Chapter 9

Improving Feasibility of High-Speed Train Project: Creating Added Value

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Additional information is available at the end of the chapter

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Abstract

Infrastructure plays a significant role in increasing economic development by providing access of transportation and improving connectivity. High-speed train (HST), one of mega infrastructure projects, has a positive impact on economic development of a nation. However, the project feasibility requires the maximum value for money and an acceptable risk to attract private investors. This study aims to improve the feasibility of the project by producing a conceptual design of Jakarta-Surabaya high-speed train in Indonesia. Value engineering will be used to evaluate both technical and financial aspects of the project. The methodology uses both qualitative and quantitative approaches through a case study, in-depth interviews, and life-cycle cost analysis. The result shows an optimum route sketching for the project and potential added value to the project. It consists of the solar cell, fiber optic, tourism, and transit-oriented development. The output also generates the division of responsibility between the government and business entity during the project lifecycle regarding the project financing. The institutional scheme will regulate the position and roles for each related stakeholder that was involved in the HST project development.

Keywords: infrastructure, feasibility, high-speed train, mega project, value engineering

1. Introduction

Infrastructure development is one of the most significant aspects in accelerating economic and social growth [1]. Global competitiveness report published that the quality and quantity of infrastructure improves the ease of investment and creates more productive activities. Access for the people to use infrastructure is the key to accommodate individual activities and community engagement [2]. Reducing the distance among regions and establishing connectivity of national and international markets are significant to improve economic growth of a nation [3]. Infrastructure itself contributed about 60% to the economic growth of the United States [4]. Many other countries also experience similar benefits from the infrastructure and transportation connectivity to the people's daily activity and mobility.

Indonesia's gross domestic product (GDP) mainly depends on the economic development in Java Island. Jakarta located in western part of the island contributes about 20%, while Surabaya in the opposite location produces 6% of the GDP [5]. Location of both cities in the national context can be seen in **Figure 1**. The distance between those cities is approximately about 700 km and can be accessed through particular transportation modes with different travel times. Private vehicles require 22–26 h, 10–14 h by train and 1.5 h by airplane. Travel by plane saves the time but requires a double-to-triple cost compared to other transportation modes. Private vehicles consume less amount of cost but needs longer travel time to reach the destination. On the other hand, rail transportation offers competitive price compared to air transportation but proposes faster travel time over private vehicles and in some way, a minimum gap of travel time to air transportation [6].

Figure 1. City of Jakarta and Surabaya in Indonesia context.

In 2012, the Government of Indonesia launched a high-speed train (HST) project to connect Jakarta and Surabaya. The project has been offered to national and international investors, but progress of the project remains limited due to technical issues and financial deficiency. The needs of massive investment become the main issues investors tend to hold their investment, and the government has insufficient funds to support the project.

Levinson [7] argued that high capital costs and passengers' demand play a significant role to attract business entities. The United States requires 6–9 million passengers per year to meet the targeted return on investment, and thus the HST project in the country remains on hold. A high-occupancy high-speed train only reaches a maximum of 3.4 million passengers per year. Based on the situation, the study uses an alternative approach through value engineering (VE) process to improve the feasibility of the HST project. It has been proven to produce a strategic outcome regarding quality [8, 9], technology breakthrough [10], efficiency [11], and innovative creation [12]. VE generates value by proposing more benefits over cost. Transportation project in the United States experiences cost saving for VE implementation about 5.9% from the total cost of the project in 2015.

The study advocates the alternative use of value engineering to improve the performance of the infrastructure project. The result expected can be used for practical implementation in the industry, assist the decision-making process and regulatory framework for government institutions, as well as knowledge dissemination and debates for academic purposes.

2. Jakarta-Surabaya route planning

The route for high-speed train considers technical issues such as topography, length of the route, population, and economic development in a region expressed by gross regional domestic product (GRDP). Cities in western part of Java Island are mostly located at high elevations with mountains and cliffs. The trajectory recommends passing flat surface and minimizes the use of bridge and tunnel to reduce higher costs. From the analysis, green areas are recommended for the high-speed train line due to the flat surface. Moreover, the yellow to the orange area is chosen when the slope and topography meet the minimum technical requirement. The elevation map of Java can be seen in **Figure 2**.

The analysis identifies potential 9 cities out of 67 cities in Java Island for the high-speed train station. Jakarta ranked as the highest contributor in terms of GRDP and population. It is followed by Surabaya, Yogyakarta, Bandung, and Semarang. Four cities that are categorized into a mid-size city in terms of the population also included Kediri, Cilacap, Cirebon, and Solo due to their enormous contribution to the regional economic development. The location for each city can be seen in **Figure 3**.

The nine cities generate seven alternative routes, and each of them has a varied length from 754 to 958.6 km. Further analysis identified two possible routes for the project. Route 1 connects the city of Jakarta-Cilacap-Yogyakarta-Semarang-Solo-Kediri and Surabaya. The total distance for this route is about 958.6 km. Route 1 can be seen in **Figure 4**.

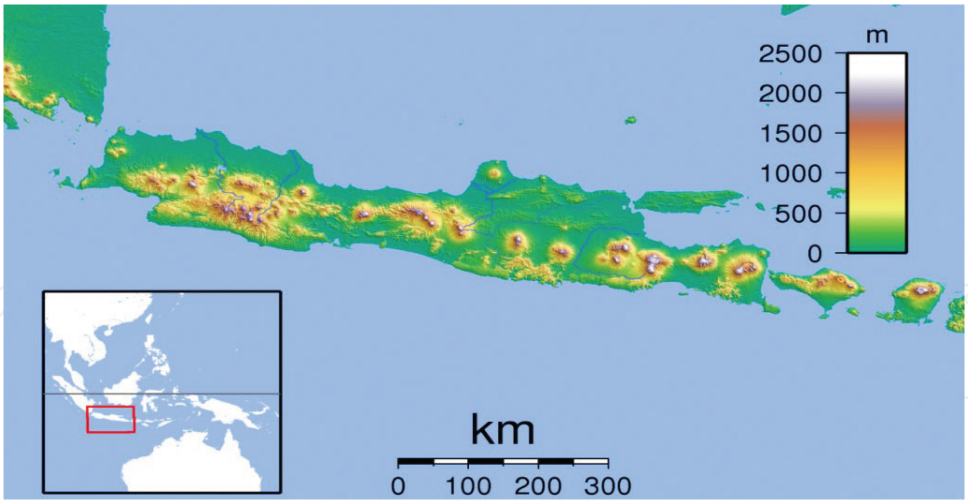

Figure 2. Elevation map of Java Island.

Figure 3. Nine potential cities for high-speed train station.

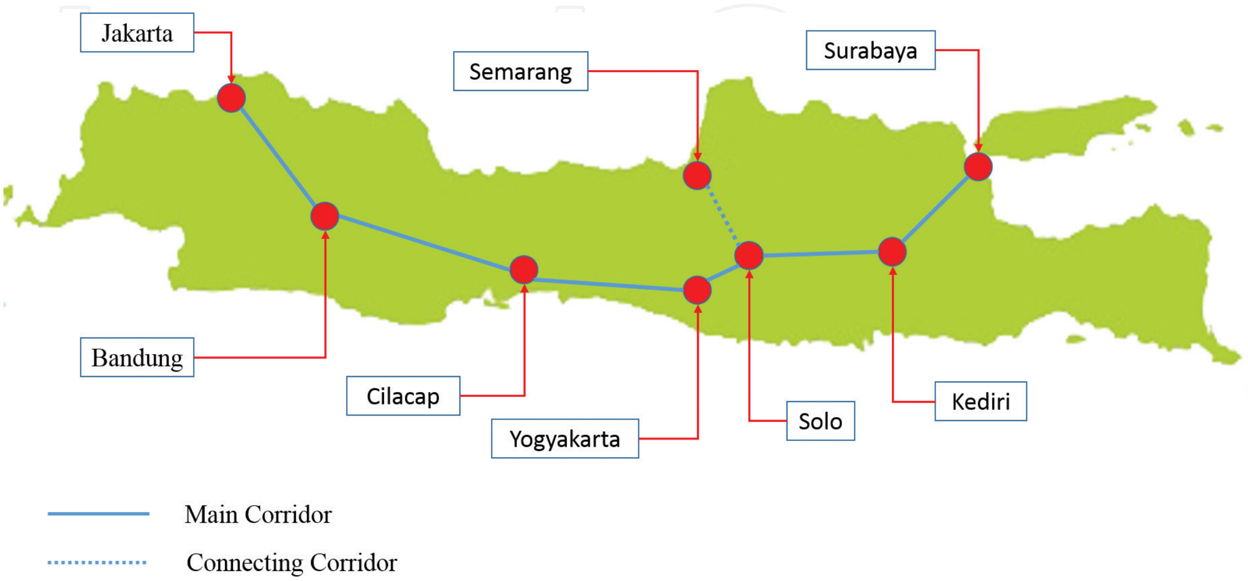

Figure 4. Route 1 from Jakarta – Surabaya high-speed train.

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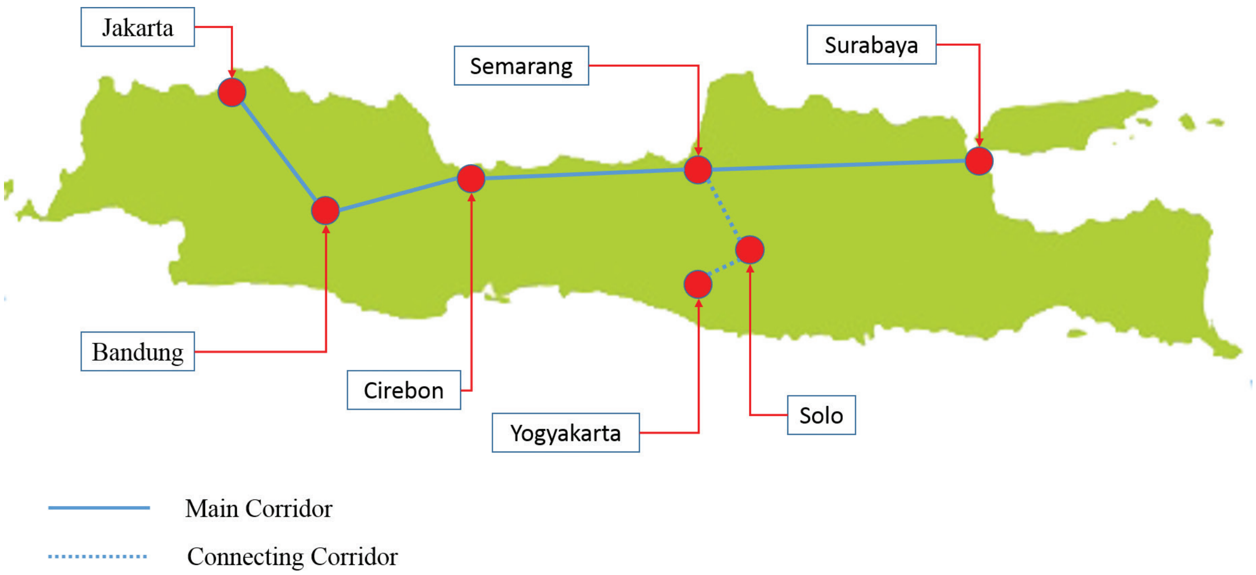

Figure 5. Route 2 from Jakarta-Surabaya high-speed train.

On the other hand, route 2 connects Jakarta-Bandung-Cirebon-Semarang (+Solo-Yogyakarta)-Surabaya. The total distance for this path is about 868.5 km, as shown in **Figure 5**. Each section in both alternative routes has different lengths and varied use of infrastructure components (rail structure, viaduct, bridge, or tunnel). The components were determined by estimating the topography of sections using Google Earth program. The maximum slope also affects the speed of the train [13]. As topography contributes to the cost of construction, careful planning must further be evaluated.

3. Value engineering of Jakarta-Surabaya HST project

Value engineering (VE) is a multidisciplinary approach that analyses and systematically improves function by reducing the cost and increasing the value of a product, design, system, or service.

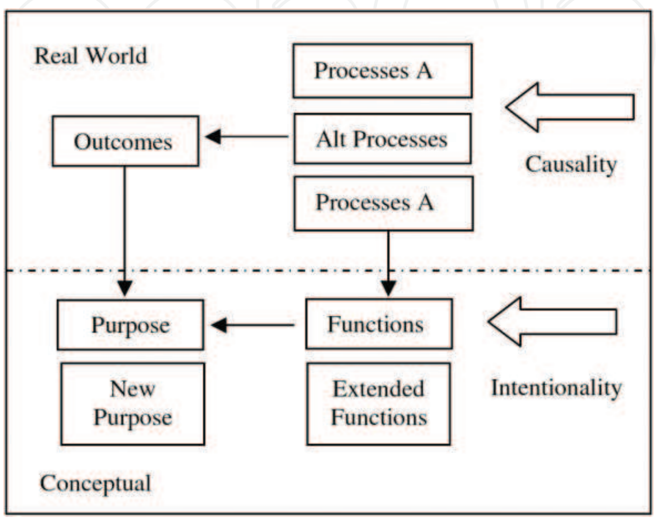

Figure 6. Functional thinking enables innovation.

VE is argued as a proven method to solve problems and to improve projects' competitiveness [14]. VE capability to increase competitiveness driven by the ability to produce creative ideas and innovation [15–17]. Innovation made from the creativity stage [18], formalization processes [19], and the successful application of the concept concerning output or product [20].

It measures the performance of designated functions and how it achieves the targeted purpose. When idea generation emerged during the value engineering process, the extended function enables the VE team to produce new objectives of a system. This process demonstrates how innovative and idea generation might improve the whole perspective in conceptual thinking and contribute to the real world [8]. The concept can be seen in **Figure 6**.

The Jakarta-Surabaya HST project development adopts value engineering job plan [8]. Firstly, information phase was conducted by observing literature study about the project detail. Secondly, function analysis is developed by identifying the function from existing data and information as follows:

- Scope of the problem under study: high-speed train between Jakarta and Surabaya
- Highest order function: stimulate economic growth
- Lowest order function: generate income
- Design objective: create added value and develop infrastructure connectivity
- Basic function: increasing mobility
- Dependent functions: transport people and goods
- Processes: construct line

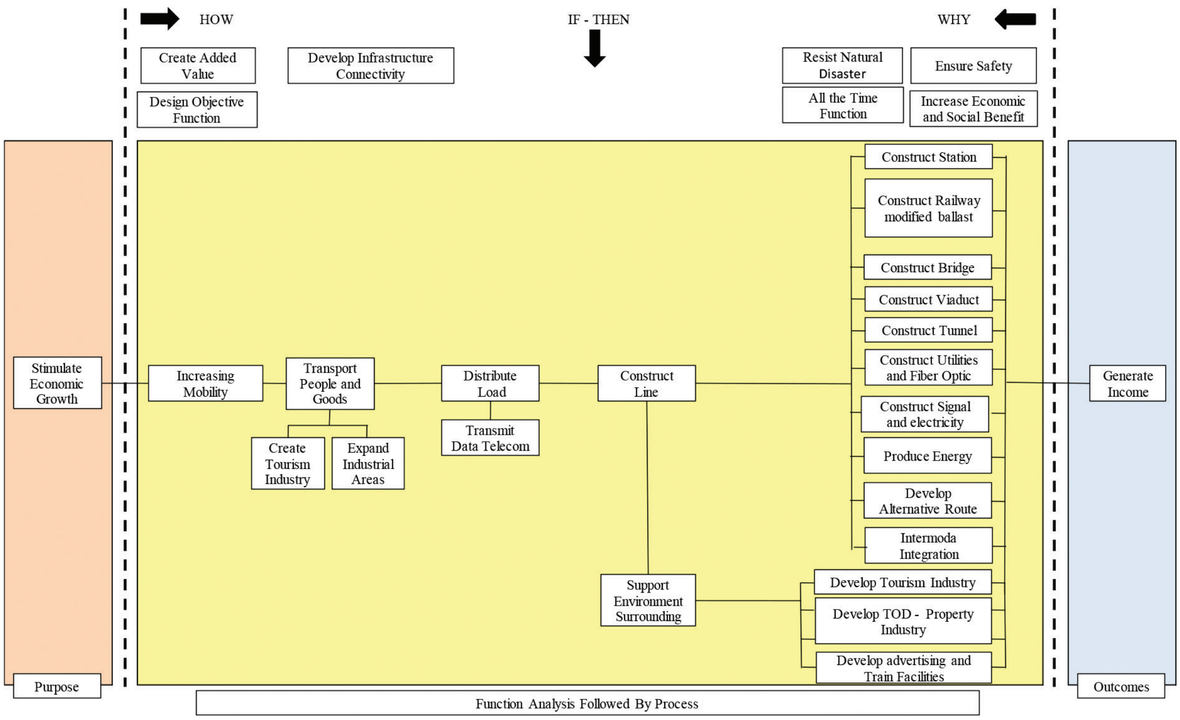

Figure 7. FAST diagram for Jakarta-Surabaya high-speed train.

The logical order of the previous function is mapping through a FAST diagram tool. The 'how-why' logical model is used to identify, classify, develop, and select functions that could create higher value and benefit to the project development. The FAST diagram, as shown in **Figure 7**, produces four additional functions such as solar cell, tourism, transit-oriented development (TOD), and fiber optic. Evaluation phase will be used to assess the benefits of additional functions from the financial perspective. Furthermore, public-private partnership (PPP) acts as the development phase to investigate the identified functions and financial engineering. It attempts to find the best formulation for both private investors and government in financing the project.

4. Financial scenario

Financial scenario elaborates initial cost, operational and maintenance cost, and revenue to generate an internal rate of return (IRR) and net present value (NPV). Initial cost, operation, and maintenance cost of high-speed train infrastructure consider railway infrastructure such as tracks, signaling, electricity, tunnel, bridge, and station area.

The scenario for revenue uses three categories of income from the low tariff, mid-tariff, and high tariff. Several assumptions are proposed for estimation boundary that is retrieved from Statistics Indonesia and other reliable sources. The discount rate is set about 6.81%. Inflation categorized from general inflation, transportation, fossil fuel, electricity, and telecommunication to property ranges from 1.63 to 5.95%. The scenario will compare the single function and multifunction from the life-cycle cost perspective. The result shows the benefits from value engineering process by an increased value of the rate of return.

4.1. Single function

The analysis produces route two from Jakarta-Bandung-Cirebon-Semarang-(Solo-Yogyakarta)-Surabaya as the main path of the high-speed train. The initial cost of the route is about 118.64 trillion rupiahs for 868.5 km or equal to 136.60 billion rupiahs/km. The operational and maintenance cost projected is about 5.3 trillion rupiahs/year or equal to 6.10 billion rupiahs/year. Revenue of HST considers demand forecast based on the shifting from the existing transportation mode such as the airplane, private vehicles, and regular train. The tariff for HST of Jakarta–Surabaya is set into three scenarios from 600,000 rupiahs, 750,000 rupiahs, and 1,000,000 rupiahs.

The result shows that low tariff produces a 5.12% of the internal rate of return (IRR), while mid-tariff claimed 8.7% of IRR and 13.8% for the high tariff. The low and mid-tariffs are failed to reach a minimum attractive rate of return (MARR) of the most infrastructure investors approximately about 12%. Subsequently, further elaboration is required by proposing additional functions to increase the feasibility of the project.

4.2. Multifunction

In a multifunction concept, the additional function includes solar cell, fiber optic, tourism, and transit-oriented development (TOD). Solar cell's initial cost depends on the number of solar cells and its capacity. Nine units of solar cells were generated with each one's capacity as about 70 kW with a unit efficiency of 20.83%. Overall, the initial cost is about 32.02 billion rupiahs.

Typology	Location	Description
Type 1	Jakarta, Surabaya, and Bandung	Land area: 10,000 sqm Residence area: 61,000 sqm Offices area: 19,000 sqm Commercial area : 3700 sqm Parking area : 1400 sqm
Type 2	Cirebon, Yogyakarta, and Semarang	Land area : 9000 sqm Residence area : 41,000 sqm Offices area: 13,000 sqm Commercial area : 2500 sqm Parking area : 1200 sqm
Type 3	Solo, Cilacap, Kediri	Land area : 8000 sqm Residence area : 31,000 sqm Offices area: 10,000 sqm Commercial area : 2000 sqm Parking area : 700 sqm

Table 1. Transit-oriented development typology.

The operation and maintenance cost is 1% of the initial cost or equal to 25.09 billion rupiahs/year and is assumed to increase about 5.9% per year. Revenue considers baseline tariff from the government for about 1000 rupiahs and is multiplied by the electricity output from the solar cell. It will increase 10% per 2 years. Revenue for the low tariff is about 129.57 billion rupiahs; mid-tariff equals to 194.35 billion rupiahs; and high tariff around 259.13 billion rupiahs.

Fiber optic considers material cost and installation cost to determine its investment. The initial cost is about 571.73 billion rupiahs and 678.99 billion rupiahs/year for operational and maintenance cost. Revenue is generated from the number of services per month that charged about 2 million rupiahs. The result shows the lowest to highest annual revenue of fiber optic by 9.53 trillion rupiahs, 11.91 trillion rupiahs, and 13.11 trillion rupiahs, respectively.

The initial cost of tourism follows a benchmark from other tourism area developmental sectors and considers global cost construction index. The initial cost is estimated as about 17.31 trillion rupiahs. Operational and maintenance cost is 23.22 trillion rupiahs. Revenue is generated from ticketing and other related components such as retails, parking area, and commercials. Ticket proposes for about 300,000 rupiahs per person and increases 10% per two years. The revenue ranges from 83.94 trillion rupiahs, 119.91 trillion rupiahs, and 155 trillion rupiahs.

Lastly, the initial cost of TOD follows several factors such as land acquisition, apartment, commercials, offices, and parking area. Each cost component is multiplied by land area for selected cities. The initial cost for TOD is about 5.24 trillion rupiahs. Operation and maintenance (O&M) cost only considers the parking area since apartment, commercials, and offices have been handled by the users and tenants. The O&M cost is estimated for about 276.17 billion rupiahs. Revenue consists of apartment sales, offices rental, commercial leasing, and parking

Function	IC (Rp. Billion)	OM (Rp. Billion)	Revenue		
			Low (Rp. Billion)	Intermediate (Rp. Billion)	High (Rp. Billion)
HST	118,643.14	203,917.52	443,799.16	554,748.95	739,665.26
Commercial and Adv	821.83	236.91	5,799.12	10,902.36	16,005.57
TOD	5,244.67	276.17	125,475.38	159,961.23	179,291.61
Tourism	17,315.74	23,219.10	83,940.69	119,915.27	155,889.86
Fiber optic	571.73	678.99	9532.72	11,915.90	13,107.49
Solar cell	32.02	25.09	129.57	194.35	259.13
Total	142,629.13	228,353.78	668,676.64	857,638.06	1,104,218.92

Table 2. Life cycle cost analysis of Jakarta-Surabaya high-speed train.

usage. The TOD is divided into three types by considering the regional economy and population density. The location of each type depends on the size of cities, potential economic development, and land availability; thus, the revenue ranges from 138.70 trillion rupiahs, 178.49 trillion rupiahs, and 202.01 trillion rupiahs. The details of TOD typology can be seen in **Table 1**.

Overall, the life-cycle cost for the high-speed train, Jakarta-Surabaya, can be generated, as shown in **Table 2**. The total initial cost is about 142.63 trillion rupiahs, while operational and maintenance cost is about 228.35 trillion rupiahs and a range of revenue from 668.67 trillion rupiahs to 1,104.22 trillion rupiahs.

The result of the multifunction project shows an increased IRR compared to a single function of a high-speed train. Despite the increased feasibility, further evaluation through public-private partnership shall be conducted to elaborate the optimum financing scheme for government and investors.

5. Public-private partnership

Public-private partnership scheme in the project comprises scenarios by considering cost sharing from initial cost, operational and maintenance cost, as well as revenue between government and business entity. The cost sharing is conducted among functions because each of them generates a different internal rate of return (IRR), thus affecting investors' interest to involve in the project. The IRR should meet the investors' expectation by reaching their minimum attractive rate of return (MARR) and above interest rate.

Each function simulates 36 main scenarios and generates 252 scenarios in total to propose a maximum financial scheme output. Overall, initial cost and operation and maintenance cost consist of three assumptions from 40, 50, and 60%. It considers a similar division of responsibility between government and business entity as well as when one party should be responsible to the other. Sharing in revenue attempts to accommodate private interest by giving a higher percentage from 50 to 80%.

Most of the initial cost component in this project such as the high-speed train, fiber optic, tourism, and TOD use a share 40% government and 60% business entity. It is because the national budget plan is limited while the need for infrastructure financing is enormous; thus, transferring the cost to the business entity is most preferred. In terms of operational and maintenance cost, equal responsibility in the high-speed train, fiber optic and tourism between government and business entity are selected to minimize monopoly by the business. When the government has shared in this phase, the ticket price will be adjusted properly to match user ability to pay and their willingness to pay. Conversely, operation and maintenance of solar cell is relatively small compared to other functions. Thus, government portion in the service has a limited effect on the national budget plan. Lastly, the cost of TOD in this phase is only for the parking area; therefore, private entity proposes to be responsible for the cost.

The division of revenue between two parties considers business perspective where the project should meet their expectation of income and level of risk. High-speed train and tourism have the most significant income compared to the other functions; thus, 80% of the revenue will be transferred to the business entity. Although fiber optic contributes lower income in total compared to the other functions, the internal rate of return is relatively high for about 32%. The simulation shows that 50% sharing for both parties is the most suitable by considering equality among functions and minimizing monopoly of the sector. As a result, the multifunction project of high-speed train using PPP scheme produces an internal rate of return for about 16.1% with a positive net present value (NPV). The value-added project arguably produces a significant impact on increasing the infrastructure feasibility and possibility for other similar project development.

6. Institutional scheme

The institutional scheme is generated from previous financial engineering and PPP scheme of Jakarta-Surabaya HST project development. The system will administer the responsibility between government, private investors, and other parties in the project. Firstly, the companies that involved in the project consist of several backgrounds and provide distinct role and capabilities according to the five functions from value engineering process. They collaborated with the government for an agreement and supported by other entities such as contractors, consultants, donors for the whole project's lifecycle. The framework can be seen in **Figure 8**.

Investors will support the initial cost of about 142 trillion rupiahs and 9 trillion rupiahs of operation and maintenance subjected to the financial scheme. The investors might consist of domestic or foreign companies by considering their experiences, capabilities, and other related factors. On the other hand, the consultant consists of Center for Sustainable Infrastructure Development (CSID) who generates the concept and other established foreign companies to support the project's feasibility.

For the contractors, high-speed train function will be managed by an international company in collaboration with railway state-owned enterprise (SOE) who has experience in running railroad business. The agreement shall govern technology and knowledge transfer from the foreign and domestic partner during the concession period. The scheme is expected to improve capacity and capability of the SOE in developing and managing rail, signaling, and station to rolling stock of high-speed train. Other functions such as fiber optic, transit-oriented development, solar cell,

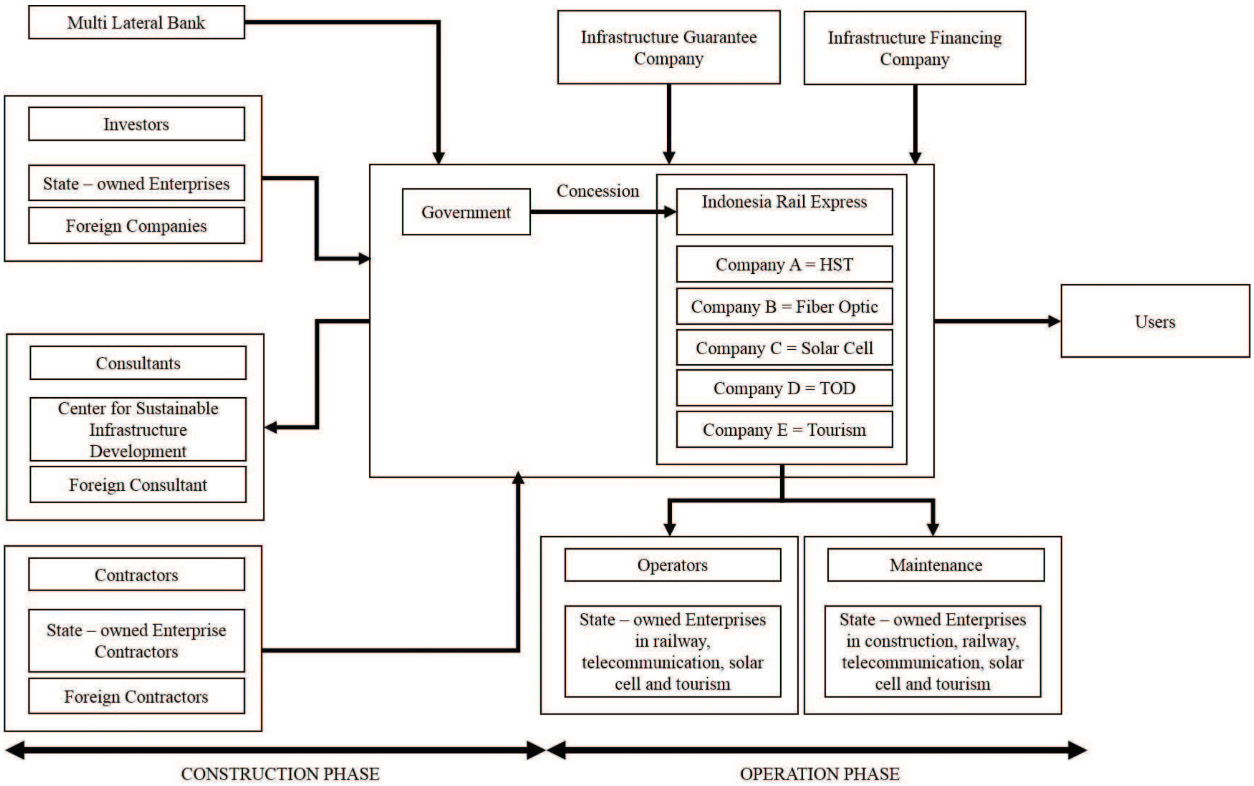

Figure 8. Institutional framework for HST project development in Indonesia.

and tourism will be selected based on their capability and innovative ways to generate revenues. The companies might be from domestic, foreign, or a partnership between both parties.

Operation and maintenance are for about 30 years. Operators are from the state-owned enterprise in collaboration with reputable international companies. Maintenance is also conducted in similar ways with the operation. In this phase, cost sharing during operation and maintenance within the joint venture will be divided equally between the government and business entity. Revenues generated from the services or product in the project will be shared—23.19% by the government and 78.81% for the business entity. The government through appointed institution collects revenues as part of the involvement in financing the initial stage and operation and maintenance stage. The scheme generates optimal revenues for business and government acquires income, which can be used to build other infrastructure or support local transportation through subsidy.

7. Conclusion and progress of the project

Value engineering implementation in the HST project development has transformed a single-function project from transporting people into a multifunction project. Additional functions that have been identified are transit-oriented development (TOD), fiber optic, tourism, and solar cell.

Added value from the innovative function enables the project to reach an expected value of feasibility through significant internal rate of return (IRR) and positive net present value

(NPV). Before value engineering method, the single-function project only reaches 5.20% of IRR. Meanwhile, the additional function has been successfully improving the IRR value into 12.30%. Furthermore, public-private partnership scheme elaborates the division of responsibility between government and business entity about financing the project. The result increases the IRR value to 16.1% Thus, a collaboration between value engineering and the public-private partnership is a package to improve project feasibility particularly railway development to reach its expected outcome from stakeholders' perspective.

Currently, high-speed train project in Indonesia is in the construction phase. However, the progress remains low below 5% in the past 2 years due to land acquisition, funding, and institutional scheme. The project needs 700 ha for land acquisition and currently achieved 54.5%. Land owned by the state-owned enterprise and government institution is relatively more accessible for acquisition due to robust communication and coordination among them. However, the private property is required further negotiation. The project has been receiving a loan from Chinese bank—about 13 trillion rupiahs or equal to US$ 1 billion. The funding attempt to support the consortium consists of Indonesia's and Chinese state-owned enterprises in accelerating project realization.

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