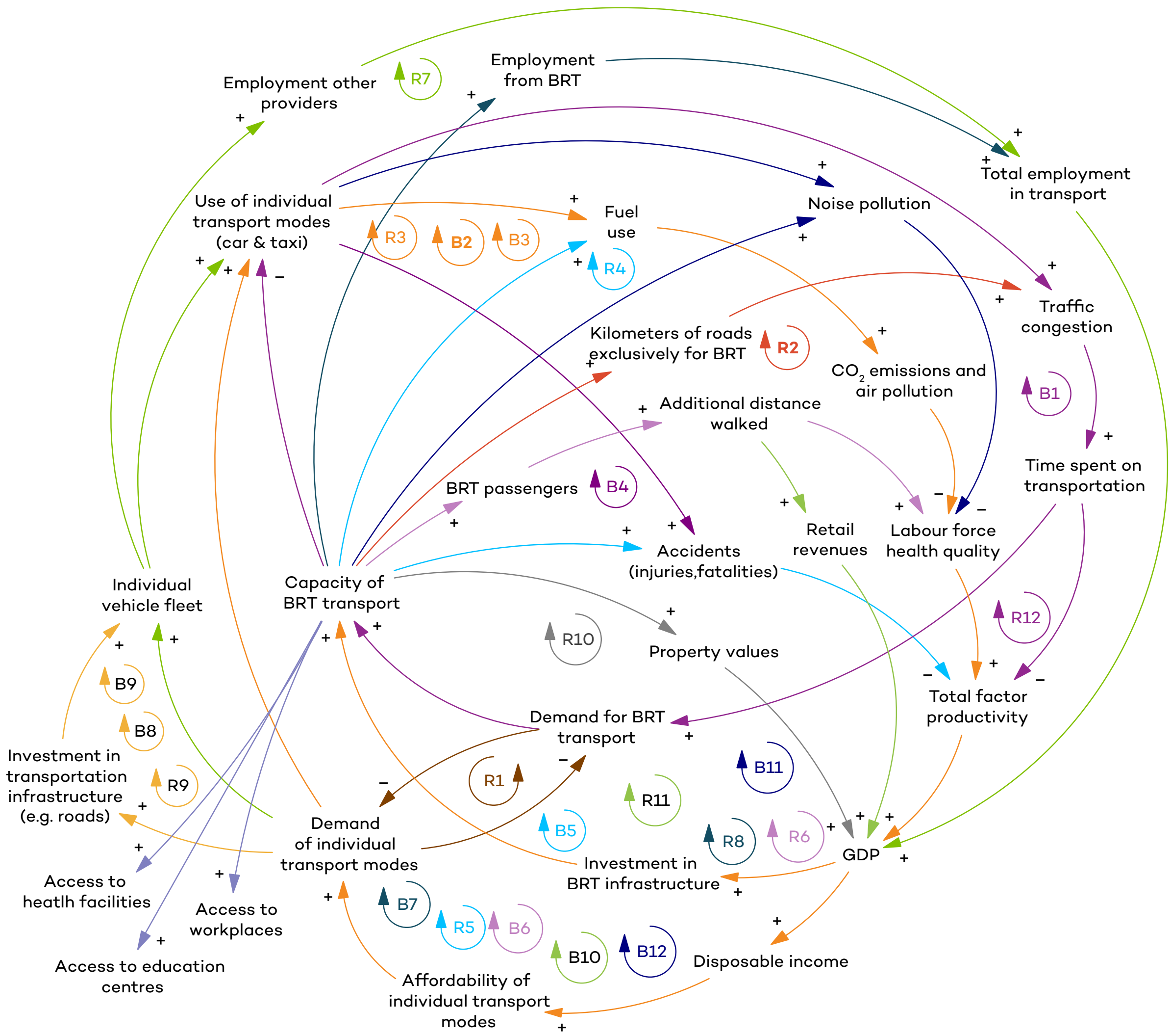
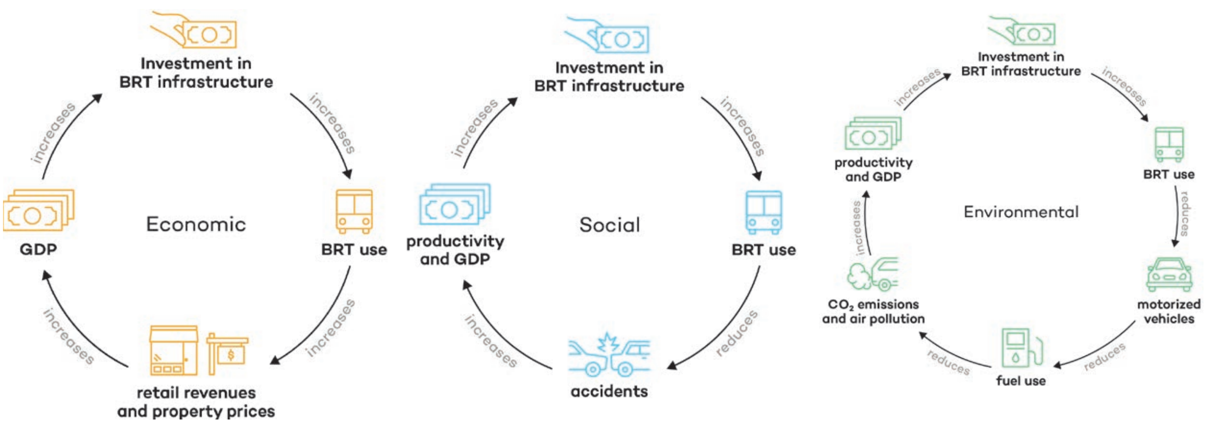


Figure 3. Examples of economic, social, and environmental causal relationships



2.2 Added Benefits and Avoided Costs Valued by the SAVi Assessment

The SAVi assessment provides the monetary valuation of project-related added benefits and avoided costs of an implemented BRT system in Bandung. Table 2 lists all added benefits and avoided costs considered in this assessment, as well as stakeholders and indicators of relevance. Section 3.2 explains in detail how each of these indicators is quantified and includes all data sources and assumptions.

Table 2. Added benefits and avoided costs considered in the SAVi assessment

Added benefit or avoided cost	Stakeholders of relevance (government, households, private sector)	Social, environmental, or economic
Revenues from BRT use	Households	Economic
Income creation from employment	Government, households	Economic
Health impacts	Households	Social
Value of time saved	Households, private sector	Economic
Retail revenues	Private sector, households	Economic
CO_2 emissions	Households	Environmental
Fuel use	Households	Economic
Accidents	Government, households	Social

2.3 Pre-Financial Analysis for BRT Projects

The pre-financial analysis provides an overview of the performance of BRT projects before the evaluation of the financing and the related investor financial return requirements. This analysis moves from the total lifetime integrated CBA to a time-based analysis, equivalent to flow-based financial analysis (profit and loss, cash flows).

The viability of the BRT projects is assessed on the integrated value statement, which includes the internal rate of return (IRR) and present value analysis.

3.0 Scenarios and Assumptions

3.1 Scenarios of the BRT SAVi Assessment

Table 3 provides an overview of the two BRT scenarios simulated for the SAVi BRT assessment and includes the relevant assumptions. The SAVi assessment consists of the baseline or status quo scenario, a current BRT scenario that is based on demand projections from the Bandung BRT feasibility study (GIZ, 2020a, 2020b, 2020c), and a high-ambition BRT scenario that is based on assumptions that demand doubles in 2035 and triples in 2045, after which it stays linear until 2050. The high-ambition BRT scenario was modelled to compare the benefits of the BRT system in the case that long-term BRT demand is higher than anticipated in the Bandung BRT feasibility study. The three scenarios are explained in more detail in Table 3.

Table 3. Scenarios simulated for the BRT SAVi assessment

Scenario	Assumptions
Status quo scenario	The modal shares of the status quo scenario are assumed to be constant over the entire project period. No shift to the BRT system takes place.
Current BRT scenario	Assumptions for this scenario are based on calculations of BRT trip demand projections in Bandung for each transportation mode and are taken from modal share data included in the BBMA Urban Mobility Strategy (IDSUN, 2020a, 2020b) and the Bandung BRT Feasibility Study (GIZ, 2020a, 2020b, 2020c). In this scenario, BRT demand projections are divided into two different time periods. The first period spans from the first year (2023) until the third year (2025) of operation and the second period spans from the fourth year (2026) of operation until the year 2050.
High-ambition BRT scenario	In this scenario, BRT demand projections are divided into four different time periods. The first period spans from the first year (2023) until the third year (2025) of operation, similar to the current BRT scenario. The second period spans from the fourth year (2026) of operation until the year 2034, during which BRT demand gradually increases. The third period starts in 2035, the year that BRT demand has doubled since 2026 and gradually increases until 2044. The fourth and final period starts in 2045, the year that demand has tripled since 2026 and stays linear until 2050.

In addition, Table 4 below, shows the different mobility shifts in the status quo and BRT scenarios, and more importantly the shift from individual motorized transportation modes to the BRT system.

Table 4. Transportation modes share per scenario simulated for the BRT SAVi assessment (by percentage of trips)

	Status quo scenario	BRT current plan scenario				BRT high-ambition scenario				
Transportation modes	**2022–2050**	**2022**	**2023**	**2026**	**2050**	**2022**	**2026**	**2035**	**2045**	**2050**
Motorcycles	62%	62%	61%	59%	59%	62%	59%	56%	52%	52%
Angkots	19%	19%	18.5%	18%	18%	19%	18%	17%	16%	16%
Taxis	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Private cars	15%	15%	14%	12%	12%	15%	12%	9%	6%	6%
Buses (other)	3%	3%	2.5%	2%	2%	3%	2%	1%	1%	1%
BRT	0%	0%	3%	8%	8%	0%	8%	16%	24%	24%

For the two BRT scenarios, we have assumed that when BRT demand increases, trips are shifted from individual transportation modes to BRT, and demand for taxis and other buses stays the same. Individual motorized transportation modes, in this case, include motorcycles, angkots, and private cars, and an equal share of each of these three transportation modes is shifted to BRT as demand for the latter increases.

3.2 Valuation Methodologies of the Added Benefits and Avoided Costs

3.2.1 REVENUES FROM BRT USE

Revenues from the use of the BRT system simply represent the revenues from the purchase of BRT tickets that passengers buy. Data for the BRT system found in the Bandung BRT Feasibility Study (GIZ, 2020a, 2020b, 2020c) show that the average BRT ticket price of a trip is IDR 6,000. The average BRT ticket price was then multiplied by the number of trips per year until 2050 for both BRT scenarios. The number of trips per year was calculated by using BRT demand projections and assumptions about the number of daily trips per person (1.37), based on current travel habits in Bandung (GIZ, 2020a, 2020b, 2020c).

For the current BRT scenario, BRT demand projections are based on modal share data included in the BBMA Urban Mobility Strategy (IDSUN, 2020b) and the Bandung BRT Feasibility Study (GIZ, 2020a, 2020b, 2020c) and are divided into two different periods. From the first to the third year of operation of the BRT system, demand projections show 73,000 passengers per day, and from the fourth year of operation until 2050, demand projections show 204,000 passengers per day. The demand projections represent a 3% shift to BRT during the first period and an 8% shift to BRT during the second period, which goes to 2050.

For the high-ambition BRT scenario, it is assumed that demand projections start similarly to the current BRT scenario but then gradually increase from the fourth year of operation (2026) until 2044. According to these assumptions, in 2035 passengers using the BRT will have doubled (16% shift), and in 2045 they will have tripled (24% shift) compared to 2026. The number of passengers using the BRT system stays the same from 2045 to 2050. The BRT demand projections and the modal shift assumptions used are presented in more detail in Table 4.

3.2.2 INCOME CREATION FROM EMPLOYMENT

Income creation from employment, or discretionary spending, represents the amount of money that flows back into the economy in the form of additional consumption. Construction and O&M of the BRT project leads to employment creation, which has beneficial socio-economic impacts, such as increased discretionary spending.

To estimate the construction employment creation that results from the BRT system, employment data per km from the TransMilenio BRT project in Bogota, Colombia, were used (World Resources Institute & EMBARQ, 2002). Based on that data, 19 construction jobs were created per km. Subsequently, the jobs per km were multiplied by the rate of construction (km per year), considering the length of the BRT system in Bandung.

For employment creation for O&M, the number of proposed vehicles for the BRT system in Bandung (357) was used (GIZ, 2020a, 2020b, 2020c) and multiplied by jobs per vehicle multipliers that were divided into two categories: drivers and crew (1.6 jobs per vehicle) and maintenance (0.26 jobs per vehicle). It was assumed that the number of private vehicles in circulation in Bandung will remain the same because even if private car owners choose to use the BRT system, they are unlikely to sell or never use their private cars. Therefore, the jobs created as a result of the BRT system are additional.

Moreover, to demonstrate the benefits of income creation that result from the number of jobs created following the implementation of the BRT system, the latter was multiplied by the average annual salary in Bandung. Finally, the income creation was multiplied by the share of discretionary spending (18.9%), which is the share of the salary that people usually spend on categories such as restaurants, sports and leisure, and clothing.

3.2.3 HEALTH IMPACTS

The shift from motorized transportation modes to BRT will have significant positive health impacts. In the BRT SAVi assessment, two different health impacts are grouped together, namely benefits from increased physical activity and avoided costs of air pollution. The avoided costs of traffic accidents are considered in a separate section.

Benefits from physical activity arise primarily from the additional time spent walking to and from BRT stations. The assumption used in the SAVi assessment is that each BRT user will walk 2.75 additional minutes per day (World Resources Institute & EMBARQ, 2002). The additional distance walked represents the additional minutes walked by BRT users per day, which is then multiplied by the average walking speed and divided by daily trips in Bandung, which amounts to 2.64 daily trips per person (Dharmowijoyo et al., 2017). The total additional distance walked is then estimated using the additional distance walked per trip and the total annual BRT trips. Finally, the economic benefits of walking (EUR 0.37/km) (Gossling et al., 2019) are applied to the above in order to estimate the total economic benefits of physical activity.

In addition to benefits from increased physical activity, the shift from individual motorized, fuel-based transportation modes to the use of the BRT system in Bandung will reduce levels of air pollution that are generated from Bandung's transportation sector. This is primarily due to a reduction in the number of vehicles circulating on the road as a result of the implementation of the BRT system. The avoided costs of air pollution are estimated using the environmental costs of different pollutants, such as $PM_{2.5}$, SO_2, and NO_x, that result from the burning of fossil fuels. Emissions related to burning fossil fuels have many negative health and economic impacts and can cause respiratory diseases, cardiac diseases, and negative impacts on agriculture yields. The valuation of these emissions is based on a socio-economic impact study by Conseil Exécutif des Transports Urbains de Dakar (2015) and estimated by using vehicle-km values at IDR 290.14 (USD 0.02), with an annual increase of 2%. These costs are estimated by the SAVi model by multiplying the vehicle-km of each transportation mode by the per vehicle-km cost of pollution. Transport-related air pollution is likely to decrease over time regardless of the implementation of the BRT system in Bandung, as fossil fuel-powered vehicles will become more energy efficient and will be gradually replaced by electric vehicles.

3.2.4 VALUE OF TIME SAVED

The value of time saved represents the economic value of improved mobility resulting from the BRT system. The shift from other transportation modes to BRT will result in differing travel speeds. Consequently, the BRT system will lead to either time savings or additional time spent on commuting, depending on the current mode of transportation. The value of time saved is estimated in real terms, which means this assessment does not apply a growth rate to the value of time saved over time.

The value of time saved is estimated by assuming an average travel time for each assessed transportation mode, which is calculated using data on the average trip length and travel speed of different transportation modes in Bandung (GIZ, 2020a, 2020b, 2020c). Subsequently, the value of time for Bandung was estimated by using the average value between the values of time for business and leisure, found in the Bandung BRT prefeasibility studies (GIZ, 2020a, 2020b, 2020c). The average travel time for each transportation mode was then multiplied by the value of time for Bandung to estimate the value of time saved from the implementation of the BRT system and the shift from other transportation modes to BRT. The analysis does not differentiate BRT users based on income and socio-economic background. If a dominant share of users is connected to a specific income class, this will impact the calculation of the economic value of time saved, which is based on the average value between the values for business and leisure in Bandung (GIZ, 2020a, 2020b, 2020c).

3.2.5 RETAIL REVENUES

Studies suggest that mode of transportation and commuting speed have an impact on retail spending. For instance, walking is associated with higher retail spending. If the walkability of an area improves, people tend to spend more time—and money—in that area (Rabl & Nazelle, 2012; Victoria Transport Policy Institute, 2018). In this assessment, it is assumed that a BRT system will encourage users to spend additional time walking to and from BRT stations, and therefore they are likely to spend more on retail establishments that are located near BRT stations.

Literature shows that people who are walking spend approximately 42.2% more than people using any other means of transportation (Rabl & Nazelle, 2012). The result yields the total additional retail spending resulting from improved walkability over a defined period. After undertaking sensitivity analyses with different percentage scenarios of increases in retail revenues following the implementation of the BRT system (10%, 20%, and 40%), it was decided to use the middle value of 20%. This value was then applied to the total yearly retail spending of the BRT users. The latter was estimated by multiplying the average yearly expenditure on non-food goods per urban dweller in Indonesia (DBS Asian Insights, 2018) with the yearly projections of BRT user numbers.

While the BRT system will increase retail revenues around BRT infrastructure, there will likely be a shift in retail spending from other areas in Bandung to areas with BRT infrastructure. However, there is a stronger economic multiplier as smaller shops near BRT infrastructure will increase their retail revenues which, coupled with reductions in vehicle and energy use, will contribute to Bandung's vibrancy.

3.2.6 CO_2 EMISSIONS

The introduction of the BRT system will lead to a shift from individual motorized, fossil fuel-based transportation modes to BRT. This will be accompanied by a reduction in the number of vehicles in Bandung and therefore a reduction in CO_2 emissions generated from Bandung's transportation sector.

The CO_2 emissions were calculated by multiplying the vehicle-km travel by the different transportation modes and the emissions factors that correspond to each transportation mode. The emissions factors are based on a prior SAVi assessment undertaken for a BRT system in Dakar, Senegal, and the values are presented in Table 5. Finally, the cost of CO_2 emissions is estimated by multiplying the emissions generated by each transportation mode by the cost of emissions per tonne. The cost of emissions in the SAVi BRT model for 2020 is IDR 303,758/tonne, increasing at a rate of 2% per year, based on the assumptions by Conseil Exécutif des Transports Urbains de Dakar (2016).

Table 5. CO_2 emission factors per vehicle type

Transportation mode	**Fuel consumption** (tonnes CO_2/km)
Motorcycles	0.0001
Angkots	0.0004
Taxis	0.00018
Private vehicles	0.00018
Buses	0.0009
BRT	0.00035

Source: Bassi et al., 2019.

3.2.7 FUEL USE

The BRT system will lead to a shift from individual motorized, fossil fuel-based transportation modes to BRT, and this will be accompanied by a reduction in fuel costs that result from fuel savings due to a reduced number of vehicles circulating on the road. The number of trips by transportation mode per vehicle-km that have been shifted to BRT is used to estimate the total amount of fuel saved through the shift. The fuel consumption by transportation mode in litres/km (Goel et al., 2016) is multiplied by vehicle-km values per transportation mode to determine the total fuel consumption. Subsequently, the amount of fuel saved as a result of the shift is multiplied by the price per litre of fuel (IDR 5,295/l) (GIZ, 2020a, 2020b, 2020c). Table 6 shows fuel consumption values per vehicle-km by transportation mode in Bandung.

Table 6. Fuel consumption per vehicle-km by transportation mode

Transportation mode	**Fuel consumption** (l/km)
Motorcycles	0.019
Angkots	0.074
Taxis	0.063
Private vehicles	0.063
Buses	0.074
BRT	0.074

Source: Goel et al., 2016.

3.2.8 ACCIDENTS

The valuation of traffic accidents is calculated using accident data from the BBMA Urban Mobility Strategy (IDSUN, 2020a) and the ENG Bandung Road Safety Annual Report 2015–2017 (Gemah Ripah Wibjawa Mukti, 2017). The annual number of accidents in Bandung prior to the implementation of the BRT network per accident severity is shown in Table 7. Annual accident rates following the implementation of the BRT system are estimated based on changing accident risk levels. The number of accidents is assumed to decrease if the number of motorized vehicle-km is reduced.

Table 7. Annual number of accidents in Bandung prior to the implementation of the BRT system

Type of accident severity	Accidents/year in Bandung (status quo)
Fatal accident	112
Major injury	23
Minor injury	352
Total	487

Source: IDSUN, 2020a.

Moreover, the risk of accidents (accidents per 100,000 km) is estimated by dividing annual accident rates in Bandung (IDSUN, 2020a) and yearly vehicle-km data from Bandung. Table 8 shows the risk of accidents by severity per 100,000 km.

Table 8. Risk of accident by severity per 100,000 km

Type of accident severity (accidents/100,000 km)	Value
Fatal accidents	0.002158
Major injuries	0.000443
Minor injuries	0.006781

Source: IDSUN, 2020a.

The next step in valuing the avoided costs from a reduction in the number of accidents as a result of the implementation of the BRT system is to estimate the economic value of accidents by accident severity. Fatal accidents imply that human life is lost and are consequently valued the highest among the three accident categories. The indicators considered for the cost valuation are human capital cost (consumption loss) and resource cost (damages, administrative costs, medical costs), which is considered a public cost, and human suffering cost, which is considered a private cost. Table 9 provides an estimate of the monetary value of fatal, minor, and major accidents (Sugiyanto, 2017).

Table 9. Valuation of accidents per accident severity

Cost of accidents per severity	Cost (IDR) per accident
Fatal accident	263,025,680.96
Major injury	12,066,000
Minor injury	1,904,312.87

Source: Sugiyanto, 2017.

4.0 Results

This section describes the results of the SAVi assessment. The first part of this section presents two integrated CBA tables for the BRT system in Bandung, the former including undiscounted values and the latter discounted values at 3.5%, shown in Table 10 and Table 11, respectively. It is an integrated analysis because, in addition to the BRT's conventional investment costs (capital and O&M costs), the valued economic, social, and environmental added benefits and avoided costs are integrated into the analysis. The second part of this section includes a comparison between the conventional project finance analysis and the integrated analysis to demonstrate the importance of valuing the multiple added benefits and avoided costs. The last part of this section provides a summary of all economic, social, and environmental added benefits and avoided costs that have been quantified, as well as the valuation results for each added benefit and avoided cost of the BRT demand scenario independently.

4.1 Integrated CBA

Table 10. Integrated CBA (undiscounted values for the BRT scenarios based on a project period of 28 years)

	BRT scenarios (2022–2050)	
Integrated CBA (undiscounted)	**Current BRT scenario (IDR billion)**	**High-ambition BRT scenario (IDR billion)**
Total investment	**8,712.52**	**17,557.65**
Capital costs	1,538.69	1,538.69
O&M costs	7,173.83	16,018.96
Total added benefits	**59,806.14**	**135,489.49**
Revenues from BRT use	419.52	936.78
Income creation from employment	516.97	516.97
Health impacts	3,629.29	8,776.02
Value of time saved	44,467.86	101,205.04
Retail revenues	10,772.50	24,054.69
Total avoided costs	**2,107.70**	**4,853.81**
CO_2 emissions	481.82	1,134.70
Fuel use	1,570.09	3,588.94
Accidents	55.79	130.17

Integrated CBA (undiscounted)	BRT scenarios (2022–2050)	
	Current BRT scenario (IDR billion)	**High-ambition BRT scenario (IDR billion)**
Cumulative net benefits (undiscounted)	**53,201.31**	**122,785.65**
Benefit-cost ratio (BCR)	0.29	0.29
Sustainable BCR (S-BCR)	**7.11**	**7.99**

Table 11. Integrated CBA (discounted values at 3.5%, for the BRT scenarios based on a project period of 28 years)

Integrated CBA (discounted at 3.5%)	BRT scenarios (2022–2050) (IDR billion)	
	Current BRT scenario	**High-ambition BRT scenario**
Total investment	**5,501.38**	**10,001.55**
Capital costs	1,244.34	1,244.34
O&M costs	4,257.04	8,757.21
Total added benefits	**35,441.02**	**74,114.93**
Revenues from BRT use	248.95	512.12
Income creation from employment	323.94	323.94
Health impacts	2,089.81	4,651.08
Value of time saved	26,385.79	55,477.63
Retail revenues	6,392.53	13,150.16
Total avoided costs	**1,241.76**	**2,637.18**
CO_2 emissions	277.43	607.07
Fuel use	931.24	1,959.39
Accidents	33.09	70.72
Cumulative net benefits (discounted)	**31,181.39**	**66,750.56**
BCR	0.27	0.28
S-BCR	**6.67**	**7.67**

An integrated CBA provides a more holistic view for assessing whether the BRT generates net benefits and can be considered a worthwhile investment from a societal perspective. This is because the integrated CBA considers both conventional costs and revenues as well as added benefits and avoided costs. A project period of 28 years is considered to highlight the BRT's net benefits and provide a reference point for the overall investments required for the wider BRT infrastructure. The cumulative net benefits for the BRT scenario indicate the maximum number of investments that are viable for the BRT infrastructure in order to consider the entire BRT worthwhile from a societal point of view.

Table 10 provides the undiscounted net results of both the current BRT and the high-ambition BRT scenarios. The current BRT scenario yields cumulative benefits of IDR 53,201.31 billion, while the high-ambition BRT scenario yields cumulative benefits of IDR 122,785.65 billion.

Once a discount factor is applied to future costs and benefits, the SAVi net results are naturally lower. A discount rate of 3.5% is applied to all economic, social, and environmental indicators of this assessment, including investment and costs, added benefits, and avoided costs, as per *The Green Book* guidance (UK Government, 2022).

Following the application of the discount rate, the current BRT scenario yields cumulative benefits of IDR 31,181.39 billion, while the high-ambition BRT scenario yields cumulative benefits of IDR 66,750.56 billion, as demonstrated in Table 11. The S-BCR of the current BRT scenario is 6.67, and the S-BCR of the high-ambition scenario is 7.67.

The next subsections will examine the different parts of the integrated CBA independently, differentiating between the conventional project finance benefits and costs and the valued economic, social, and environmental added benefits and avoided costs. In the later section, the valuation results for each added benefit and avoided cost are demonstrated in more detail.

4.2 Summary of Investment Costs and BCRs

The SAVi assessment of the BRT in Bandung starts with the conventional investment costs. As shown in the first part of the discounted integrated CBA in Table 11, the investment costs include capital and O&M costs, which are always incorporated into a conventional project finance analysis. Table 12 displays only the capital and O&M expenditures for the BRT system as cumulative values over the project period.

Table 12. Capital and O&M costs of the BRT scenarios (discounted at 3.5%)

CBA	Current BRT scenario (2022–2050) (IDR billion)	High-ambition BRT scenario (2022–2050) (IDR billion)
Investment and costs	5,501.38	10,001.55
Capital costs	1,244.34	1,244.34
O&M cost	4,257.04	8,757.21

It is important to differentiate between a conventional BCR and an S-BCR, as indicated in Table 13. The conventional BCR is based on estimates of only tangible parameters and, in this case, includes capital costs, O&M costs, revenues from BRT system use, income creation from BRT employment, and avoided costs of fuel use. The S-BCR considers the project from a societal point of view and is based on an estimate of the full range of economic, social, and environmental added benefits and avoided costs. As indicated in Table 13, the conventional BCR is significantly lower than the S-BCR.

Table 13. Conventional BCR vs S-BCR (discounted at 3.5%)

	BCR		S-BCR	
Parameters considered	Investment and costs, revenues from BRT, income creation from employment, avoided cost of fuel use		Investment and costs; full range of economic, social, and environmental added benefits and avoided costs	
Scenario	Current BRT scenario	High-ambition BRT scenario	Current BRT scenario	High-ambition BRT scenario
BCR	0.27	0.28	6.67	7.67

It is also interesting to consider how the S-BCR changes over time. In the beginning, the investment costs are more noticeable than the added benefits and avoided costs. However, as the added benefits and avoided costs accumulate over the years of the project period, the S-BCR increases. The SAVi model estimates the S-BCR increases over four time periods for both BRT scenarios, as shown in Table 14.

Table 14. S-BCR changes over time during the project period (2022–2050) (discounted at 3.5%)

Scenarios	2022–2015	2022–2030	2022–2040	2020–2050
Current BRT scenario S-BCR	1.71	4.92	6.02	6.67
High-ambition BRT scenario S-BCR	1.80	5.54	6.97	7.67

4.3 Summary of Valued-Added Benefits and Avoided Costs

The SAVi assessment of the BRT in Bandung calculates monetary values for a range of added benefits and avoided costs arising from the implementation and use of the BRT system. Table 15 excludes the investment costs section of the integrated CBA and summarizes the cumulative net values of the added benefits and avoided costs over the 28-year project period. Both current BRT and high-ambition BRT scenarios are presented. In addition, for each value-added benefit or avoided cost, the table shows which stakeholders are the most relevant and whether social, environmental, or economic indicators are the most suitable. As mentioned earlier, a discount factor of 3.5% is used for all added benefits and avoided costs. The discounted net value of the current BRT scenario amounts to IDR 31,425.81 billion, and the high-ambition BRT scenario amounts to IDR 65,605.71 billion.

Table 15. Summary table of valued-added benefits and avoided costs of the BRT scenarios (discounted at 3.5% and cumulative 2022–2050)

	BRT scenarios (2022–2050)			
Costs and benefits	**Current BRT scenario (IDR billion)**	**High-ambition BRT scenario (IDR billion)**	**Stakeholder of relevance (G = government, H = households, P = private sector)**	**Social, environmental, or economic**
Total added benefits	**35,441.02**	**74,114.93**		
Revenues from BRT use	248.95	512.12	H	Economic
Income creation from employment	323.94	323.94	G, H	Economic
Health impacts	2,089.81	4,651.08	H	Social
Value of time saved	26,385.79	55,477.63	H, P	Economic
Retail revenues	6,392.53	13,150.16	H, P	Economic
Total avoided costs	**1,241.76**	**2,637.18**		
CO_2 emissions	277.43	607.07	H	Environmental
Fuel use	931.24	1,959.39	H	Economic
Accidents	33.09	70.72	G, H	Social
Cumulative net benefits (discounted)	**36,682.77**	**76,752.11**		

4.4 Valuation Results per Added Benefit and Avoided Cost

4.4.1 REVENUES FROM BRT USE

The introduction of the BRT system will lead to increased revenues through the purchase of BRT tickets by BRT users. As mentioned in Section 3.2.1, the average BRT ticket price of a trip is IDR 6,000. This is then multiplied by BRT demand projections according to the two BRT scenarios. In the current BRT scenario, data are based on BRT demand projections from the Bandung BRT Feasibility Study (GIZ, 2020a, 2020b, 2020c) and are divided into two periods, the first lasting until 2025 and the second spanning from 2026 to 2050. The resulting cumulative revenues over the project period amount to IDR 248.95 billion. In the high-ambition BRT scenario, according to which BRT demand starts similarly to the current BRT scenario but doubles by 2035 and triples by 2045, cumulative revenues amount to IDR 512.12 billion. Annual values of BRT revenues for both BRT scenarios are summarized in Table 16.

Table 16. Annual values of revenues from BRT use (discounted at 3.5%)

	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
Annual values of revenues from BRT use (IDR billion)	Current BRT scenario	7.26	11.41	10.10	8.94	7.91	7.00	248.95
	High-ambition BRT scenario	7.26	16.49	20.21	22.36	23.74	21.01	512.12

4.4.2 INCOME CREATION FROM EMPLOYMENT

Construction and O&M of the BRT system will lead to employment creation, which has beneficial socio-economic impacts, such as increased discretionary spending. It has been assumed that the jobs created as a result of the BRT system are additional.

Moreover, additional discretionary spending per year from income generation from both construction and O&M jobs has been considered to calculate the total annual income creation. The total cumulative income creation from employment from 2022 to 2050 amounts to IDR 323.94 billion for both BRT scenarios. In total, 677 jobs are created during the same period. Table 17 shows the annual values of income creation from employment for selected years for both BRT scenarios. It is important to note that in both BRT scenarios, annual and cumulative values of income creation from employment stay the same as employment creation is not affected by BRT demand.

Table 17. Annual values of income creation from increased employment (discounted at 3.5%)

Annual values of income creation from employment (IDR billion)	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
	Both current BRT and high-ambition BRT scenarios	18.29	14.18	11.94	10.05	8.46	7.13	323.94

4.4.3 HEALTH IMPACTS

The implementation of the BRT system in Bandung leads to significant health benefits from increased levels of physical activity and reduced air pollution levels resulting from the shift from individual motorized transportation modes to BRT. The total cumulative net health benefits amount to IDR 2,089.81 billion in the current BRT scenario and IDR 4,651.08 billion in the high-ambition BRT scenario.

Primarily, the BRT system leads to increased levels of physical activity for BRT users that spend additional time walking to and from BRT stations. The additional minutes per day walked, the average walking speed of BRT users, and the number of BRT trips were considered in the estimation of the total economic benefits from physical activity. Values represent the cumulative net health benefits resulting from increased physical activity from the new mobility pattern compared to the baseline. Annual values of benefits resulting from the increased physical activity of BRT users are indicated in the first two rows of Table 17 for both BRT scenarios.

In addition, if transportation users in Bandung shift from individual motorized, fuel-based transportation modes to the use of BRT, the number of vehicles on the road will decrease, causing the level of air pollutants emitted by vehicles to decrease as well. Table 18 provides the annual avoided health costs from reduced pollution levels for both BRT scenarios caused by the shift from individual transportation modes to BRT. It is important to note that only emissions from fuel combustion are assessed and valued. Emissions originating from upstream supply chain stages for fuel production are not assessed; hence, transportation modes such as metro and railway are not associated with any health cost since no fuel combustion takes place during transportation use. Consequently, shifting from these transportation modes to BRT does not result in reduced air pollution costs.

Table 18. Annual values of health impacts, including health benefits from increased physical activity and avoided air pollution costs (discounted at 3.5%)

	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
Annual values of benefits from physical activity (IDR billion)	Current BRT scenario	0.57	0.89	0.79	0.70	0.62	0.55	19.45
	High-ambition BRT scenario	0.57	1.29	1.58	1.75	1.85	1.64	40.00
Annual values of avoided air pollution costs (IDR billion)	Current BRT scenario	48.94	85.68	82.49	78.91	75.05	71.04	2,070.36
	High-ambition BRT scenario	49.79	124.78	165.06	205.94	241.49	228.59	4,611.08
Total annual values of health impacts (IDR billion)	Current BRT scenario	49.50	86.58	83.28	79.60	75.67	71.59	2,089.81
	High-ambition BRT scenario	50.36	126.07	166.64	207.69	243.34	230.23	4,651.08

4.4.4 VALUE OF TIME SAVED

The value of time saved represents the economic value of improved mobility resulting from the BRT system. The shift from other transportation modes to BRT will result in differing travel speeds, hence the BRT system will lead to either time savings or additional time spent for commuting, depending on the current mode of transportation. Transport-related time savings increase economic productivity by allowing employees to work more hours and increase leisure time, which has a wide range of benefits, including health benefits and benefits to the local economy through higher retail revenues.

In the current BRT scenario, the cumulative value of time saved over the project period is valued at IDR 26,385.79 billion, and in the high-ambition BRT scenario, the cumulative value of time saved amounts to IDR 55,477.63 billion. Assumptions used for calculating the monetary value of time saved are explained in Section 3.2.4. Annual values of time saved for both BRT scenarios are indicated in Table 19.

Table 19. Annual values of benefits from time saved due to improved mobility (discounted at 3.5%)

	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
Annual values of time saved (IDR billion)	Current BRT scenario	768.37	1,209.79	1,070.81	947.80	838.92	742.55	26,385.79
	High-ambition BRT scenario	837.58	1,819.75	2,142.44	2,394.32	2,558.98	2,265.02	55,477.63

4.4.5 RETAIL REVENUES

The shift from individual motorized transportation modes to BRT will result in additional time spent walking to and from BRT stations. As explained in Section 3.2.5, the increased walkability around retail establishments implies higher retail spending for BRT users in retail establishments that are located near BRT stations. The increase in retail revenues reflects the total additional retail spending in the BRT scenarios over the project period. Naturally, the higher the demand for the BRT system, the higher the total amount of additional retail spending. The cumulative increase in retail revenues due to additional retail spending expected from BRT users over the project period amounts to IDR 6,392.53 billion in the current BRT scenario and IDR 13,150.16 billion in the high-ambition BRT scenario. Selected annual values of additional retail spending for the BRT scenarios are included in Table 20.

Table 20. Annual values of additional retail spending (discounted at 3.5%)

	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
Annual values of increased retail revenue (IDR billion)	Current BRT scenario	186.53	293.04	259.37	229.58	203.20	179.86	6,392.53
	High-ambition BRT scenario	186.53	423.43	518.94	574.17	609.61	539.58	13,150.16

4.4.6 CO_2 EMISSIONS

The implementation of the BRT system will lead to a shift from individual motorized transportation to the BRT system, which will result in a reduction in the number of vehicles on the roads of Bandung. This will be accompanied by a reduction of CO_2 emissions generated from Bandung's transportation sector.

CO_2 emissions are calculated by multiplying the vehicle-km travelled by the different transportation modes and the emissions factors that correspond to each transportation mode, based on a SAVi assessment that was undertaken in Dakar, Senegal. The valuation approach is described in more detail in Section 3.2.6. The cumulative avoided costs of CO_2 emissions that result from the implementation of the BRT system amount to IDR 277.43 billion, or 1.2 million tonnes of CO_2 avoided in the current BRT scenario. In the high-ambition BRT scenario, cumulative avoided costs of CO_2 emissions amount to IDR 607.07 billion, or 2.7 million tonnes of CO_2 avoided. Table 21 shows the annual values of avoided CO_2 emissions costs.

Table 21. Annual values of avoided CO_2 emissions costs (discounted at 3.5%)

	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
Annual avoided cost of CO_2 emissions (IDR billion)	Current BRT scenario	6.61	11.47	11.05	10.57	10.05	9.51	277.43
	High-ambition BRT scenario	7.42	17.50	22.10	26.65	30.58	28.95	607.07

4.4.7 FUEL USE

The implementation of the BRT system will lead to a shift from individual motorized, fossil fuel-based transportation modes to BRT, resulting in a diminishing number of vehicles on the roads of Bandung. This will result in fuel savings that are used to estimate the avoided cost of fuel in the SAVi BRT assessment. The calculation includes the number of trips, the vehicle-km, and fuel consumption by transportation mode, as well as the price per litre of fuel.

Results show that cumulative fuel savings from the implementation of the BRT system in Bandung over the project period amount to IDR 931.24 billion in the current BRT scenario and IDR 1,959.39 billion in the high-ambition BRT scenario over the project period. Annual values of avoided costs of fuel are summarized in Table 22.

Table 22. Annual values of avoided fuel costs (discounted at 3.5%)

	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
Annual avoided cost of fuel (IDR billion)	Current BRT scenario	26.80	42.75	37.84	33.49	29.64	26.24	931.24
	High-ambition BRT scenario	27.91	62.92	75.70	85.38	91.80	81.25	1,959.39

4.4.8 ACCIDENTS

The BRT system will lead to a shift from individual motorized, fossil fuel-based transportation modes to BRT, diminishing the number of vehicles circulating on the roads of Bandung and hence reducing the number of accidents. The SAVi BRT model distinguishes between three levels of accident severity: minor injuries, major injuries, and fatalities. Different values have been applied for the monetary valuation of each severity type. The avoided costs of accidents in Bandung after the implementation of the BRT system by accident severity are estimated using data on the number of accidents per year, the risk of accidents (accidents per 100,000 km), and the economic value of accidents by accident severity. More details on accident statistics and risk levels in Bandung are explained in Section 3.2.8 of this report.

According to the valuation results for both BRT scenarios, the BRT system reduces the number of accidents in Bandung. SAVi results indicate that when more vehicle-km travelled by motorized transportation is replaced by BRT, fewer accidents happen across all accident categories. The total cumulative avoided accident costs in the current BRT scenario and in the high-ambition BRT scenario amount to IDR 33.09 billion and IDR 70.72 billion, respectively. Over the same period, in the current BRT scenario, 646 accidents are avoided, including 205 fatalities, and in the high-ambition BRT scenario, 1,507 accidents are avoided, of which 479 are fatalities. The annual avoided costs of accidents are summarized in Table 23.

Table 23. Annual values of avoided accident costs (discounted at 3.5%)

	Scenarios	2025	2030	2035	2040	2045	2050	Cumulative (2022–2050)
Annual avoided cost of accidents (IDR billion)	Current BRT scenario	0.95	1.52	1.34	1.19	1.05	0.93	33.09
	High-ambition BRT scenario	0.97	2.21	2.69	3.11	3.39	3.00	70.72

4.5 Results From the Financial Model

4.5.1 PRE-FINANCING ANALYSIS

The main purpose of this analysis is to assess the extent to which the environmental, social, and economic benefits of BRT projects impact the financial attractiveness of the project. Pre-financing analysis consists of three elements, namely the cash flow statement, the impact statement, and the integrated value statement. The cash flow statement includes only costs and revenues that are considered actual cash flows to the project itself. The impact statement includes all other benefits generated by the implementation of the BRT system. The integrated value statement is the combination of the two.

The above is presented in discounted terms using a discount rate of 3.5% per year. Importantly, this is a "real" rate of discount (i.e., excluding inflation) to match the uninflated format of the cost and benefit values. Values are discounted to December 31, 2022.

This extension from cash flow to an integrated value analysis makes sense for decision-makers who want to take a more holistic approach when assessing whether the BRT system would deliver value for money to society over its life cycle.

Table 24. Pre-financial analysis

		BRT scenarios (2022–2050)	
In present value (PV) terms, discounted at 3.5% p.a. real to December 31, 2022		**Current BRT scenario**	**High-ambition BRT scenario**
Cash flow statement	Capital costs	-1,244.34	-1,244.34
	O&M costs	-4,257.04	-8,757.21
	Revenues from BRT	248.95	512.12
	Net cash flow – PV at December 22	**-5,252.43**	**-9,489.44**
	IRR of net cash flow	**N.A.**	**N.A.**
Impact statement	Income creation from employment	323.94	323.94
	Health impact benefits	2,089.81	4,651.08
	Value of time saved	26,385.79	55,477.63
	Retail revenues	6,392.53	13,150.16
	Avoided social cost of carbon benefit	277.43	607.07
	Avoided cost of accidents benefit	33.09	70.72
	Avoided cost of fuel use benefit	931.24	1,959.39
	Net impact – PV at December 22	**36,433.82**	**76,239.99**
Integrated value statement	**Net integrated value – PV at December 22**	**31,181.39**	**66,750.56**
	IRR of net integrated value	**168.8 %**	**181.8 %**

If we consider the cash flow statement, the project generates negative net cash flow for both BRT scenarios due to high direct costs and low direct revenues generated by the BRT project. Due to the lack of positive cash inflows to offset the upfront investment costs, the IRR of net cash flow provides meaningless values for the analysis.

On the contrary, when avoided costs and added benefits are integrated into the calculation, we obtain much better results. As shown in Table 24, the net integrated value shows that the project is viable for both the current and high-ambition BRT scenarios. However, it remains noticeable that the BRT system generates the largest value for the high-ambition scenario with an amount of IDR 66,750 billion. The worthiness of the project is also assessed through the IRR. In this case, the IRR of the net integrated value shows high values for both scenarios. This is due to the large amount of added benefits and avoided costs generated by the project. In order to understand the magnitude of these added benefits and avoided costs, it is possible to observe the impact statement in Table 24. The largest net impact (PV) is generated by the BRT system in the high-ambition scenario with an amount of IDR 76,239 billion.

4.5.2 DEBT FINANCING ANALYSIS

The objective of this section is to evaluate possible financing structures for the BRT system under both current and high-ambition scenarios. BRT projects require a large amount of upfront capital. Debt financing, in the form of loans, is often used by project promoters to cover the necessary capital and operating expenditures (Institute for Transportation & Development Policy, 2014.).

Generally, a sound BRT system project is eligible for debt financing of 70% of total costs and for public grants (Institute for Transportation & Development Policy, 2014). Starting from this assumption, we built a financing model that considers three simple combinations of debt and a non-repayable grant. These combinations enable the observation of the investment opportunity of the BRT project under different financing conditions.

We assessed three levels of debt financing used for the current and high-ambition scenarios, assuming that eligible costs are financed by a combination of debt and a non-repayable grant: 70% debt and 30% grant; 50% debt and 50% grant; or 100% grant (no debt).

In terms of debt repayment, we assumed a 0.25% front-end fee rate, a commitment fee of 0.25%, and an interest rate of 8.88%. The interest rate includes a 7.12% base rate, a 1.6% interest margin, and a 0.50% maturity premium. The repayment period is 13 years, starting from January 2027. These assumptions are based on the financial terms of the International Bank for Reconstruction and Development flexible loans for Indonesia (World Bank, 2023).

To determine how much revenue is required to repay debt and cover project costs under the three financing combinations, we look at alternative revenue streams generated by the internalization of externalities and tax revenues from benefits (Table 25).

The mechanism of internalizing externalities is already applied in other financing mechanisms, such as outcome-based financing (Brand et al., 2021). Here, the key aspect is to convert benefits and avoided costs into revenue streams to pay for project implementation and generate revenue for investors (Brand et al., 2021). In this analysis, we want to apply the same concept of integrating externalities into project cash flow to repay the debt and project costs. While how to practically generate revenue from these externalities depends on the municipality or local governments, we want to demonstrate how externalities can improve the financial viability of the BRT project.

We also consider the increased tax revenue from benefits as used in other financing mechanisms, such as tax increment financing (World Bank, 2015). In this case, governments can forecast an increase in tax revenue based on the value generated by the project. For example, by implementing a large-scale project, the local administration can expect an increase in tax revenue favoured by a rise in property values in the area (World Bank, 2015). In this analysis, we want to demonstrate that incremental tax revenue generated from the BRT added benefits and avoided costs can support the financing of the project.

As a first step, this analysis assesses whether the BRT revenue can be considered as the only source of financing. Looking at the operational revenue generated by the BRT tickets, we can observe that the BRT revenue is able to cover only a small portion of costs and debt. For instance, in the high-ambition scenario with 70% debt, the BRT revenue can cover only 4.2% of total costs and debt and only 3.4% in the current ambition scenario (Table 25). Therefore, an increase in BRT revenue is needed to reach the break-even point.

Table 25. Percentage of capital expenditures (capex) and operating expenditures (opex) and debt costs covered by the BRT revenue

	Current BRT scenario			**High-ambition BRT scenario**		
	70% debt – 30% grant	**50% debt – 50% grant**	**100% grant**	**70% debt – 30% grant**	**50% debt – 50% grant**	**100% grant**
% of costs and debt covered by BRT revenue	3.5 %	3.8 %	5.0 %	4.2 %	4.5 %	5.3 %

By assuming that it is possible to increase BRT revenue using a higher ticket price, we can observe that a large increase in revenue is needed to cover costs and debt (Table 26). For example, in the high-ambition scenario with 70% debt, the BRT revenue should increase from 512.1 IDR billion to 12.1 IDR trillion to reach the break-even point. This would result in increasing the ticket price by 23.7 times. Such a price change is not economically viable, as it could affect the societal impact of the project, preventing access for low-income families.

Table 26. BRT revenues (IDR billion) in PV terms

	Current	High	Current BRT scenario			High-ambition BRT scenario		
	Pre-financial analysis	Pre-financial analysis	70% debt – 30% grant	50% debt – 50% grant	100% grant	70% debt – 30% grant	50% debt – 50% grant	100% grant
BRT revenue multiplier	20.0	18.7	28.8	26.1	20.0	23.7	22.2	18.7
BRT revenue (IDR billion – PV)	248.95	512.12	7,180.37	6,503.17	4,988.54	12,126.27	11,345.81	9,600.22

As a result, the BRT revenue is insufficient to fund the project, as it cannot fully cover costs and debt. As an increase in ticket price to generate additional revenue is not a viable option, it is necessary to identify alternative revenue streams that will allow the BRT project to break even and be worthy of investment from a societal perspective.

In the following section, we assess whether benefits and avoided costs can serve as a source of revenue in addition to the existing BRT revenue.

Table 27. Financing scenarios

	Current BRT scenario			High-ambition BRT scenario		
	70% debt – 30% grant	50% debt – 50% grant	0% debt – 100% grant	70% debt -30% grant	50% debt – 50% grant	0% debt – 100% grant
Internalization of externalities	19.1%	17.2%	13.1%	15.4%	14.3%	12.0%
Tax revenue on/from taxable benefits	21.0%	18.9%	14.3%	16.9%	15.7%	13.2%

The "internalization of externalities" determines how much of the monetized benefits need to be internalized on top of the cash inflow generated by the BRT revenue to reach the break-even point. This shows that alternative revenue streams, as monetized benefits, can improve the financial viability of the project. This is achieved by calculating the portion of monetized benefits that are needed to fund capex, opex, and repay the debt. Table 27 shows that between 12% and 19% of externalities would allow the project to reach the break-even point. In perspective, it is possible to generate enough revenue stream to fund the project by only internalizing part of the larger benefits, such as *value of time saved* and *retail revenue*.

Interestingly, a smaller revenue stream from externalities is required to fund the project in the high-ambition BRT scenario compared to the current BRT scenario. This means that it is easier to fund the project under the high-ambition scenario, as it is supported by higher ridership, generating higher BRT revenue. The high-ambition scenario also generates a revenue stream from higher-value benefits. As previously observed, the high-ambition scenario generates a larger net impact value compared to the current ambition scenario.

From a government perspective, we assessed the tax percentage on taxable benefits as a possible source of financing. The objective is to determine how much tax revenue needs to be leveraged to make the project break even. Tax revenues would enable the government to finance the opex and capex and repay the costs of debt. In this case, we identified three benefits from which it would be possible to generate tax revenues: employment benefits, the value of time saved, and retail revenue. We assumed that these three benefits are both the most relevant and the easiest to leverage to generate future tax revenue from a local government perspective.

The tax percentage required from these externalities ranges from 21% with 70% debt financing in the current ambition scenario to 13.2% with full grant financing in the high-ambition BRT scenario. In this case, we also observed that a small portion of externalities is sufficient to generate enough tax revenue to make the project break even. Also, the high-ambition scenario is supported by higher ridership and higher BRT revenue, requiring a smaller portion of tax revenue from externalities compared to the current ambition scenario.

To conclude, these considerations are useful to quantify the revenue streams that could potentially cover project costs and debt. In this case, only a small portion of monetized benefits and avoided costs is needed to generate additional revenue streams to fund the project. This shows that revenue from monetizing externalities and taxable benefits can reinforce the financial justification of the BRT system, demonstrating to stakeholders its economic viability. Also, the high-ambition scenario requires smaller revenue streams to cover project costs and repay the debt compared to the current BRT scenario.

Therefore, a BRT system under the higher-ambition BRT scenario is easier to fund, showing itself to be the preferable option from a financing perspective.

5.0 Conclusions

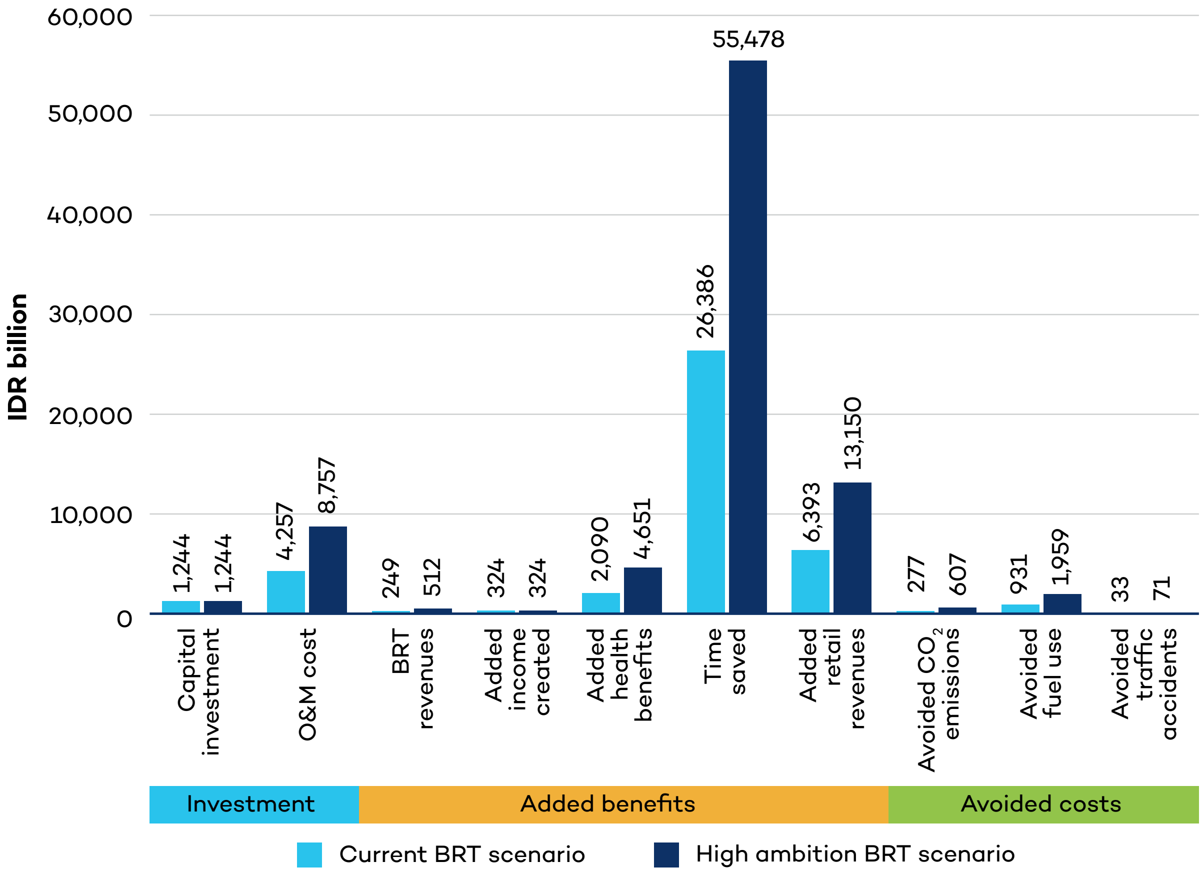
The SAVi assessment of the BRT system in Bandung provides valuable insights into the multiple economic, social, and environmental benefits resulting from the successful implementation of the mobility project. The main objective of the SAVi assessment is to inform transportation infrastructure planners about the positive impacts that the BRT system can have. It also demonstrates the importance of carrying out integrated assessments that quantify the added benefits and avoided costs of BRT systems, as they demonstrate the investment worthiness of the project for the government and for citizens. In other words, the SAVi assessment shows the societal value of sustainable transportation infrastructure, such as the BRT system in Bandung.

The multiple economic, social, and environmental added benefits and avoided costs have been assigned a financial value and integrated into the CBA. This assessment hence goes beyond merely providing anecdotal evidence on the benefits of BRT systems since it clearly shows that the benefits arising from the implementation of the BRT system are significantly higher when the valued-added benefits and avoided costs are integrated into the CBA for both BRT scenarios. This is demonstrated by the difference between the conventional BCR, which is based on an estimate of only tangible parameters, such as investment costs, BRT revenues, income creation from employment, and avoided costs of fuel use and the S-BCR, which includes the full range of economic, social, and environmental benefits and costs. The BCR in the current BRT scenario is 0.27, whereas the S-BCR in the same scenario is 6.67. Similarly, in the high-ambition BRT scenario, the BCR and the S-BCR show values of 0.28 and 7.67, respectively. It is also important to consider how the S-BCR changes over time. In the beginning, the investment costs are more noticeable than the added benefits and avoided costs, but as the added benefits and avoided costs accumulate over the years of the project period, the S-BCR increases.

Over the project period, both BRT scenarios yield positive results. The current BRT scenario shows cumulative discounted net results of IDR 31,181.39 billion, and the high-ambition BRT scenario shows cumulative net results of IDR 66,750.56 billion. According to these results, **the SAVi assessment provides evidence that investing in the BRT system in Bandung is worthwhile if the multiple environmental, social, and economic benefits and avoided costs are taken into account.**

Integrated assessments, such as this one conducted using the SAVi methodology, can help make a stronger case for the BRT system and other forms of sustainable mobility solutions. Overall, investment in BRT stimulates economic growth, either directly through employment creation or indirectly through stimulating retail and property value increases, as well as increasing the value of time saved for commuters. From the perspective of the public sector, higher GDP has led to increased government revenues, allowing the allocation of more resources to BRT infrastructure. Altogether, this assessment has shown that the BRT system advances the realization of sustainable mobility targets in Bandung and gives more citizens access to the formal job market, thereby improving their overall quality of life. In addition, the BRT system delivers the transportation policy objectives defined in the RPJMD and the BUMP. All of the results from the SAVi assessment, including investment costs, added benefits, and avoided costs, are demonstrated in Figure 4.

Figure 4. Investment costs, revenues, added benefits, and avoided costs of the BRT system in Bandung



Some of the benefits that the BRT system in Bandung will provide include the following:

- **Economic benefits, such as increased government revenues and employment creation:** The BRT system in Bandung will lead to increased government revenues through the purchase of BRT tickets by BRT users. According to the SAVi results, the cumulative revenues from BRT use over the project period are IDR 248.95 billion in the current BRT scenario and IDR 512.12 billion in the high-ambition BRT scenario. In addition, the BRT system's employment creation will have beneficial socio-economic impacts, such as income creation and increased discretionary spending, which represents the amount of money that will flow back to the economy in the form of additional consumption. The total cumulative income creation from employment amounts to IDR 323.94 billion, and 677 jobs will be created in both BRT scenarios.
- **Improved traffic congestion and transportation efficiency:** The use of the BRT system will improve traffic conditions and enhance the efficiency of movement in Bandung, as evidenced by the value of time saved, amounting to IDR 26,385.79 billion cumulatively over the project period in the current BRT scenario. The high-ambition BRT scenario shows a cumulative value of time saved of IDR 55,477.63 billion.

- **Increased health benefits and decreased fatality events:** The valued health benefits associated with increased physical activity and reduced air pollution are further indications of the improved quality of life for Bandung's citizens resulting from the availability and use of the BRT system. The total cumulative net health benefits over the project period amount to IDR 2,089.81 billion in the current BRT scenario and IDR 4,651.08 billion in the high-ambition BRT scenario. In addition, the BRT system will contribute to reducing fatality rates in Bandung, resulting from the shift from motorized transportation modes to BRT, which will reduce the number of vehicles on the road. The total cumulative avoided costs of accidents over the project period amount to IDR 33.09 billion in the current BRT scenario and IDR 70.72 billion in the high-ambition BRT scenario. In the current BRT and high-ambition BRT scenarios, 205 and 479 fatalities are avoided cumulatively, respectively.
- **Reduced emissions:** The SAVi results demonstrate that the shift from motorized transportation to using the BRT system contributes to reduced vehicular emissions. The results of the current BRT scenario provide evidence that more than IDR 277.43 billion in the social cost of carbon, or 1.2 million tonnes of CO_2, will be avoided cumulatively over the project period. The high-ambition BRT scenario shows cumulative values of IDR 607.07 billion in the social cost of carbon avoided, or 2.7 million tonnes.

Based on the above, the SAVi assessment demonstrates that the biggest benefits of the BRT system in Bandung are the added benefits related to the value of time saved, increases in retail revenues around BRT stations, and the positive health benefits that result from increased physical activity and diminishing air pollution levels in Bandung. The successful implementation of the BRT system in Bandung has the potential to address some of the challenges that keep the city in a car-oriented, high-carbon mobility pathway and transform Bandung into a pilot area for BRT systems and sustainable mobility more generally.

Limitations of the methodology used for this SAVi assessment are related to the valuation and quantification of some qualitative indicators. While the CLD (qualitative model) can identify a wide range of impacts, not all can be quantified due to the lack of data and literature that support their valuation or the limitations in their scope. This is the case with indicators such as GDP and labour force health quality. However, it could be possible to link SAVi to another model and determine other indicators or dynamics where the feedback loops can be represented more explicitly (e.g., macroeconomic/dynamic model to estimate GDP). The application of SAVi allows for diverse performance assessments beyond what has been applied for valuing the BRT system in Bandung and provides insights to government, citizens, and investors on the different value-creation elements of BRT systems. This can inform future sustainable mobility strategies and help make the case for better transportation investments in cities, as well as identify sources of funding/financing that match the different financial and social returns of the project.

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Appendix A. Causal Loop Diagram Description of the BRT Project in Bandung, Indonesia

Reinforcing loops (R)

R1 – Transportation demand shift dynamics: An increase in demand for BRT transportation generates a decrease in demand for individual transportation modes, which in turn generates an increase in BRT demand. On the contrary, an increase in demand for individual transportation modes generates a decrease in demand for BRT, which increases the demand for individual transportation modes.

R2 – BRT demand driven by congestion: If demand for BRT transportation increases, the capacity of BRT transportation increases and there are more km of roads used exclusively for BRT, which generates traffic congestion and increases the time spent on transportation. An increase in the time spent on transportation increases the demand for BRT transport, which increases the capacity of BRT transport. Note: This is based on the assumption that BRT is faster than individual transportation modes because it circulates in lanes that are exclusive to buses.

R3 – Investment in BRT driven by fuel use from individual vehicle fleet: An increase in the capacity of BRT generates a decrease in the use of individual transportation modes, which decreases fuel use, CO_2 emissions, and air pollution, increasing the labour force health quality, the total factor productivity, and GDP. An increase in GDP leads to an increase in investment in and capacity of the BRT.

R4 – BRT demand driven by fuel use: An increase in demand for BRT generates an increase in capacity for BRT, which leads to more fuel use and more CO_2 emissions and air pollution, decreasing the labour force health quality, total factor productivity, and GDP; a decrease in GDP leads to a decrease in disposable income and affordability of individual transportation modes, decreasing the demand for individual transportation modes and increasing the demand for BRT the next time around.

R5 – Accidents driven by demand for individual transportation modes: An increase in individual transportation modes generates a decrease in demand for BRT and hence BRT capacity, which decreases accidents and increases total factor productivity. An increase in total factor productivity increases GDP and disposable income, resulting in higher affordability capacity for individual transportation modes and higher demand for individual transportation modes.

R6 – Demand for BRT driven by physical activity and investment: an increase in the capacity for BRT leads to an increase in BRT passengers. If BRT passengers increase, the additional distance walked by the users increases, increasing labour force health quality, total factor productivity, and GDP, which increases investment and capacity for BRT.

R7 – Employment from individual transportation modes driven by demand for individual transportation modes: An increase in the demand for individual transportation modes increases the individual vehicle fleet, increasing employment from individual transportation service providers and increasing total employment from transport. An increase in employment leads to an increase in GDP, increasing the affordability of individual transportation modes and the demand for individual transportation modes as a result.

R8 – Employment from BRT driven by investment in BRT: The increase in capacity for BRT transportation increases the employment from BRT and total employment from transport, which increases GDP and the investment in BRT transport, increasing the capacity for BRT.

R9 – Individual transportation modes infrastructure driven by total employment: An increase in the investment in transportation infrastructure increases the use of individual transportation modes and the employment from individual transportation service providers, which increases the total employment from transportation. An increase in employment leads to an increase in GDP, increasing the affordability of individual transportation modes, as well as demand and investment in individual transportation modes as a result.

R10 – Property valorization driven by the BRT system: As the capacity of BRT increases, the valorization of the properties that are surrounding BRT increases as well. This raises GDP, which leads to more investment in BRT and an increase in the capacity of BRT transportation.

R11 – Retail revenues driven by the BRT system: An increase in the capacity of BRT transportation increases the distance walked by additional BRT passengers, which increases retail revenues around BRT infrastructure. An increase in retail revenues leads to more GDP, which leads to increased investment in BRT infrastructure and an increase in the capacity BRT transport.

Balancing loops (B)

B1 – Effect of time spent in transportation on BRT demand: An increase in BRT demand generates an increase in the capacity of BRT and a decrease in the use of individual transportation modes, which leads to a decrease in congestion and less time spent on transportation, decreasing the demand for BRT transportation and increasing the demand of individual transportation modes as a result.

B2 – Effect of fuel use on private transportation demand: An increase in the demand of individual transportation modes increases the use of individual transportation modes, which increases fuel use, CO_2 emissions, and air pollution, decreasing labour force health quality, total factor productivity, and GDP. A decrease in GDP leads to a decrease in the affordability of individual transportation modes, leading to a decrease in the demand for individual transportation modes as a result.

B3 – Effect of fuel use from BRT on investment in BRT: An increase in the capacity of BRT generates an increase in fuel use, CO_2 emissions, and air pollution, decreasing labour force health quality, total factor productivity, and GDP. A decrease in GDP leads to a decrease in investment in BRT and a decrease in the capacity of BRT.

B4 – Effect of accidents on the usage of individual transportation modes: An increase in the use of individual transportation modes leads to an increase in accidents, leading to a decrease in the total factor productivity and hence a decrease in GDP and affordability of individual transportation modes. This decreases the demand for individual transportation modes, which leads to a decrease in the use of individual transportation modes and a decrease in accidents.

B5 – Effect of accidents on investment in BRT: An increase in the capacity of BRT transportation increases accidentality, decreasing the total factor productivity and GDP, which leads to a decrease in the investment in BRT infrastructure and a decrease in the capacity of BRT transport.

B6 – Effect of physical activity and affordability of individual transportation modes on BRT demand: An increase in BRT demand leads to an increase in BRT capacity and BRT passengers, increasing the additional distance walked by passengers and the labour force health quality, which increases GDP and disposable income, increasing the affordability of individual transportation modes and decreasing BRT demand as a consequence.

B7 – Effect of affordability of individual transportation modes on employment from BRT: An increase in BRT demand leads to an increase in the capacity of BRT transportation and to an increase in employment from BRT. An increase in employment from BRT generates an increase in the total employment from transportation, increasing GDP and the affordability of individual transportation modes, which increases the demand for individual transportation modes and decreases BRT demand.

B8 – Effect of CO_2 emissions and air pollution on individual transportation modes infrastructure investment: An increase in transportation infrastructure leads to an increase in the individual vehicle fleet, increasing the use of individual transportation modes and fuel use, increasing CO_2 emissions and air pollution, and decreasing total factor productivity. The decrease in total factor productivity generates a decrease in GDP, disposable income, and affordability of individual transportation modes, leading to a decrease in the demand for individual transportation modes and a decrease in investment in transportation infrastructure as a result.

B9 – Effect of accidents on individual transportation modes infrastructure investment: An increase in transportation infrastructure leads to an increase in the individual vehicle fleet, increasing the use of individual transportation modes and traffic accidents, which leads to a decrease in labour force health quality and total factor productivity. The decrease in total factor productivity generates a decrease in GDP, disposable income, and affordability of individual transportation modes, leading to a decrease in the demand for individual transportation modes and a decrease in investment in BRT infrastructure as a result.

B10 – Effect of the BRT system on retail revenues: An increase in the capacity of BRT increases the distance walked by additional BRT passengers, which increases retail revenues around BRT infrastructure. An increase in retail revenues leads to more GDP, which leads to more disposable income and hence more affordability and demand for individual transportation modes.

B11 – Effect of individual transportation modes on noise pollution: An increase in the use of individual transportation modes increases the amount of noise pollution, which reduces labour force health quality and total factor productivity. This, in turn, reduces GDP and disposable income and hence affordability and demand and use for individual transportation modes.

B12 – Effect of the BRT system on noise pollution: An increase in the capacity of BRT transportation increases the amount of noise pollution, which reduces labour force health quality and total factor productivity. This, in turn, reduces GDP and hence investment in BRT infrastructure, which reduces the capacity of BRT transportation.

Appendix B. System Dynamics/ Excel-Based Model

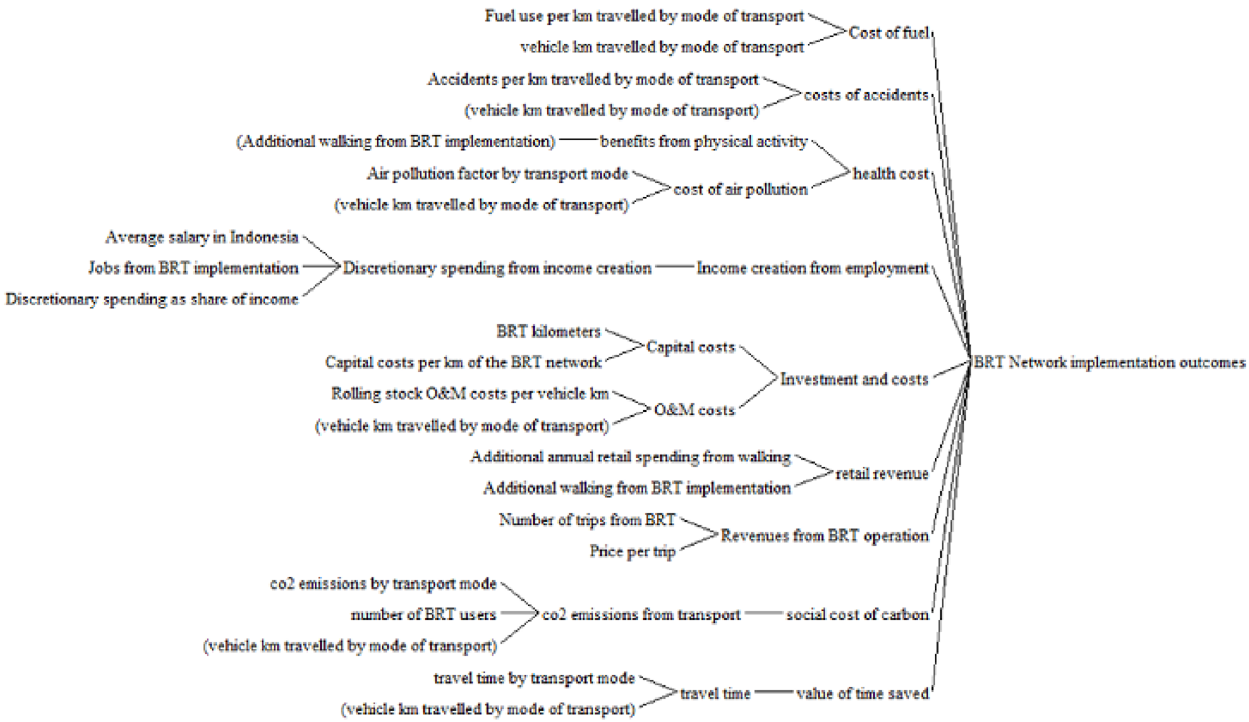
This approved methodology for infrastructure valuation is based on multistakeholder engagement techniques, the use of systems thinking, and project finance modelling to capture the life-cycle costs of environmental, social, economic, and governance risks. Moreover, the Sustainable Asset Valuation (SAVi) tool calculates the monetary value of environmental, social, and economic added benefits and avoided costs that result from deploying infrastructure projects. The SAVi assessment for the BRT system in Bandung focuses on this latter element.

SAVi uses a spreadsheet-based modelling approach that integrates data from project-specific documents and peer-reviewed research and scientific reports to estimate infrastructure performance and related externalities. In the case of the BRT system in Bandung, data on demand for transport, vehicle mix, and the expected reduction in vehicle-km and passenger-km were obtained from the BRT feasibility studies prepared by Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) in 2020 (GIZ, 2020a, 2020b, 2020c). The added benefits and avoided costs analyzed were identified in collaboration with local stakeholders. Where required, in most cases due to the presence of strong causality but a lack of location-specific data, additional data sources were used to quantify variables that served to measure and monetize added benefits and avoided costs in Bandung.

The SAVi approach quantifies and monetizes the costs and benefits of the assessed infrastructure projects. The added benefits and avoided costs assessed for this SAVi application are illustrated in the form of a causes tree in Figure B1. A causes tree highlights the causal chain of variables used for estimating the outcomes (positive and negative) of the BRT system. For example, the cost of air pollution is estimated based on the vehicle-km travelled and the emissions factors of air pollutants per km of various transportation modes. The vehicle-km travelled with motorized vehicles is affected by the number of people that shift to BRT, reducing system-wide air pollution, which leads to lower health costs in return. All valued-added benefits and avoided costs and the results are discussed in detail in Sections 3 and 4 of this report. Each added benefit and avoided cost is calculated and valued separately and contributes to estimating the net benefits of the BRT system.

It is worth noting that a causes tree does not indicate the sense of causality (i.e., direct or inverse relation) that connects two variables. This is only captured in the mathematical model through the use of specific equations. For instance, in the case of "costs of accidents," it is assumed that a shift from motorized vehicle-km travelled to km travelled by BRT contributes to a reduction in accidents, as a reduced number of vehicles are on the road. This, in turn, reduces the health costs incurred from accidents. A similar causal relation is made for the cost of air pollution: the more people shift from motorized modes of transportation to the BRT system, the lower the number of vehicles on the road, and the higher the reduction in air emissions, such as $PM_{2.5}$ or NO_x. The reduction in emissions leads to a reduction in emission-related health impacts and hence reduces health costs.

Figure B1. Causes tree of the SAVi assessment for the BRT system in Bandung



The SAVi model estimates the net difference of biophysical parameters between a baseline scenario and an intervention scenario (e.g., tonnes of CO_2 emissions reduced due to the use of the BRT system instead of individual motorized vehicles). These biophysical parameters and their changing values between scenarios are the underlying elements for determining the economic value of an added benefit and avoided cost (e.g., a reduction of health costs due to lower air pollution and fewer health implications for citizens). The valuation of added benefits and avoided costs are based on scientific literature, providing an economic value linked to a specific biophysical parameter. These multipliers are applied and customized to the local context to the extent possible, using studies conducted in Bandung, Indonesia.

Appendix C. Main Assumptions and Data Sources Used

Table C1. Overview of key assumptions used in the BRT Bandung SAVi assessment

Parameters for calculating added benefits and avoided costs				Level of data collection			
Added benefit or avoided cost	**Indicator**	**Value**	**Data source**	**Project-specific**	**Urban/ regional**	**National**	**International**
Revenues from BRT use	Average BRT ticket price	IDR 6,000	GIZ, 2020b	X			
	BRT demand statistics	73,000 passengers (from the first to third years of operation), 204,000 passengers (from fourth year onwards)	GIZ, 2020c	X			
Income creation from employment	Proposed fleet size of BRT	78 large buses (11.5m–12m) 170 medium buses (9m–10.5m), 109 small buses (6m–8m). A total of 357 buses.	GIZ, 2020b	X			
	Jobs created per vehicle	Drivers and crew – 1.6, maintenance – 0.26	Ekosgen, 2010				X
	Share of discretionary spending	9.3% for restaurants, 5.9% for sports and leisure, 3.7% for clothing and shoes	Numbeo, 2022			X	
	Average construction jobs per month	1,600	World Resources Institute & EMBARQ, 2002				X

Parameters for calculating added benefits and avoided costs				Level of data collection			
Added benefit or avoided cost	**Indicator**	**Value**	**Data source**	**Project-specific**	**Urban/ regional**	**National**	**International**
Health impacts	Additional time spent walking	2.75 minutes	World Resources Institute & EMBARQ, 2002				X
	Average number of daily trips in Bandung	2.64 trips	Dharmowijoyo et al., 2017		X		
	Economic benefits of walking per km	EUR 0.37/km	Gossling et al., 2019				X
	Cost of air pollution	290 per vehicle-km	Bassi et al., 2019		X		
Value of time saved	Travel speed	For BRT – 25 km/h	GIZ, 2020c	X			
	Travel time	For BRT – 21.4 minutes per trip	GIZ, 2020c	X			
	Value of time	Business – IDR 33,042; Leisure – IDR 13,217	GIZ, 2020c	X			
Retail revenues	Average monthly spend on non-food goods for urban dwellers in Indonesia	IDR 729,562	DBS Asian Insights, 2018			X	
	Average added retail spending from walkability	42.2%	Rabl & Nazelle, 2012				X

Parameters for calculating added benefits and avoided costs				Level of data collection			
Added benefit or avoided cost	**Indicator**	**Value**	**Data source**	**Project-specific**	**Urban/ regional**	**National**	**International**
CO_2 emissions	CO_2 emission factors by transport-ation mode	Motorcycles – 0.0001; Angkot – 0.0004; taxis/private vehicles – 0.00018; buses – 0,0009; BRT – 0.00035	Bassi et al., 2019		X		
	Cost of emissions per tonne	IDR 303,758/tonne	Conseil Exécutif des Transports Urbains de Dakar, 2016		X		X
Fuel use	Fuel consumption by transportation mode	0.074 l/km	Goel et al., 2016				X
	Fuel price in Bandung	IDR 5,295/l	GIZ, 2020b		X		
Accidents	Cost of accidents per severity	Fatal (IDR 263,025,680.96/ accident); major injury (IDR 12,066,000/accident); minor injury (IDR 1,904,312.87/accident)	Sugiyanto, 2017				X
	Risk of accident per severity/ 100,000 km	Fatal accidents (0.002158), major injuries (0.000443), minor injuries (0.006781)	IDSUN, 2020a		X		

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Published by the International Institute for Sustainable Development.

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