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# Strategies Encouraging Mode Shifting on Rail-Based Transportation: A Case Study in Jakarta

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***Abstract*— Public rail transport infrastructure has been developed to address urban issues in some major cities worldwide, including Jakarta, Indonesia. Despite its development, the rail transit ridership is not optimal yet, since traffic flows on the roads are still heavy and cause congestion. Therefore, the modal shift on rail transit in should be increased. The objective of this study is twofold; determining factors affecting the mode split on rail transit and exploring strategies to improve the modal shifting to rail-based transportation by taking into account the development of properties near the transit stations of Greater Jakarta's commuter line, including hotel, retail, office, and residential. Both quantitative and qualitative methods through questionnaire survey and benchmarking study were used to obtain these objectives. The survey results show that punctuality is the factor that affects the modal shifting to rail the most, followed by train comfort and shorter waiting time. Benchmarking studies were conducted to develop strategies for improving the train performance in terms of those factors, which include utilizing planning and management tool for train scheduling and rail infrastructure control, improving the air conditioning system on board trains, and increasing the information availability by installing real-time information monitors.**

***Keywords*— Public rail transport; ridership; modal shifting.**

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## I. INTRODUCTION

Cities worldwide are experiencing astounding growth caused by urbanization and industrialization over the past decades [1]. Although cities' development contributes to enabling higher economic growth [2], it is frequently accompanied by negative externalities, such as traffic congestion, pollution, and urban sprawl [3]–[6]. Various approaches were taken to address those urban issues, such as improving public services, providing affordable modes of transportation, and developing integrated urban infrastructure inclusive for all city inhabitants [6].

Jakarta, the capital city of Indonesia, is currently developing its urban infrastructure with an emphasis on rail transportation to decrease car dependency and improve traffic flows, such as the Light Rapid Transit (LRT) Jakarta. Furthermore, Transit-Oriented Development (TOD), a compact, mixed-use area organized around a transit point, was also developed to increase the ridership of public transport [7], [8].

Ridership is the number of persons who ride a mode of public transportation on a trip at a particular time. Transit ridership is affected by several factors, such as fares, route, service frequency, accessibility to the station, safety, private vehicle ownership levels, population density, land use, availability of parking space, and cost [9]. On the other hand, the passengers' choice of transportation modes depends on some considerations related to the characteristics of the trip, the land use, and the service [10], [11]. Consequently, the modal split on public transport should be improved to increase the public transport's ridership. Modal split is the process of separating one's travel based on the transportation mode. The purpose is to estimate road user decisions and the effects caused by the decisions taken [12].

Jabodetabek commuter trains, the commuter rail service in Greater Jakarta, carried 1.4 passengers per day [13]. The

Greater Jakarta LRT and Jakarta MRT services were estimated to mobilize 40,000 and 7,000 passengers, respectively. These figures are still relatively low compared to the ridership of LRT in neighboring countries such as Malaysia and Singapore. Malaysia's Kelana Jaya LRT provides service to more than 250,000 passengers daily [14], and Singapore LRT carries 150,000 passengers daily [15].

Transit ridership can be encouraged through the integrated public transportation network connecting Transjakarta Bus Rapid Transit (BRT), LRT, MRT, and Commuter Line, which is expected to increase passengers' ease and efficiency. Moreover, urban development with the TOD concept can also promote transit ridership [16]. However, other strategic changes are also needed to optimize transit conditions, thus improving the modal split on rail transit. This paper aims to determine the dominant factors affecting the transportation mode shifting to rail transit by considering passengers traveling from property development, including hotel, retail, office, and residential functions. Furthermore, the strategies to boost mode shifting to rail-based transportation were also determined.

Previous studies have been conducted exploring strategies to improve modal split on rail transit. For example, a study investigating the European transport system argued that modal shifts could be increased by improving service quality through the adoption of technology for operationality and an integrated supply chain approach for maintenance [17]. Another study concluded that some aspects of the public transport systems must be improved to increase public transport ridership, particularly in Braunschweig, Germany, and Tampere, Finland [18]. However, the ridership in both cities has grown over the last 20 years, indicating that these systems have performed well. On the other hand, the studies on strategies to improve rail-based transport system modal split in developing countries are still very limited. This paper presents Jabodebek LRT as the case study where the dominant factors affecting modal split on rail transit will be examined, and the improvement strategies will be determined. The results of this study are expected to provide recommendations for policymakers in urban rail transport in developing countries.

## II. Materials and Methods

This study identified dominant factors of the modal shift in rail transit. This study applied a quantitative method to describe situations, examine causes, and establish relationships among variables [19]. A questionnaire survey was distributed to collect data in this study. The filling-in process of the questionnaire survey began with a question regarding whether the location of the respondent's residence or working place is within a radius of 0-1,000 meters from the transit stop. Respondents meeting the requirement were then invited to complete the questionnaire survey, which consists of questions on the transport mode selection and the type of property where they reside or work so that the impact of the development of hotel, retails, office, and residential properties on the transportation mode selection can be determined.

A total of 271 respondents from all property types participated in the survey. However, due to invalid answers and incomplete questionnaires, only 210 respondents were deemed valid, with the respondent composition of 49, 111, 34, and 16 respondents from hotel, retail, office, and residential property, respectively. These numbers indicate that the analyzed data were not biased because the rate of return is more than 30-40% [20]. The transportation modes discussed in this questionnaire survey are train, bus, private vehicle, ride-hailing, and walking. The number of respondents with each transport mode can be seen in Table 1. The respondents were asked to state the factors that enable the mode shifting to rail-based transportation, summarized in Table 2.

TABLE I
TRANSPORT MODE USED BY THE RESPONDENTS

| Transport Mode | Respondents in Each Property Function (%) | | | |
|---|---|---|---|---|
| | Hotel | Retail | Office | Residential |
| Train | 5.71% | 5.71% | 3.33% | 7.62% |
| Bus | 1.90% | 1.90% | 1.43% | 1.90% |
| Private Vehicle | 14.29% | 34.29% | 2.86% | 6.67% |
| Ride-Hailing | 1.43% | 8.10% | 0% | 0% |
| Walking | 0% | 2.86% | 0% | 0% |

TABLE II
FACTORS AFFECTING MODE SHIFTING TO RAIL-BASED TRANSPORTATION

| | Factor Variables |
|---|---|
| X1 | Punctuality |
| X2 | Development of train system services |
| X3 | Cooperation with external parties |
| X4 | Land use development |
| X5 | Affordable travel expense |
| X6 | Comfort |
| X7 | Connectivity of transit points |
| X8 | Distance to the transit station |
| X9 | Waiting time |
| X10 | Travel time |
| X11 | Integrated payment system |
| X12 | Provision of supporting facilities |
| X13 | Ease of accessibility to destinations |

The data processing process used descriptive statistics to determine the dominant factors, including comparative and correlational methods [21]. The statistical method used was the descriptive frequency analysis, a primary descriptive statistic with discrete variables. This method includes absolute frequencies (raw quantities) for each category of discrete variables, relative frequencies (proportions or percentages of the total number of observations), and cumulative frequencies for successive types of ordinal variables [22]. Descriptive analysis is arguably the most straightforward statistical analysis to do and interpret. It provides a helpful strategy for summarizing data and providing sample descriptions but cannot provide information for causal analysis [23]. The choice of answers in the questionnaire illustrates the customer expectation of the essential factors for maintaining and increasing the use of rail-based transportation.

The second objective of this study, determining strategic solutions proposed for the continuousness of the dominant factors, aimed to avoid the failure of development with the TOD concept. Benchmarking study, a continual process that measures products, services, or methods, and compares them against the others in a better state of an aspect, was performed to obtain this objective [24].

Archive analysis conducted to literature, collected from existing journals, scientific articles, and related publications on the improvement strategies of the rail transport system was done to gather benchmarking data. Some of the international benchmarks that have succeeded in improving modal splits on rail transit are summarized in Table 3. Figure 1 illustrates the workflow of the research.

TABLE III
BENCHMARKS OBTAINED FROM ARCHIVE ANALYSIS

| Aspect | Strategy | Reference |
|---|---|---|
| Time (X1, X9, X10) | Digital technology adoption in the operation of train services to shorten travel time and ensure punctuality (US, China, UK, Switzerland) | [25]–[28] |
| Development of train system services (X2) | Expansion of urban rail transit network (Seoul, Moscow, Hong Kong, China) | [29] [30] |
| | Development of new rail line (Poland, Slovakia, Australia) | [31]–[33] |
| Cooperation with external parties (X3) | Partnered with an online ride-hailing platform in the form of pricing strategies, thus promoting rail transit (USA, Switzerland) | [34]–[36] |
| Land use development (X4) | Development of residential, commercial, and employment areas in the proximity of the public transit system (Tokyo, Bangkok, Hong Kong) | [37]–[39] |
| Comfort (X6) | Availability of real-time travel information regarding destination, travel delay, etc. | [40] |
| | Availability of electronic payment system integrated with the ticketing website and the smartphone application (China) | [41] |
| | Provision of supporting facilities regarding safety at the station that includes a protected walkway, warning sign, etc | [42] |
| Efficiency (X5, X11, X12) | Reduction of ticket fare in travel transfers between a maximum of 15 minutes and a maximum of 30 minutes (New Zealand) | [43] |
| | Reducing transfer waiting time through the optimization of train scheduling (China) | [44], [45] |
| | Reducing passengers' travel time through the optimal train speed control settings | [46] |
| Accessibility (X7, X8, X13) | Providing adequate public transit connection to high-speed rail stations (China, US) | [47], [48] |
| | Expansion of access services to the railway station (Netherlands) | [49] |
| | Further development direction to densification and land use diversity to improve distance to the destination from the transit station (Canada) | [50] |

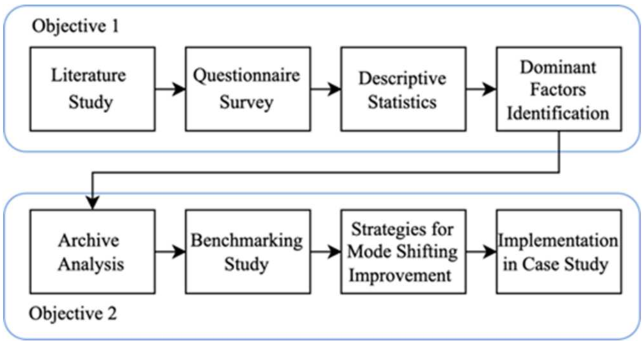


Fig. 1 Research workflow

## III. RESULTS AND DISCUSSION

### A. *Factors Affecting the Mode Shifting to Rail Transit*

The results of the questionnaire survey analyzed using the descriptive statistic technique will be discussed in terms of property functions, which include hotel, retail, office, and residential, categorized using the transportation mode chosen by the respondents, such as train, bus, private vehicle, ride-hailing, and walking.

In the hotel property function, 41.67% of respondents in the train category considered punctuality as the most dominant factor, followed by shorter waiting times, according to 33.33% of respondents. In the bus category, 50% of the respondents considered the development of train system services as the dominant factor. The respondents in the private vehicle category considered punctuality and train system services improvement with a percentage of 46.67% and 30%, respectively. However, 66,7% of the respondents in the ride-hailing category are considered as dominant. The survey result from the respondents in the hotel property showed that punctuality, comfort, and development of train system services are the most prevalent factors in choosing rail transit as a transportation mode (see Figure 2).

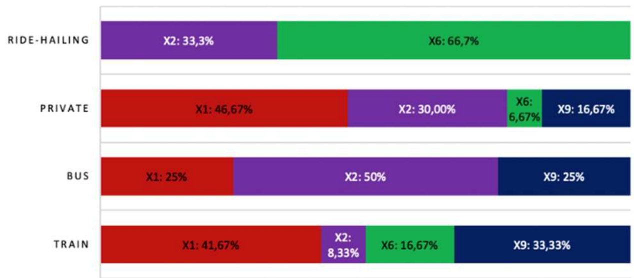


Fig. 2 Dominant Factors for Mode Shifting (Hotel Property)

In the retail property function, particularly in the train category, 66.67% of respondents considered punctuality the most dominant factor, followed by the rest 33.33% of respondents who viewed shorter waiting times. Respondents in the bus category took punctuality, development of train system services, comfort, and waiting time as the dominant factors. Furthermore, comfort and punctuality were considered dominant by 36.11% and 33.33% of respondents in the private vehicle category. While 52.9% of respondents in a ride-hailing category considered punctuality dominant, 50% of respondents in the walking category selected waiting time as a dominant factor in improving transit modal splits on rail transit. Overall, punctuality and comfort were considered dominant by the respondents in retail property. The detailed result of the survey in retail can be seen in Figure 3.


Fig. 3 Dominant Factors for Mode Shifting (Retail Property)

In the office property function, respondents in the train category considered punctuality the most dominant factor, followed by the development of train system services and cooperation with external parties, with a share of 42.86%, 28.57%, and 28.57%, respectively. All respondents in the bus category considered punctuality connectivity of transit points as the dominant factor. Meanwhile, 50% of respondents in the private vehicle category thought of the ease of accessibility to destinations, followed by the connectivity of transit points and provision of supporting facilities, with a share of 16.67%. From the survey results shown in Figure 4, punctuality and provision of supporting facilities are factors according to respondents in office property.


Fig. 4 Dominant Factors for Mode Shifting (Office Property)

In the residential property function, respondents in the train category considered punctuality and the development of train system services as the dominant factors, with 62.5% and 25%, respectively. Meanwhile, comfort was considered dominant by 75% of respondents in the bus category. In the private vehicle category, the dominant factors are the ease of accessibility to destinations, distance to the transit station, and travel time, with 35.7%, 28.6%, and 14.3%, respectively. The detailed survey result on residential property can be seen in Figure 5.

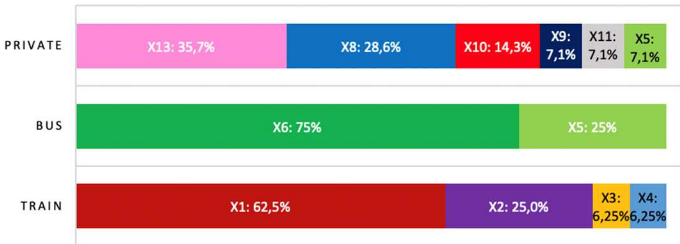


Fig. 5 Dominant Factors for Mode Shifting (Residential Property)

Based on these results, it can be concluded that generally, the most dominant factors affecting the passengers' decision to shift the transportation mode to rail-based transport related to the performance of train services affecting the passenger's convenience, such as punctuality (X1), comfort (X6), and waiting for time (X9), each with a share of respondents of 32.38%, 25.71%, and 16.19%, respectively. Table 4 below summarizes the factors and the number in percentage.

TABLE IV
THE SHARE OF FACTORS FROM ALL PROPERTY FUNCTIONS

| Variable | Dominant Factors | Percentage |
|---|---|---|
| X1 | Punctuality | 32.38% |
| X2 | Development of train system services | 12.86% |
| X3 | Cooperation with external parties | 1.43% |
| X4 | Land use development | 0.48% |
| X5 | Affordable travel expense | 0.95% |
| X6 | Comfort | 25.71% |
| X7 | Connectivity of transit points | 1.43% |
| X8 | Distance to the transit station | 2.38% |
| X9 | Waiting time | 16.19% |
| X10 | Travel time | 1.43% |
| X11 | Integrated payment system | 0.48% |
| X12 | Provision of supporting facilities | 0.48% |
| X13 | Ease of accessibility to destinations | 3.81% |

### *B. Strategies for Improving Modal Splits on Rail Transit*

#### *1) Punctuality*

Punctuality is argued to be one of the most critical indicators in rail transport that affects a person's decision in transportation modal choice [51]. Punctuality is termed as the percentage of trains arriving on time at the transit stops. The punctuality level is the percentage of punctual trains, calculated by dividing the total punctual trains by the whole trains. According to [52], the punctuality of the train system is generally influenced by the number of passengers and occupancy ratio, capacity utilization, regularity, speed restrictions, construction works, departure and arrival punctuality, and operational priority rules.

On the other hand, the delay is a measurement of the length of the train's late from the schedule presented in time units [53]. In the case of Greater Jakarta's commuter line, the delays are caused by the limitation on the speed of the train, synchronization of operating patterns, the performance of signaling control and scheduling system, as well as the policies on level crossings [54].

The performance of scheduling and maximum speed to ensure train punctuality can be optimized by utilizing advanced computer programs [27], [28]. Switzerland's railway system has the highest Railway Performance Index (RPI) in Europe for scheduling and maximum speed [55]. The railway operating companies in Switzerland, such as Swiss Federal Railways and Rhaetian Railways, employ a planning and simulation tool developed at the Swiss Federal Institute of Technology as a solution for practical economics and a tool for dealing with complex rail technology problems called OpenTrack.

All modes of rail systems can use OpenTrack to perform a number of railway system works, such as determining requirements for rail network infrastructure, analyzing the capacity of train lines and stations, calculating the minimum headway, examining rolling stocks, analyzing the quality of the schedule to plan train schedules, evaluating and designing various signaling systems, analyzing the impact of system failures, calculating the power and energy consumption of rail services; simulation the power supply system of the train [56].

Heterogeneous train operation is one of the train operating patterns where commuter and intercity trains share the same railway tracks [57]. This operation can cause delays caused by other trains. The time performance of the Jabodebek LRT can be improved by formulating regulations regarding the train operating lines, where the speed of the commuter line is increased by reducing running time supplements or by using faster rolling stock and overtaking by paying attention to differences in running time [58], [59]. Furthermore, the cross capacitance of the train system with a high passenger capacity must consider the ever-increasing demand by creating a forecast model that focuses on the Origin/Destination (OD) traffic flow. The utilization of OD matrices has been proved to optimize train scheduling and train routes [60].

Moreover, to improve the performance of the train signaling control system, the government has made regulations regarding the operation procedures for the security measures of level crossings. However, without proper supporting infrastructure, this strategy is not yet effective. Therefore, another solution to overcome level crossings should be taken, such as developing underground tunnels and elevated railroads adapted to city conditions and transportation characteristics, including the type of transit systems and the corridors served.

*2) Comfort*

Passengers' travel comfort is associated with the departure time and degree of accessibility to trains [61]. Train comfort is defined by multiple factors such as vibration, noise, temperature, humidity, smell, visual stimulation, and design layout [62]. According to the respondents' comments in the questionnaire survey, train comfort includes the train's air conditioning system and information.

To improve the thermal comfort of a passenger train, the Heating, ventilation, and air conditioning (HVAC) system should be upgraded to a healthier and energy-efficient system by considering the influencing factors on the thermal loads compensated by the system (see Figure 6). Improving the HVAC system of the existing trains with a greener advanced technology will not only improve the thermal comfort but also minimize the impact of the train on the environment.

Furthermore, the availability of information is an essential service provided by the train operating company that influences passengers' satisfaction. Therefore, accurate real-time information should be easily accessed by passengers and displayed in various ways, such as in-vehicle, at-stop, mobile, and social media [63].

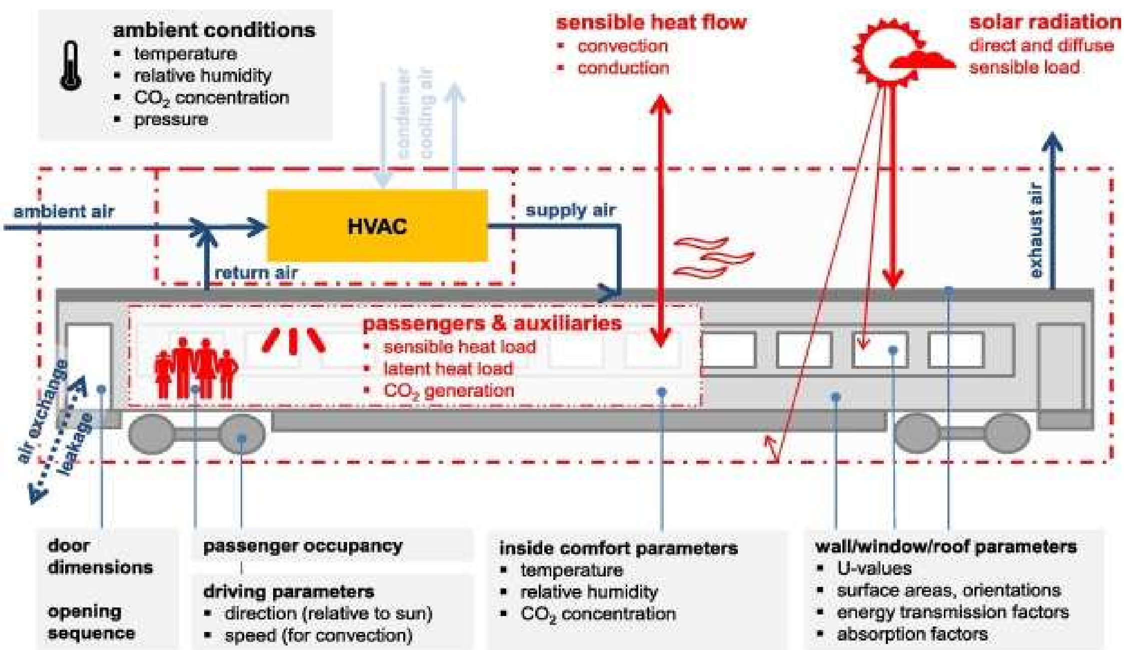


Fig. 6 The Scheme of a Passenger Train's HVAC System with the Associated Loads and Influencing Factors [64]

The reliable information regarding the schedule can help reduce the transit waiting time, along with basic amenities, such as shelters and benches [65], [66]. Operating company in the Jabodebek LRT, as the case study of this study, should consider adding these facilities to improve the modal shift to rail transit significantly.

## *C. Determining Strategy for Jakarta's Commuter Line*

The punctuality of the train schedule in MRT Jakarta can be improved by utilizing reliable software tools to simulate and plan the operation of the heterogeneous train. Figure 7 illustrates the scheme of the Swiss OpenTrack software.

With an estimated ambient air temperature in Indonesia of 35°C, the standard temperature in the training room is 23°C, humidity is 65%, and the velocity of the air falling above the passenger's head does not exceed 0.3 m/s [67]. PT Commuter Line Indonesia, as the company that manages the commuter train services in Indonesia, should regularly ensure that the air conditioning system meets these standards. Furthermore, advanced technology should also be adopted, such as the sensors that help maintain the in-vehicle thermal comfort and enable the system to perform correctly.

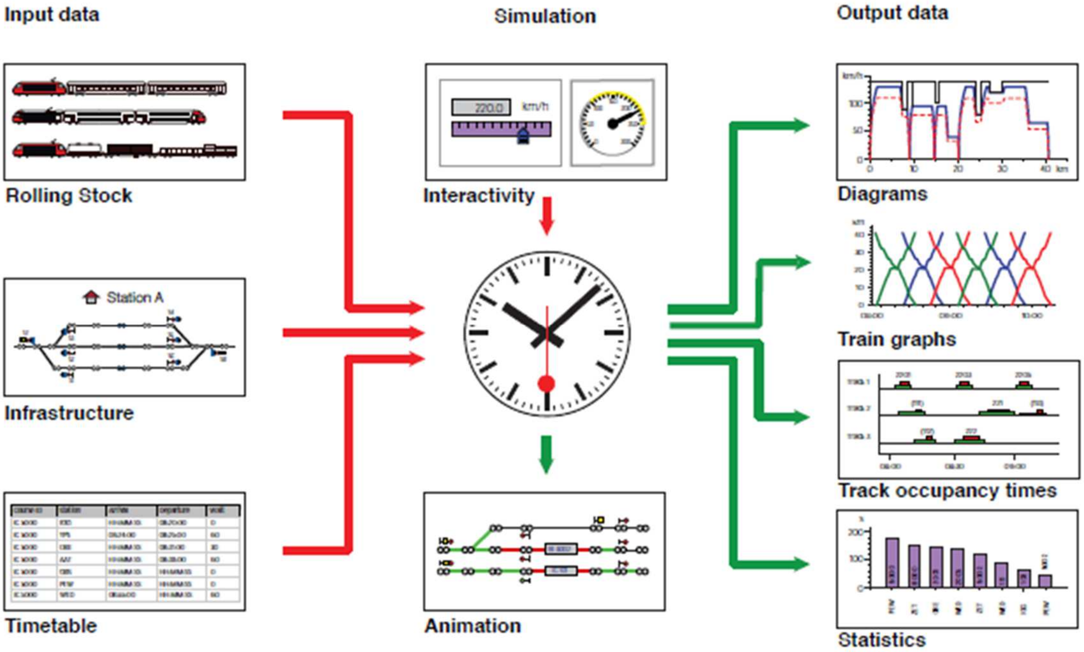


Fig. 7 Data flow in OpenTrack Planning Software [68]

Moreover, devices displaying real-time information regarding the schedule, travel time, transit waiting time, and public announcements can be installed on board and at the transit stations, such as the devices showing information in the newly operated LRT Jakarta, both onboard (see Figure 8) and at the stations (see Figure 9).


Fig. 8 Monitor onboard LRT Jakarta [69]

Fig. 9 Monitor at the LRT Jakarta station [70]

## IV. Conclusion

Though urban rail infrastructure has been provided, the ridership is still relatively slow, as shown by the road traffic issues caused by private vehicles. Some strategies must be taken to encourage the shift from private vehicles to rail-based transportation modes. This study investigates the factors that affect the mode shifting to rail transit by conducting a questionnaire survey, which shows that punctuality, train comfort, and shorter waiting time are the dominant factors. Strategies recommended for improving the modal shift include the usage of the train's schedule management tool, air conditioning, and the availability of accurate information.

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