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Transport Planning for Improving Mobility into Industrial Area : a case study in East Java-Indonesia

TESINA DI LAUREA MAGISTRALE IN
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Abstract

Mobility is a hot topic today, since the development of technology and the urban planning, mobility become main concern. Recently public transport access industrial area is rarely discussed topic. Meanwhile By looking at the current level of mobility in East Java-Indonesia either not to and to the industrial area, improving mobility around industrial area become significant topic, it has been discussed by local professional, researcher, and decision maker. Some solutions are applied like expanding existing road, build alternative route, and new scenario of road flow etc. cannot solve the congestion issue. Based on the Indonesia's Police recorded the road accident in 2019 reaches 11,502 cases in East Java. However, the absence of good public transport is the main reason of increasing volume of private vehicle, leads to congestion as the main issue of mobility and huge amounts of pollutants emitted. The solution to increase mobility is to improve or build new public transport. The purpose of following research is to solve mobility problem based on some scenarios, either by improving current public transport or build new public transport line. The study case is the industrial area in East Java. The analysis carried out by 4 phase method for demand analysis and multicriteria analysis for each alternative public transport scenarios. As result the best option of new public transport with the best performance based on multicriteria analysis can be obtained, and so can be considered as first step for transport planning into the industrial area in east java for specific and public transport for entire East Java in general.

Key-words Mobility, Public transport, Industrial area, 4 phase method, well to wheel.

Abstract in lingua italiana

La mobilità è oggi un tema caldo, dal momento che lo sviluppo della tecnologia e la pianificazione urbana, la mobilità diventa la preoccupazione principale. Recentemente l'accesso ai trasporti pubblici nell'area industriale è raramente discusso. Nel frattempo, osservando l'attuale livello di mobilità in East Java-Indonesia o non verso e verso l'area industriale, il miglioramento della mobilità intorno all'area industriale è diventato un argomento significativo, è stato discusso da professionisti, ricercatori e decisori locali. Alcune soluzioni applicate come l'espansione della strada esistente, la costruzione di percorsi alternativi e un nuovo scenario di flusso stradale ecc. Non possono risolvere il problema della congestione. Secondo la polizia indonesiana, l'incidente stradale nel 2019 ha raggiunto 11.502 casi a East Java. Tuttavia, l'assenza di un buon trasporto pubblico è la ragione principale dell'aumento del volume dei veicoli privati, porta alla congestione come il problema principale della mobilità e alle enormi quantità di inquinanti emessi. La soluzione per aumentare la mobilità è migliorare o costruire nuovi trasporti pubblici. Lo scopo della seguente ricerca è quello di risolvere il problema della mobilità sulla base di alcuni scenari, migliorando il trasporto pubblico attuale o costruendo una nuova linea di trasporto pubblico. Il caso di studio è l'area industriale di East Java. L'analisi effettuata dal metodo a 4 fasi per l'analisi della domanda e l'analisi multicriterio per ogni scenario alternativo di trasporto pubblico. Di conseguenza, è possibile ottenere la migliore opzione di nuovo trasporto pubblico con le migliori prestazioni sulla base dell'analisi multicriterio, e quindi può essere considerata come il primo passo per la pianificazione del trasporto nell'area industriale di East Java per il trasporto pubblico e specifico per l'intera East Java in generale.

Parole chiave: Mobilità, trasporto pubblico, zona industriale, metodo 4 fasi, pozzo a ruota.

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1 Introduction

1.1 Introduction

Mobility is a hot topic today, since the development of technology and the urban planning, mobility become main concern. Rapid economic growth in industrial area, leads to enormous increase of mobility, and the public transport become very significant. Poor performance of public transport, influence the private vehicles ownership, highly number of private vehicles leads to bad traffic condition. Traffic congestion of route access industrial area in the developing country almost happens every day especially during peak hour, while the safety issue regarding the majority of road user is motorcyclist mixed up with heavy vehicle on the road.

As archipelagic country, Indonesia has very good access to the ocean, because of this, it's possible to have more than one industrial area, since it gives more gate for export-import activities. The study area in this thesis is East Java (Jawa Timur), with the area around 47,800 km2[1] and for comparison Lombardi has area around 23,884 km2[2], and in the east java there are 10 industrial area and focusing into 6 industrial areas which are close to each other.

East Java has second biggest industrial area in Indonesia, and the road access to the industrial area suffering severe traffic congestion, due to rapid urbanization after industrial area built in 1985. In the peak hour there is enormous mobility into industrial area, the peak hour pattern follows the factory's shift schedule, it happens in 06:00 am to 08:00 am and from 04:00 pm to 07:00 pm, almost every day at some section road accessing industrial area. Huge volume of vehicle accessing the road during peak hours affects social and economic aspect, but also rapidly reduce the health quality by emitting huge amounts of pollutants. In other hand the safety issue, which is most of the road user are motorcyclist, in fact motorcyclist face higher risk than other road user, this aligns with highly accident rate of motorcycle.

Recently public transport access industrial area is rarely discussed topic. Meanwhile By looking at the current level of mobility in East Java-Indonesia either not to and to the industrial area, improving mobility around industrial area become significant topic, it has been discussed by local professional, researcher, and decision maker. Some solutions are applied like expanding existing road, build alternative route, and new scenario of road flow etc. cannot solve the congestion issue. Based on the Indonesia's Police recorded the road accident in 2019 reaches 11,502 cases in East Java. However, the absence of good public transport is the main reason of increasing volume of private vehicle, leads to congestion as the main issue of mobility and huge amounts of pollutants emitted. The solution to increase mobility is to improve or build new public transport.

The purpose of following research is to solve mobility problem based on some scenarios, either by improving current public transport or build new public transport line. The study case will be industrial area in east java and considers other industrial area public transport management.

1.2 Problem Definition and Research Hypothesis

1.2.1 A gaze in Indonesia

Indonesia is a country in Southeast Asia and Oceania between the Indian and pacific oceans. It consists of over 17,000 islands, including Sumatra, Sulawesi, Java, and parts of Borneo and New Guinea. Indonesia is the world's largest island country and the 14th largest country by area, at 1,904,569 km2, with population around 270 million, Indonesia as the world's fourth-most populous country and the most populous Muslim-majority country. Java, the world's most populous Island, is home to more than half of the country's population.

High population concentrated in Java Island, the center of government, economic, education attract migration to Java Island. Massive improvement has been done by government by building new highway, toll, and new public transport, to accommodate the mobility in Java Island. However, the improvement of new public transport does not finish yet, while in East Java still lack of reliable public transport, leads to highly number of private vehicle ownership, causing congestion. The congestion mostly happens in the road section accessing industrial area, since the number of employees is much higher compared to other job sectors.

Figure 1.1 The Congestion in Jakarta, Indonesia's Capital City

(Source: https://www.wowshack.com/idul-fitri-the-best-time-of-year-to-be-in-jakarta/contoh-kemacetan-di-indonesia-terutama-jakarta/)

Industrialization has historically led to urbanization by creating economic growth and job opportunities that draw people to it, the change of land use also happens. Before industrialization, the most common profession is farmer, but after industrialization, the shifting profession happen, and land use transformation to residence area.

1.2.2 Problem Definition

Industrialization has historically led to urbanization by creating economic growth and job opportunities that draw people to cities. Urbanization typically begins when a factory or multiple factories are established within a region, thus creating a high demand for factory labor. Urbanization closing to industrial area leads to increasing density of resident on surrounding area, which lead to high mobility during peak hours. The different polices regarding private vehicle ownership which low of ownership cost compared to European countries and very affordable loan system, affecting on tendency of people have private vehicle than using public transport.

Figure 1.2 The location of industrial area in East Java province in Indonesia

East Java has the second largest industrial area in Indonesia, the industrial area distributed as Figure 1.2, the distance between industrial area A and B is 106 km accessed by highway and toll. Industrial locations are complex in nature, many factors involved for example, raw material availability, land use, water availability, power, accessibility, transport, and many factors. For case industrial area in east java, the export-import gate is the significant aspect to be considered, the international harbor is located 24 km away from Surabaya Industrial area, this fact leads to tendency to have industrial area close to each other.

a. Traffic Congestion

The poor condition of public transport, make the employees use private vehicle as main transportation leads to congestion due to high number road user, especially during peak hour. With characteristic of socio economic, demography and geographical, Indonesian has different preference of private transport comparing with the European country. Motorcycle is the most favorite private vehicle, and the road user dominated by motorcycle user.

The population mobility influenced by many factors, one of the main factors is the profession. The profession influences the destination of mobility, the number of mobility and the specific time for mobility to be happen. The mobility based on profession easily to be seen the pattern, since the workplace is the main attractiveness. The attractiveness level between some category workplace is different, it depends on how many employees on specific workplace, the industrial area is the workplace that has highest number of employees than other categories (workplace for service, government etc.), it's leads to massive mobility to/from industrial area during peak hour. Furthermore, the industrial area not only influence the mobility, but it also influences the land use nearby, the land-use transformation to resident area since the industrial area attract the immigration.

High number of employees coming from specific area leads to high number road user, and causing congestion, the pattern of mobility can be seen by look industrial area as attractiveness point, high mobility accessing the industrial area, by private vehicle happen in the peak hour. The living cost different between urban area and sub urban area, make the sub urban area become high density area, while the connecting line (Main Road) doesn't have good performance.

b. Safety

Indonesia's geographical and demographical condition which is totally different with European countries, affecting on different behavior and preference on the type of private vehicle. Without winter season, narrower road, and the variation of road condition, motorcycle become favorite choice. The others factor of motorcycle domination are the compactness and by economic point of view, operating and capital cost was much lower than car. In generals based on BPS 2019 data, the motorcycle ownership in Indonesia can be said as every two people have 1 motorcycle.

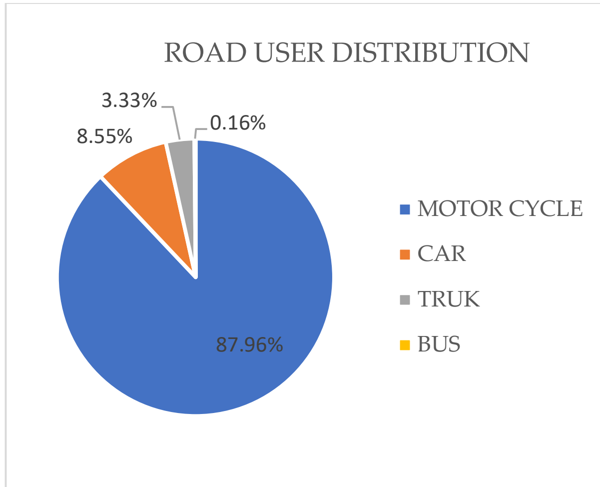


Figure 1.3 Distribution of road user in East Java Province

(Source: BPS 2019)

Based on Indonesia Statistical Organization data, in 2019s the total number of motorized vehicles is 136,32 million, with 87.96% is motorcycle, while 8.55% is car, and the rest are truck, bus and other public transport. Motorcycle faces more risk on the road, since the driver is less protected, the domination of motorcycle unit number, followed by the high of accident rate.

Figure…. The road user in Jakarta capital city of Indonesia

(Source: Liputan6.com)

The accident number data is obtained from Police Department, recorded at the end of 2018, based on the data, we can say that for every one hour three people die because traffic accident, and the cases is dominated by motorcycle users. The actual accident number is higher than recorded data, since the recorded accident is the only accident which discovered by police, while undiscovered accident is not recorded.

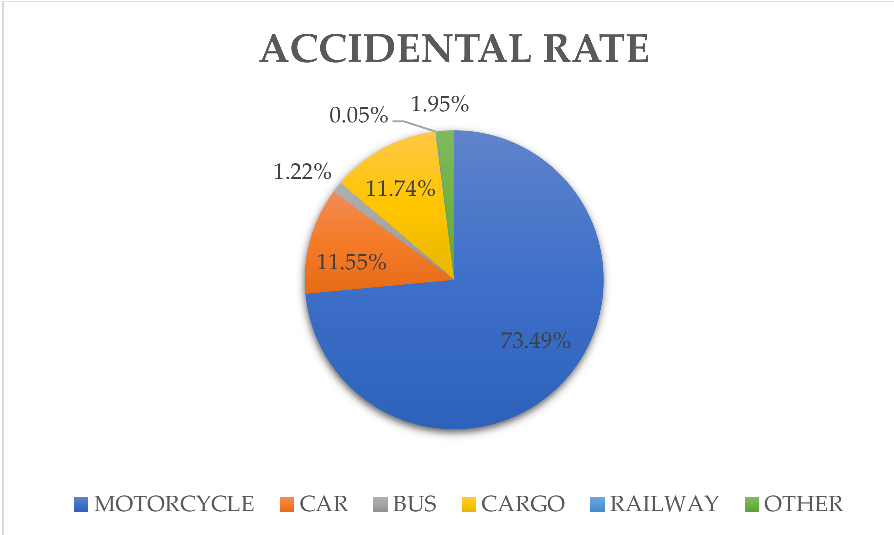


Figure 1.4 The distribution of accident rate for each transport mode
(Source: police department 2018)

The motorcycle accident dominates the total number of road accidents, with the percentage 73.49%, and followed by cargo, car etc. Focusing on the motorcycle accident, mostly the victims are in productive age (15 – 45 year). Indonesia police department records that the accident in 2019 dominated by motor cycle, The reason of motorcycle accident mostly because collision while overtaking, and then followed by single accident, mostly caused by human error and technical issue, mostly happens in the bad condition road, for example dirty road, wet road, even broken road etc., bad weather condition (during heavy rain), correspondingly motorcycle accident with big vehicle also frequently happens, since the motorcycle mixed with the others big vehicle such as truck and bus which has more blind spot, even with the complete protection gear, the motorcycle users face very high risk on the road.

Figure 1.5 The accident illustration involving big vehicle and motorcycle

(Source: http://tangerangnews.com/properti/read/15459/Ibu-Muda-Terlindas-Truk-di-Tangerang)

1.2.3 Research Hypothesis

a. Type of mobility to be considered

Improving the mobility to/from industrial area is the main objective of this research. The mobility generated by industrial area employees is the only one to be considered, the study area is high density area, and the population consisted by varied professions, the mobility is strongly influenced by the profession, so based on the ratio of profession, the data related with the type of mobility can be obtained. which are people work in service, government, farmer, and industry, beside worker there are also student resides on this area. The only mobility to be considered is mobility of resident which work in Surabaya Industrial area.

2 State of the Art

2.1 Research Methodology

Evaluation of most suitable public transport to accommodate the mobility into industrial area based on the sustainability transportation indicator. Through the recognition of available data and published materials, qualitative and quantitative information is used to analyze the most suitable public transport. Review the concept of transport planning as literature and some research regarding similar case. The methodology of research started with determine the objectives followed by specify goals and target until review the impact of most suitable scenario.

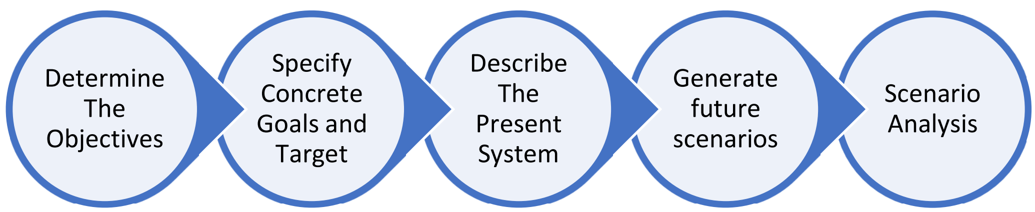


Figure 2.1 The research methodology

a. Determine the object

The purpose of this research is to analyze the most feasible solution to accommodate the high mobility to Industrial area, from area that has high number of labors residence.

b. Specify the goals and the target

What specific qualitative goals shall be expressed in quantitative targets to provide measurable result.

c. Describe the present Condition

Analyze the current condition related with the demographical condition, public transport performance, and the porblem related with the mobility nearby industrial area.

d. Generate future scenarios

Generate future scenarios based on the public transport alternative option, the scenario consider the current performance of rolling stock and the infrastructure.

e. Scenario Analysis

The scenarios analysis based on the multicriterian analysis, consider some point of view after intervention of new public transport, which area the operator, environment, safety, and private vehicle users.

2.2 Research Reference

The Thesis about a transport design strategy in response to the great East Japan Earthquake considering the trend of shrinking cities and the aging society, is performed at the Delft University of Technology as part of the Delft Deltas, Infrastructures & Mobility Initiative (DIMI). work on integrated solutions for urgent societal issues regarding vital infrastructural facilities for flood risk management and smart mobility. A work of what this thesis is contributing to in the field of smart mobility. The aim of this research is to recommend designs for regional transport systems which is capable to adjust towards the trends of an aging society and its shrinking cities. In the end, the overall goal is to guarantee the mobility of all age and population groups, especially the elderly, and to support the regions thrive within an uncertain future due to economic, social, and environmental shifts. Result is a comprehensive study about balanced transportation including a new methodology to support back casting in the field of transport design.

Related to distance and purpose, some transport modes are more suitable than others and a couple of possibilities exist to combine different modes with each other to combine their advantages. He usage of combined transport modes can therefore be seen as the result of an adequate application of them, assuming and requiring that nodes and hubs for transfers offer an efficient and lessen service. However, the transport development in Miyagi shows an increased usage of private motorization over the last decades. Resulting in a rather automobile oriented transport system which further supported the regions urban sprawl.

According to the Back casting approach two kind of scenario can be distinguished. A projective and a prospective scenario. Both were performed in a qualitative approach. Temporal scope is the year 2045 with mid-point of the year 2035. Starting point in time is the available data from 2015. The time horizon is chosen to be-long term to derive a sustainable transport system for decades and since changing on build environment within transport and land use usually is slow.

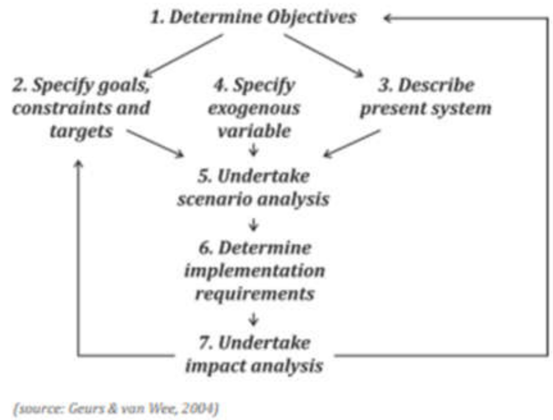


Figure 2.2 The Workflow

The back casting approach provides a general frame for any research in the field of transportation. In combination with the DTL-circle, this approach is capable to directly evaluate the impact of a measurement towards land use, demand, and transportation. Back casting in combination with the DTL-circle therefor is a sufficient tool for any other case study in the world. Mobility for everyone – not just the elderly – is not a question related to transport technology – It is a question to spatial arrangement, design quality and the linkage of available modes. It is not just a matter of transport engineering or related to the prospects of automated driving. Mobility is the result of modern skills of structuring space and the distribution of activities with the aim to bundle transport demands. Both with the aim to maximize urban and transport quality by minimizing energy consumption per capita. Special requirements for improvement are seen in the functionality and appearance of streets and transport hubs and their degree in comfortable transfers. With this in mind: A synergy between transport and urban planning which aims for a reduction in car dependency will automatically lead to a natural development of active and car independent elderly in a compact urban environment. 'Compact cities' is a concept for urban the environment which should stronger be included in traffic and transport planning. At the same time urban planning can include the knowledge about modal system characteristic of given (and potential) transport modes to provide better designs and concepts.

The following conclusions are drawn from this research. The conclusions are presented in relation to the Research questions as introduced before: How to design a regional transport system, which enhances the mobility of the elderly and can support regions thrive in the face of uncertain future economic, social, and environmental shifts? Mobility everyone – not just the elderly – is not a question related to transport technology – It is a question to spatial arrangement, design quality and the linkage of available modes. It is not just a matter of transport engineering or related to the prospects of automated driving. Mobility is the result of modern skills of structuring space and the distribution of activities with the aim to bundle transport demands. Both with the aim to maximize urban and transport quality by minimizing energy consumption per capita. Special requirements for improvement are seen in the functionality and appearance of streets and transport hubs and their degree in comfortable transfers. With this in mind: A synergy between transport and urban planning which aims for a reduction in car dependency will automatically lead to a natural development of active and car independent elderly in a compact urban environment. 'Compact cities' is a concept for urban the environment which should stronger be included in sustainable traffic and transport planning. At the same time urban planning can include the knowledge about modal system characteristic of given (and potential) transport modes to provide better designs and concepts.

2.3 My Proposal

The idea of this research is to provide the mobility of industrial employees, since industrial sector has huge number of employees compare to other sectors. The massive mobility happens in the peak hour. The current public transport performance cannot satisfy the demand during peak hour for the area nearby industrial area, so new public transport nearby industrial area is necessary, to provide better mobility, improve the environment, and safety conditions of area around industrial area. There are some scenarios alternatives regarding the new public transport, the public transport infrastructure current condition in the study area is significant point to be considered in the improvement level of public transport. The best scenarios chosen through multi criteria analysis, by considering the environmental, safety, operator, and user benefit.

Considering far future scenarios, the new public transport no only accommodate the industrial employees, but also other type mobility, the extension of line and connecting with multi-mode transportation is the future goal, so the equality for public transport accessibility can be achieved.

3 Methodology Approach

The research is about improving mobility goes to industrial area, due to the current mobility is not in good condition, since congestion during peak hour and not satisfying current public transport performance. To solve the mobility problem either by improving or build completely new public transport in the study area.

Studying the current public transport condition, considering the rolling stock condition, infrastructure availability and capability, to understand the problem and the level of service current public transport. Generating future scenarios based on analysis current condition, high-cost scenario, intermediate cost scenario or low-cost scenario. Each scenarios analyzed based on possibility to be implemented in the study area. Scenario implementation analyzed based on sustainability criteria, which are affordability, accessibility, and green energy. Reviewing the possible impact after implementation of new public transport, based on environment and demographical point of view.

3.1 Methodology Approach

Evaluation of most suitable public transport to accommodate the mobility into industrial area based on the sustainability transportation indicator. Through the recognition of available data and published materials, qualitative and quantitative information is used to analyze the most suitable public transport. Review the concept of transport planning as literature and some research regarding similar case. The methodology of research started with determine the objectives followed by specify goals and target until review the impact of most suitable scenario.

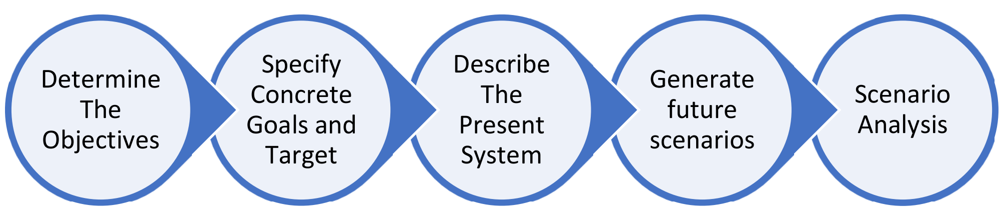


Figure 3.1 The methodology approach

a. Determine the object

The purpose of this research is to analyze the most feasible solution to accommodate the high mobility to Industrial area, from area that has high number of labors residence. Because current performance of public transport cannot satisfy the mobility level.

The study area is industrial area in East Java province, massive number of mobility generated by labor to the industrial area, is the main consideration. Based on the infrastructure and current public transport performance, some scenarios generated, and to be analyzed for the best solution.

b. Specify the goals and the target

What specific qualitative goals shall be expressed in quantitative targets to provide measurable result.

The improved/new public transport considered to be best solution if:

- Improved/new public transport can satisfy the mobility during peak hour.
- Improved/new public transport has performance better than the private vehicle (lower travel time, better safety, lower travel cost, more comfortable).

c. Describe the present Condition

- Demographical trend

  Focusing on the 6 industrial area in East Java, which close to each other. The mobility between those industrial area is very high, considering the current performance of public transport cannot satisfy the needs of people resides around and work in industrial area. The number of workers in each industrial area as Figure below, based on the Industrial area management in 2019. Considering the normal condition, since the pandemic Covid-19 effect Indonesia mobility in 2020 until now, we can assume that the normal condition is in 2019, since the mobility after 2019 decrease a lot, due to impact of lock down and government policy, regarding the national mobility or international mobility.

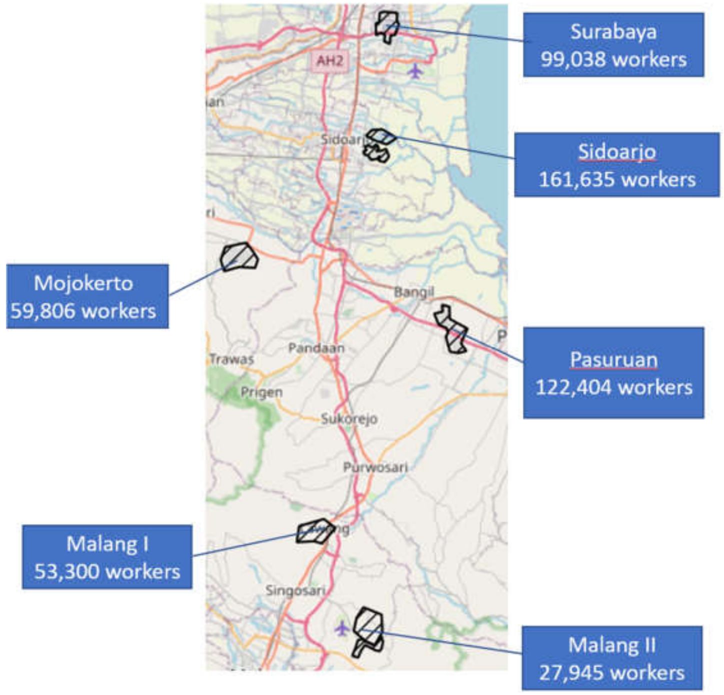


Figure 3.2 The industrial area distribution and employees number in East Java.

Surabaya industrial area as the pioneer industrial area in this location, and with the access to the harbor, give this industrial area better access for export-import activities, but considering the location is nearby urban area, it's not possible to developed more since the limitation of area, beside the limitation of area available, the high minimum level of salary is relatively high, so the idea to build other industrial area in different location with lower minimum salary is desired. The distance of Surabaya industrial area and Malang II industrial area is around 80 km measured by google maps, while there is toll which is connecting all industrial area, give better potential development.

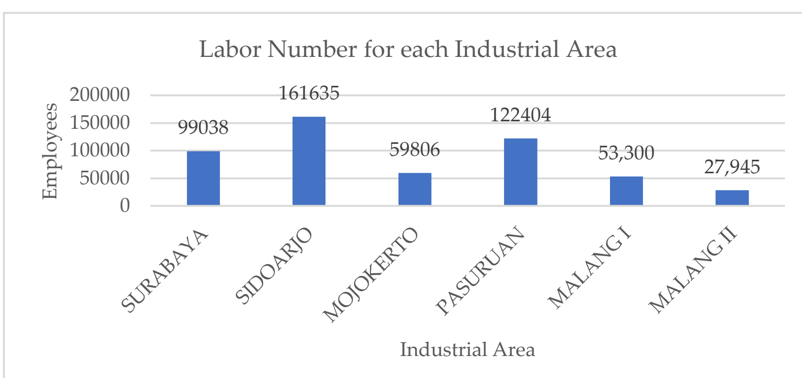


Figure 3.3 Distribution of labor in industrial area
(Source: BPS 2019)

Industrial areas affect the immigration, social economic level and the land use, the population is higher by getting closer to industrial area, since the public transport is rarely used due to poor performance, the current public transport has no significant effect on the population distribution.

The shifting profession also happen due to industrial area, followed by change of land use, for example in the family which the parent at first is farmer, this profession will not be followed by the heir, since the labor give higher salary. The land use change due to the different opportunity appears, by providing the resident for labor come from far away, the farm field are transformed into resident area. The immigration increases the social economic, since more people leads to more service needs, leads to more business opportunity.

Surabaya industrial area is the only one located in the urban area, even though it's on the peripheral area, this location gives very different affect compare with the others, the high population is not in the area nearby, but the high population is in the peripheral area of another city, different living cost significantly affects these phenomena. Sidoarjo Industrial Area as the second oldest industrial area in the East Java, located in peripheral of the city, and relatively closer to the central. The urban area is not fully surround it, but the location which close to the central city and the highway gives it very good accessibility in point of view employees.

- <u>Public transport condition</u>

There are some modes of public transport operates around industrial area, but the route cannot accommodate the user needs, leads to high number of private vehicles, the typical transport mode which used around industrial area as table below.

		Track Guided	Non-Guided
Public	Motorized	Railway - National	Bus - National
		Railway - Regional	Bus - Regional
			Online Car Taxi
			Online Motorcycle Taxi
	Non-Motorized		Rickshaw
Private	Motorized		Private Car
			Private Motorbike
	Non-Motorized		Cyclist

Table 3.1 The transport mode nearby industrial area

There are several public transports available in the study area, which are bus, train, minivan, taxi and daring public transport. But the availability and the performance of current public transport cannot satisfy the number of journeys generated in the area especially during peak hour.

1. Bus

   The rolling stocks have capacity 60 seats, and around 80 stands. The rolling stock condition is very good, but the management is the problem since there is no fix timeline of bus operation, the departure and arrival of the bus cannot be predicted, so it cannot accommodate the traveler which has thigh schedule. The inconvenient condition of bus stop station gives more flexibility of the bus to pick up or to stop everywhere as requested, but this type of operation very unsafe, and not effective.

2. Train

   The train accessibility is the worst one, because very less stop station, since the train is focusing on the long journey, and for local journey train operates only for several journey per day, it makes the train is the worst choice for mid-low distance travel.

3. Minivan

   This mode transportation has very good potential for SHORT distance travel, since the size is relatively small so it has better accessibility. The energy consumption is very low compare with the other public transport, furthermore the ticket price is very cheap. The accessibility is very good, but no fix timetable makes it less sustainable.

4. Daring

   The accessibility issue of current public transport gives room for daring transportation to enter the market, and it has a lot of users since it solves the accessibility of the existing public transport, even with the higher cost (for car), it still acceptable.

- <u>Existing infrastructures</u>

  To develop the optional scenario, it's necessary to know the current condition and the availability of public transport infrastructure. There are two main infrastructures available on the study area, which are highway for the bus and the railway for the train, but the service cannot accommodate the mobility to the industrial area.

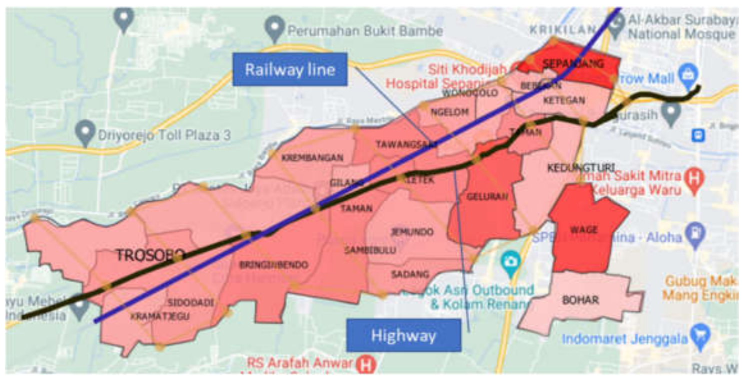


Figure 3.4 The current infrastructure relative position to the study area

Considering the accessibility of both infrastructure for resident in study area, analysis based on relative location the current infrastructure to the peripheral line of study area. The map generated by QGIS, and the relative location calculated by QGIS. Based on the Figure above, it shows that both infrastructures have similar potential since it's in the same direction and typical location.

		Railway Line	Highway
Distance [km]	Average	1.87	1.92
	Maximum	4.52	3.94
	Minimum	0.48	0.49

Table 3.2 The relative location of railway and highway line relatively to the peripheral line in study area

Those comparison is considered to analyze the public transport mode in the next chapter, and as the base to decide which scenario will be used for the analysis. The comparison will be the first step of accessibility analysis and continued by considering the maximum willingness distance to walk to access the stop station along those line.

- <u>Transport Mode Distribution</u>

The data about East Java province road user distribution as graph below, east java as the 2nd highest motorcycle owner in Indonesia. There are some modes of transportation, which are car, motorcycle, shuttle bus, other (including public transport, bike, etc.). The distribution of road user number can be seen as Figure 3.5, the motorcycle dominates the road user and followed by car, bus, and others. The data

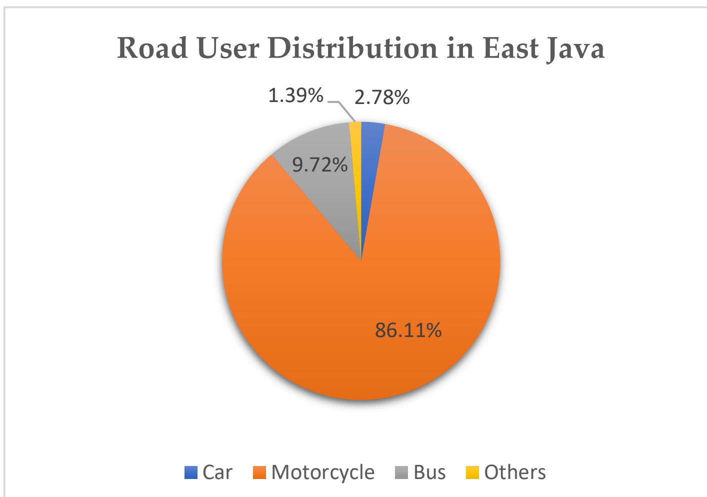


Figure 3.5 The graph distribution of road user in East Java[3]

The specific data related with the transport mode distribution in study area is not available, so assuming that the distribution data in study area is same as East Java's data. The distribution road user is 21734 motorcycle users, which is around 86.11%, and followed by bus user, car user, and the others. This data shows totally different condition compare with the European country which the private vehicle dominated by car. The climate and the resident layout affect the choice of private vehicle. The fact that the ownership cost of motorcycle very less compares with car, make the motorcycle as favorite.

d. Generate Future Scenarios

Current condition pulic transport related with the rolling stock and the infrastructure is considered to generate optional future scenarios, based on those consideration, we have 3 scenarios to be considered.

1. Scenario 1 – Do Minimum Improvement
   Without Change on The Current Infrastructure and Rolling stock.
   Do minimum scenario means, high improvement with very low cost, even without additional cost, this scenario can be implemented if the infrastructure and the rolling stock are available and capable, for example improvement managerial aspects, like timetable, distribution of public transports, re-route public transport, etc.
   The current condition of public transport in study area, by considering Bus, this scenario seems impossible to be implemented, since the current rolling stock is not ready for major improvement, due to not enough rolling stock unit, while it's necessary to improve the infrastructure, especially increasing the number of bus stop station. Current route of public transport seems to be the main reason why the most employees using private transport than public transport, because the current route of public transport has longer travel time than private vehicle, especially motorcycle, furthermore the higher travel time also caused by more than 1 times shifting mode of public transport to reach the industrial area, while the timetable of public transport unwell managed.

2. Scenario 2 – Do improvement
   Improvement or small improvement in the current public transport.
   Improving current public transport with low budget, this improvement not only on managerial aspect, but also improvement in infrastructure and rolling stock. Improvement in infrastructure should considering the capability of current infrastructure, will it be better with some improvement or leads to infrastructure's performance reduction.

Figure 3.6 Indonesia's BRT with dedicated way

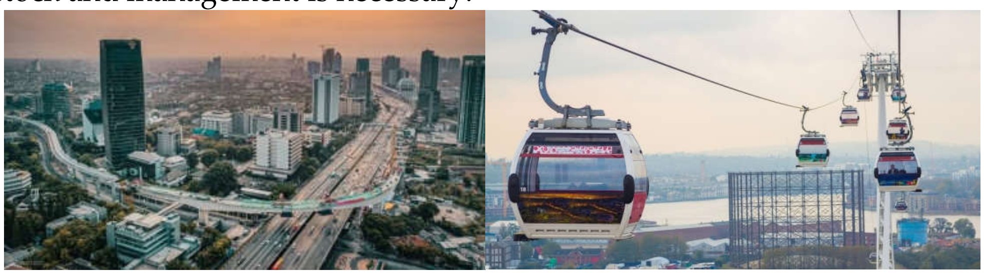
(Source: https://commons.wikimedia.org/wiki/File:Harmoni_Central_Busway_Transjakarta_3.JPG)

The public transport improvement with minimum cost can be seen on bus with dedicated way, as shown in the picture, the new public transport optimizing the existing infrastrcuture by using the existing road and do improvement by building wall for dedicated way for the new bus shown in figure 3.6, to reduce travel time by avoiding traffic mixed with private vehicles.

3. Scenario 3 – Build completely new

Building entirely new infrastructure for new public transport.

Considering building public transport, and it's difficult to use the existed infrastructure for some reasons, i.e., congestion, limited land available, technical issue etc. Therefore, build new infrastructure, rolling stock and management is necessary.



(a) (b)

Figure 3.7(a) Infrastructure for MRT in Indonesia, and (b) Cable car

(Source a: https://www.superlive.id/index.php/news/ada-yang-membanggakan-ini-4-fakta-mengejutkan-jembatan-lrt-jabodebek)
(Source b: https://newsroom.unsw.edu.au/news/science-tech/look-australia-cable-cars-could-ease-our-traffic-woes)

The LRT in capital city of Indonesia as figure 3.7(a) is one sample for build completely new public transport, from infrastructure rolling stock and manpower. The other sample is the cable car in Australi as figure 3.7(b). Build complete new public transport system required huge amount of money. The environment impact will be different as well, since new infrastructure leads to change land use on the study area.

e. Scenario Analysis

The chosen scenario will be analyzed based on following steps:

1. Define market challenge

By collecting the data form public body, related with the demographical data of study area. The data required are about the population distribution nearby industrial area, the profession diversion, and the transport mode used. The data is analyzed to obtain the potential demand and distribution potential demand based on each possible scenario. The potential demand data refer to the demographical data in 2019, since in 2020-2021 the government put limitation in mobility, so it cannot represent the real mobility level in the study area.

2. Analyze the capability to accommodate potential demand

The performance analysis based on the demand generated during peak hour, The peak hour analyzed by considering the working hour in the industrial area, travel distance, and travel time. Assume the industrial working hour following 3 shifts, and the distribution of demand during peak hour is used to analyze the performance of each scenario, for example how many percent the user can be accommodate for each scenario.

3. Economic analysis

   Economic analysis done by multicriteria analysis, which is quantify all the aspect that affected by intervention, considering some point of view, which area potential user, environment, safety, and operator point of view. The economic indicator like discount rate, depreciation coefficient refers to the previous research and the Asian World Bank.

3.2 4 Phase Model

The process of travel demand analysis essentially consists of four stage model[4]. The four stages (or four steps) transportation use model follows a sequential procedure:

- **Trip Generation**.

  For each discrete spatial unit, it is estimated the extent to which it is an origin and destination for movements. The output is usually the number of trips generated and attracted by a given spatial unit. The generation demand will be analyzed by back casting method, which is use the demographic data from 2019, considering condition before pandemic.

- **Trip Distribution**.

  Commonly a spatial interaction model estimates movements (flows) between origins and destinations and which can consider constraints such as distance. The output is a flow matrix between spatial units. In this thesis the trip distribution is used to analyze the distribution of the generated demand from each zone the nearby stop station.

- **Modal Split**.

  Movements between origins and destination are then disaggregated by modes. This function depends on the availability of each mode, their respective costs, and social preferences. Modal split cannot be used since the limitation data, so the modal split analysis in the study area uses the general proportional private vehicle from Indonesia Police data in 2019.

- **Traffic Assignment**.

All the estimated trips by origin, destination and mode and then "loaded" on the transportation network, mainly with the consideration that users want to minimize their travel time or must flow through existing transit networks. If the traffic exceeds the capacity of specific transport segments (which is often the case), congestion occurs and negatively affects travel time. This in turn, through a feedback process, may influence trip generation and distribution. The traffic assignment cannot be done since there are not enough data to perform, but the 3 steps before is enough to define how the potential demand number for each stop station.

4 APPLICATION MODEL

4.1 Study Area Definition

Each industrial area has different characteristic accessing road depend on the urban development of the location, and different number of labors. The accessibility of industrial area by private vehicle is better that accessibility by public transport, the road user going to industrial area dominated by private vehicle user, and very less public transport accessing industrial area.

a. Surabaya Industrial Area

Surabaya Industrial Estate Regency (SIER) (Industrial Area A) located in the border of Surabaya city, also the capital city of east java province. Surabaya is the biggest city in East Java, and the one and only sub-urban metropolitan city in East Java. The difference of living cost between Surabaya and its neighbor cities influences the employee decision regarding where to stay, while the workplace on the border area. The Statistical Center Organization recorded the number of populations nearby the industrial area as below.

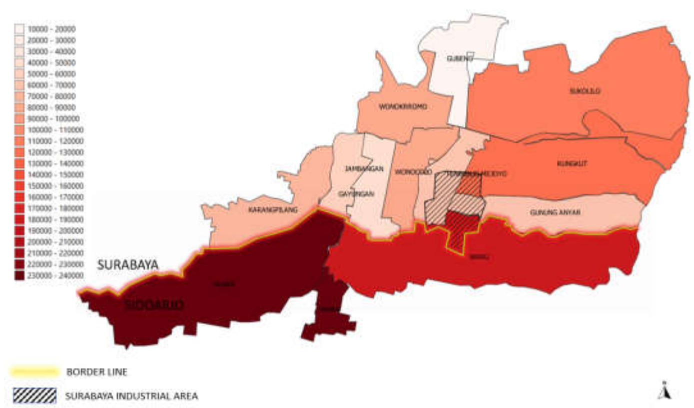


Figure 4.1 The Population distributions nearby Surabaya Industrial Area
Data source: BPS 2019

The district in the Surabaya city has lower population compare with the district on the Sidoarjo, different living cost has big role on this distribution population, Sidoarjo city has lower living cost compare with Surabaya city, it attracts more people to reside in Sidoarjo than Surabaya.

b. Sidoarjo Industrial Area

SiRIE (Sidoarjo Rangkah Industrial Estate) is in Jalan Raya Lingkar Timur Sidoarjo, which is the center of industries and warehouses located in South Surabaya. The location is close to the main road, which is very good accessibility for employees, so the employees is fairly distributed nearby the industrial area, but the public transport to access the industrial area is not managed well, so mostly employees use private vehicle.

c. Mojokerto Industrial Area

Mojokerto Industrial area located in Mojokerto city, for the specific in Ngoro district. Ngoro Industrial Park (NIP) is situated at the toe of Mount Penanggungan, Mojokerto Regency, East Java Province. The development is covering a total area of 480 Ha. The first phase development started in January 1991, covering a total area of 215 Ha land, including Export Processing Zone (EPZ), developed by PT. Kawasan Industri Intiland.

d. Pasuruan Industrial Area

Pasuruan Industrial area or usually called as Pasuruan Industrial Estate, as established on February 28, 1974, to managing and develop the industrial parks in East Java to support the Central Government's goals, which is invite and attract direct investment to contribute to the region's economic growth. Pasuruan Industrial Estate has an area of 556 Ha having covered 260 Ha. There are 84 companies comprised of 51 foreign investors and 33 domestic investors employing 23,249 workers.

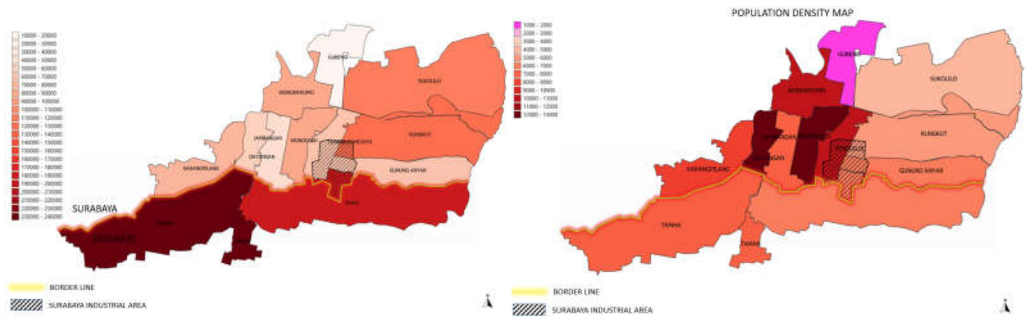
e. Malang Industrial area

Malang has 2 separated industrial area, which area located in Jabung and Lawang, each has 53300 employees and 27945 employees. The splitting location of industrial area can reduce the concentration of mobility in to one destination and can avoid the congestion on the accessing road. The fair level living cost nearby the industrial area, make the mobility during peak hour fairly distributed, but the congestion still happens since the narrow road cannot accommodate the traffic during peak hour.

From those briefly definition of each industrial area and its location, leads to conclusion Surabaya Industrial area chosen to be study area, since the different living cost between Surabaya and neighbor city (Sidoarjo), leads employees to stay in Sidoarjo (lower living cost), and work in Surabaya (higher salary). The accessing road (from Sidoarjo, which are Taman and Waru) to the industrial area has less alternative route. It makes the road during peak hour cannot accommodate the mobility leads to congestion.

4.2 Current condition of Study area

Surabaya Industrial area has 99,308 employees (source: BPS 2019), and distribution of the employee's home stay distributed among the nearby area. Surabaya Industrial area located close to the borderline, so the distribution of homestay not only in Surabaya, but also in the neighbor city, which is Sidoarjo, the lower living cost increase the tendency of employees to stay in Sidoarjo instead of Surabaya.



(a) (b)

Figure 4.2 (a) The population and (b) the population density map, nearby Surabaya Industrial Area
(Data source: BPS 2019)

The highest population number area nearby the Surabaya Industrial area is Taman District, in Sidoarjo City which is 234305 people. while for the population density shows different trend, the highest density area is Jambangan District with 12913 persons/km^2. There is main different density point about density population regarding land use between European country and Indonesia. In Cassina de Pecchi for example, with area 2948.23 m^2 there are around 60 residents, while in Indonesia consume more space for same resident number, for example in 2313.60 m^2 there are 15 houses, with each house consisted by 3 – 5 people, so the total number is 45 people, with full land used.

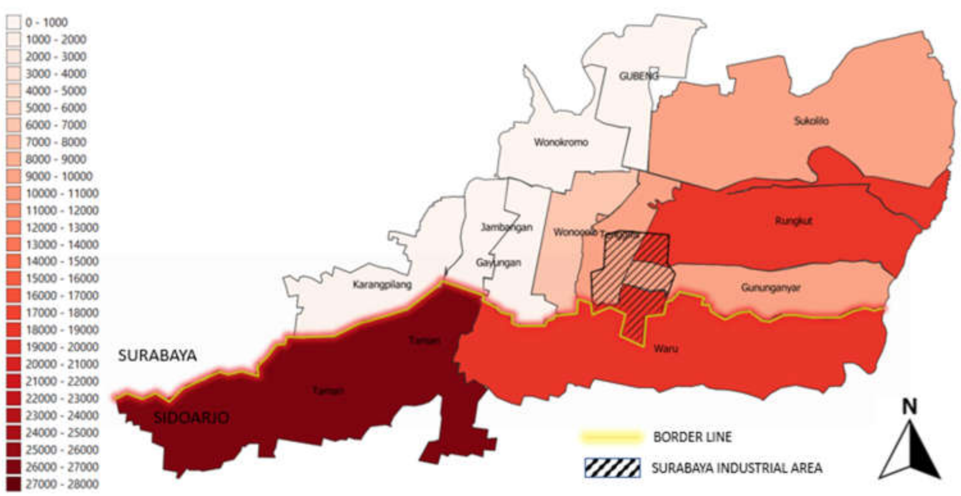


Figure 4.3 The Surabaya Industrial Area employee's distribution

(Source data: BPS 2019)

Based on Central Bureau of Statistics data (Statistical Center Organization) in 2019, the distribution of industrial worker mostly concentrated in Taman Sidoarjo, and followed by Rungkut and then Waru, while the lowest one is Gubeng. The different socio-economic and land use condition is the main reason this kind of distribution.

Surabaya is metropolitan city, and as capital city of East Java Province, these facts give an overview how different land use between Surabaya and Sidoarjo. Surabaya as province capital city, has a lot of governmental offices, Business districts, Retails, University etc. and as other metropolitan city, the resident reside outside the city limits in others city.

4.3 Potential demand Analysis by 4 phase method

4.1.2 Generation

Based on BPS data, in 2019 the total number of industrial employees in Taman District approximated around 63,145 persons, around 26.95% of total population, while the specific number for people work in Surabaya Industrial area is not available, the distribution analysis regarding Surabaya Industrial employee obtained from gravitational model 4and obtained the different percentage of each area, and the total number of SIER employees is 25,624 employees, which is 41% from total industrial employees in Taman. The distribution of employees can be seen as Figure below.

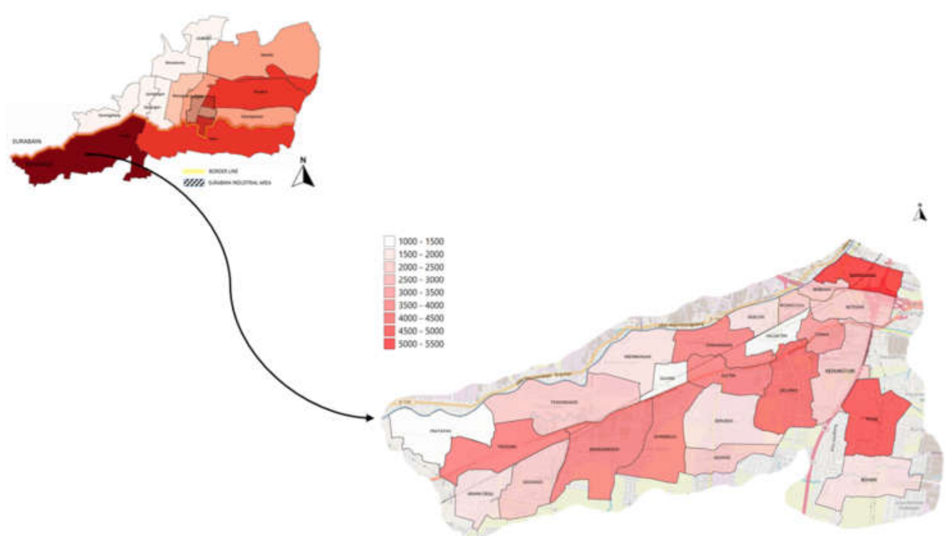


Figure 4.4 The Population Distribution of Total Industrial Worker

The concentration of worker can be seen closer to existing infrastructure (highway and railway line), the highway attracts more people, since gives more access for private vehicle user. The distribution of resident which work in industrial sector as Figure above, with the highest number is Sepanjang, and the lowest one is Pertapan. Taman district shape is very practical as origin of study area, which has area around 31.54 km², to decide the centroid it's not trivial, it necessary to divide the area into some sub areas, there are some literatures regarding what the consideration is to divide the study area to obtain better mobility data.

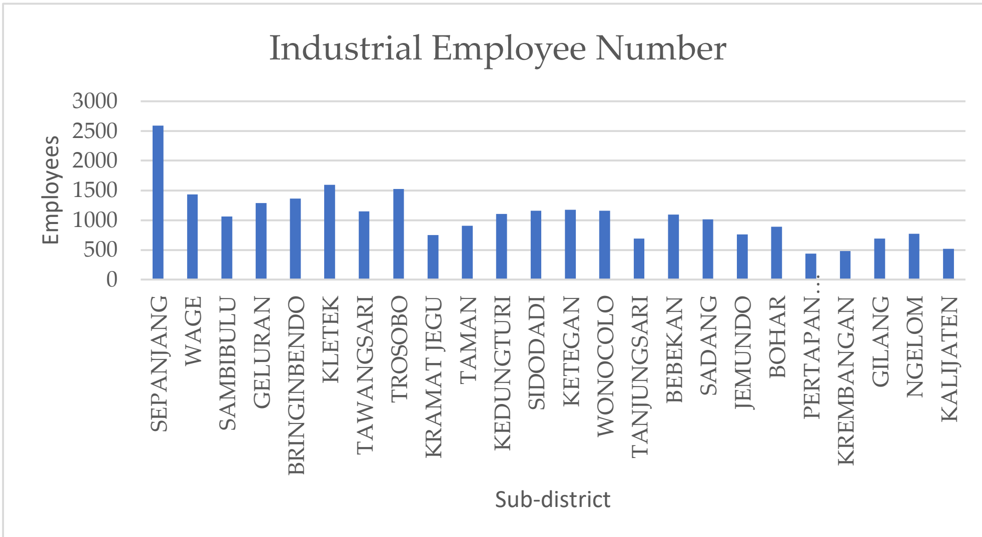


Figure 4.5 The distribution of industrial employees based on sub district (Source: BPS 2019)

The discretization/zoning of study area into numerous zones is necessary. Zoning is expected to reflect the characteristics of each area. To obtain zones for transport demand calculation, the zoning process needs to be incorporated with zonal characteristics that account for inter-zone variability of freight movements.

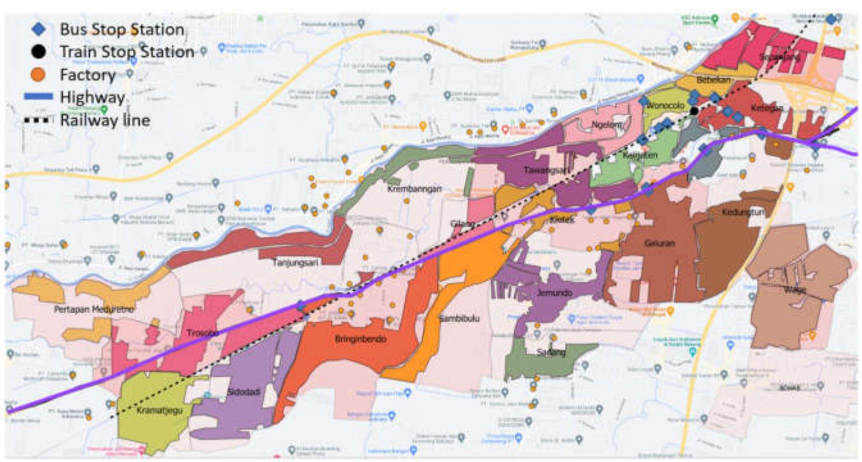


Figure 4.6 The Resident Distribution Map of The Study Area

There are some zoning methods to cluster the study area, with some characteristic similarities, socio-economic condition, geographical location etc., by looking at characteristic of study area, socio-economic condition alone cannot cluster the area in good way, since there is no pattern regarding the socio-economic condition which can be used for clustering the study area, so by combining between distance from origin and the area, the zoning result shown in Figure below.

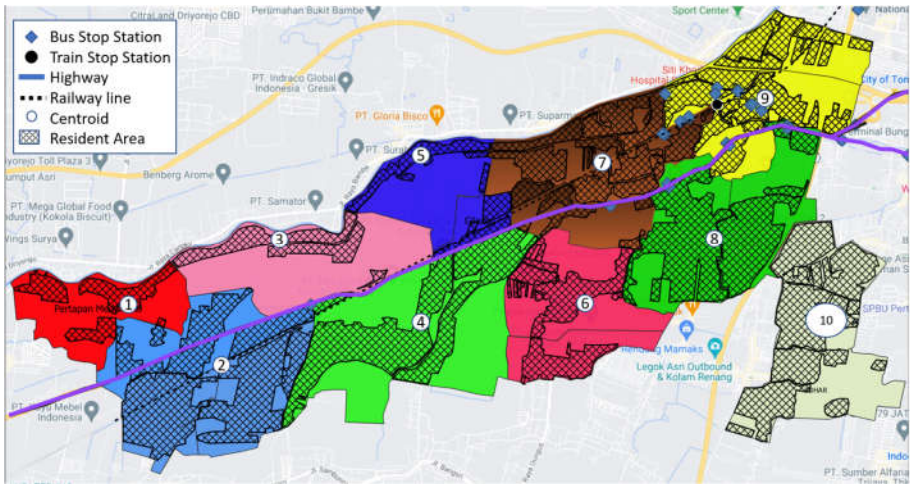


Figure 4.7 Zoning study area into 10 zones

The zonation of study area based on the resident location pattern and the location of the sub district relatively to the public transport infrastructure, obtained 10 zones as Figure above. The centroid analyzed based on resident area by QGIS software. The clustered study area can be analyzed regarding the location and considering the service area of each stop station based on the maximum walking distance for both scenarios.

Zone	1	2	3	4	5	6	7	8	9	10
#emplyoyee of Industry	436	3432	2425	690	1169	1780	4033	2396	2325	6937
Area (km^2)	1.44	4.51	4.27	2.26	2.33	2.89	3.69	3.14	3.55	3.77
Generated demand	447	3518	2486	707	1198	1825	4134	2456	2383	7110

Table 4.1 The employee's industrial distribution for each zone

The zonation of study area based on the resident location pattern, and the location of the sub district relatively to the public transport infrastructure, by considering the demand generated is home-factory travel, with **generation coefficient is 1.025**. The travel on the study area happens during peak hour. The working hour mostly start at 08.00 am, typical peak hour for Indonesian worker is around 05.30-08.00, but the peak hour will be different for each area, and the work hour of industrial area affect the peak hour distribution for the day. Based on the government rule, the maximum working hour per week is 40 hr., and the working hour schedule can be seen as Figure below.

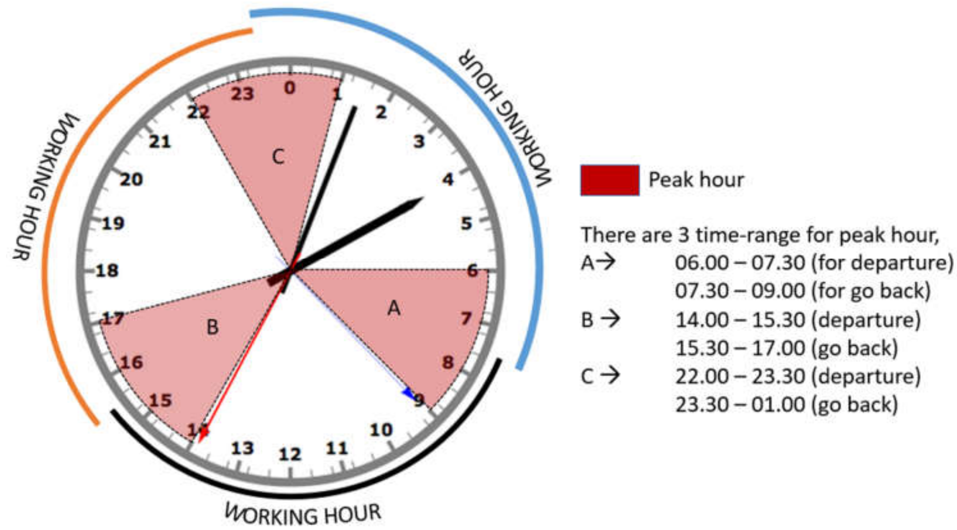


Figure 4.8 The working shift schedule commonly adopts in Indonesia

The working hour for industrial employees followed above schedule, and the peak hour happen for both destinations (SIER) and the origin (Taman District). The peak hour happens 1.5 hr. before the working hour, and after working hour, assuming the peak hour of the for time-range “A” is 3 hr. based on the travel time from study area, with the furthest sub district has normal travel time around 45 minutes, while the nearest sub district has normal travel time 20 minutes, and normally the employees come 15-30 minutes earlier. Assuming the peak hour duration divided to 2, half in the origin section (Taman district) because the start of working hour, while the other half in the Industrial area (because the end of working hour).

4.1.3 Trip Distribution

The general transport mode percentage data is based on Indonesia Police data in 2019, which is the data of national distribution percentage, while the specific percentage of transport mode in each sub district is not available, the general transport mode percentage adopts the data of national percentage of transport mode.

		General Proportion	1	2	3	4	5	6	7	8	9	10	Total
MODE	Motorcycle	86%	385	3029	2140	609	1032	1571	3560	2115	2052	6123	22616
	Bus	10%	43	342	242	69	116	177	402	239	232	691	2553
	Car	3%	12	98	69	20	33	51	115	68	66	198	730
	Others	1%	6	49	35	10	17	25	57	34	33	99	365

Table 4.2 The transport mode distribution for each zone based on the police data in 2019

The result of transport mode distribution can be seen as table 4.2. Motorcycle dominates transport mode distribution on each area, since the general proportion of transport mode is used. Then the route choice analysis executed based on the location of each zone and the transport mode distribution. The route available can be seen in figure 4.10. The Toll route only can be accessed by private car, since toll gives much faster travel time than highway and at the same time it cost more, assuming the number of toll user is 70% of all car users, and 30% of car user use highway, either highway A or B. The motorcycle cannot use Toll, so the only route available for motorcycle user highway A & B. There is no bus provide services directly to industrial area, the bus will stop in the middle of highway B route, the zone 10 is the one that generate trip through highway B.

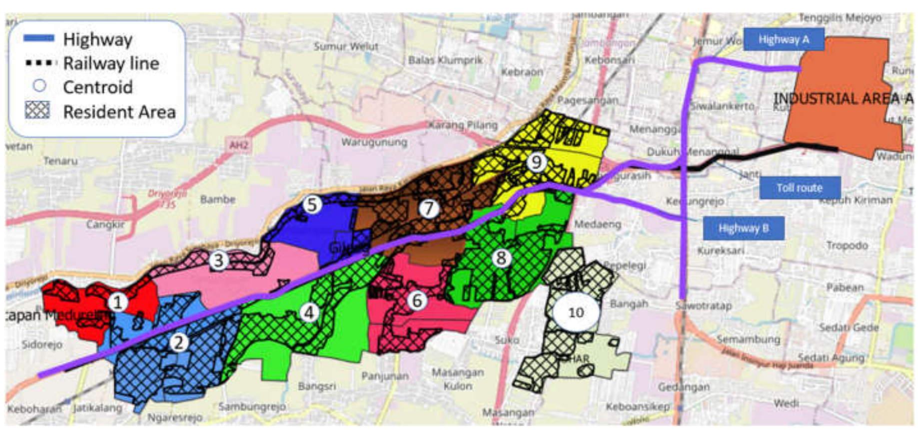


Figure 4.9 The optional route available to access SIER from study area

The trip distribution from each zone into SIER can be seen as table 4.3, it shows that the majority of private user will use highway A and followed by highway B while the Toll users are much lower than the other routes, but low value of Toll user is mainly caused by low number of private car user, since car ownership cost is much higher than motorcycle.

ROUTE	1	2	3	4	5	6	7	8	9	10	Total
TOLL	9	68	48	14	23	36	80	48	46		373
HIGHWAY 1	437	3440	2430	692	1172	1784	4042	2401	2330		18727
HIGHWAY 2										7110	7110

Table 4.3 The distribution travel on the available route to access SIER from study area

The generated demand per zone can be analyzed by assuming the potential users are the employees that accessing workplace by private vehicle by non-Toll route, since the Toll gives very good travel time, the possibility of Toll user shift to new public transport is lower. The result of potential demand per-zone can be seen as table 4.4, with the highest potential user in zone 10, and the lowest one in zone 1.

	1	2	3	4	5	6	7	8	9	10
Potential Demand	437	3440	2430	692	1172	1784	4042	2401	2330	7110

Table 4.4 The Distribution of peak hour daily potential demand in Study Area

Trip dsitribution analyzed by gravitational model to define the distribution of potential demand for each stop stations, considering both scenarios sub-urban train and bus/tram. The characteristics of bus and tram is similar in terms of maximum distance of willingness to walk to access the stop station, while the sub-urban train line have more maximum walking distance. The trip distritbution data relates with the data of potential demand for each stop stations so the maximum potential demand for eact stop station can be obtained.

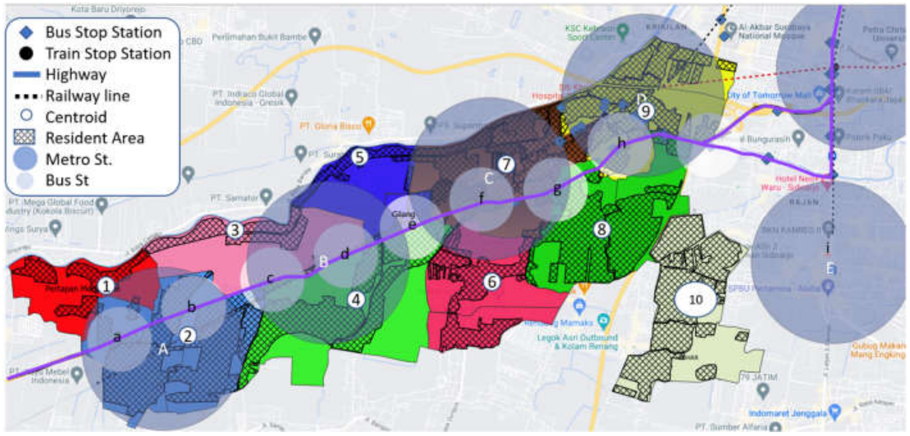


Figure 4.10 The service area for train and bus/tram station

The proposed stop station location considered only the maximum walking distance for each bus/tram and sub-urban train line. The maximum walking distance sub-urban train line is around 1259 m, while for the BRT/Tram has much lower walking distance around 524 m. The orbs of in the Figure represents the service area of each stop station, to avoid the overlapping service area of each stop station, the sub-urban train stop station shown as capital alphabet and the BRT/Tram shown with lower case alphabet. The distance calculated from industrial area for each stop station, the calculation to be done through google map and QGIS software, the bus/tram route following the private vehicle route generated by Google maps, while for the sub-urban train route, following the existed infrastructure until stop station "D", and continue with completely new railway line either with floating construction or surface construction, the floating construction takes less area but higher cost, while the surface design, takes more space but with lower cost.

Origin	A	B	C	D	E	a	b	c	d	e	f	g	h	i
Distance to the destination [km]	14.5	11.7	9.0	6.3	6.4	16.9	15.5	14.2	12.8	12.1	10.9	9.4	8.6	7.0

Table 4.5 Travel distance of each stop station to the industrial area.

The travel distance to industrial area of both scenario BRT/Tram and Sub-Urban train can be seen as table 4.5. The distance measure by QGIS software. The sub-urban train station written in capital letter, the sub-urban train needs completely new railway in the last section of route to access industrial area, and the distance measured based on the new route. The distance for bus/tram stops stations measured based on the highway "A" route, since the route design of Bus/Tram following the most used road route.

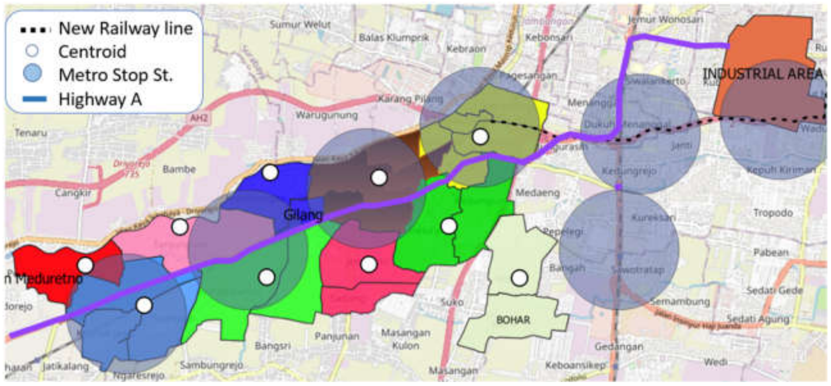


Figure 4.11 The map of new proposed route from Study area into industrial area

The new railway line will be parallel with the toll route, concerning the land use of new public transport, by designing the new railway line parallel to the toll route expect to use less land use, this design already adopted in Indonesia's capital city, the MRT line is parallel with the highway, by considering less land use expansion.

	Distance to Nearby Stop Station [m]													
	Metro Stop Station					Bus Stop Station								
Zone	A	B	C	D	E	a	b	c	d	e	f	g	h	i
1	1271					910	1448							
2	415					1096	465							
3		1540						932	1780					
4		730						1340	694					
5		1663	2031						1504	1364	2037			
6			1581							1514	1228	1730		
7			412								689	915		
8			1915	2079								985	1348	
9				182									650	
10					2151									2589

Table 4.6 Relative distance of each zone's centroid to the closest stop station

The relative distance between each zone to the stop station both sub-urban train and BRT/Tram scenarios. This relative distance shows how the accessibility of stop station to the centroid of each zone, on other hand is used to analyze the potential demand distribution, along the route for both scenarios. The gravitational model used to define the attractiveness of each stop station from each zone.

	Stop station									
Bus/Tram	a	b	c	d	e	f	g	h	i	Total
Potential Demand	437	3,440	2,430	692	1,172	1,784	5,483	3,291	7,110	25838
Metro	A	B	C	D	E					
Potential Demand	3,877	3,883	7,554	3,531	7,110					25955

Table 4.7 The daily potential demand per day for each stop stations in the study area

The total potential demand generated in each stop station can be seen in the table 4.7, for Bus/Tram scenario the highest number of potential demands is on the stop station "i", which is in other side of study area, or in the previous section we called highway "B", with the users come only from zone 10 (only considering study area). The sub-urban train scenario has highest daily potential demand in the stop station "C", look at the orbs area (refer to service area), the orbs cover more resident area than the others, so stop station C has the highest daily potential demand is acceptable.

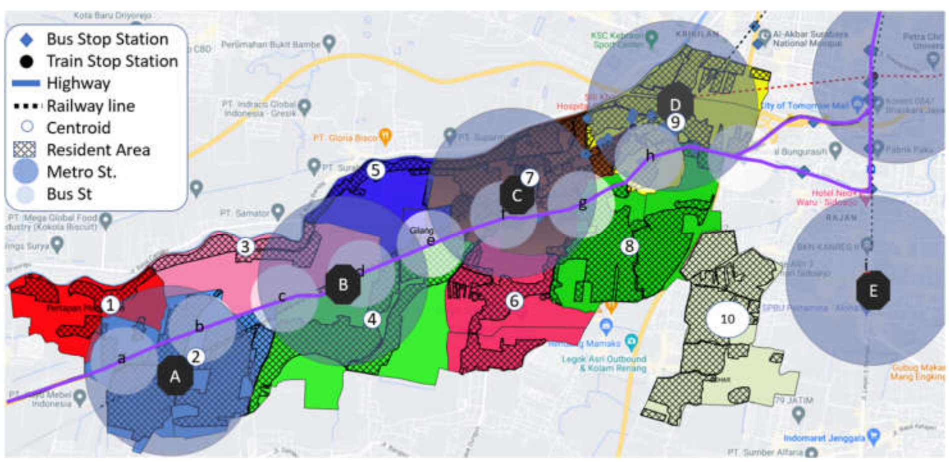


Figure 4.12 The maps new public transport scenario in study area

The map of stop station distribution can be seen as figure 4.13, with the transparent orbs represent the service area for both sub-urban train and BRT/Tram stop station. The shaded area represents the resident for each sub district, while the white circle represent the centroid for each sub-district, the centroid analyzed based on the QGIS software, based on the geometry dimension.

4.4 Scenario Analysis

The scenario analysis carried on by looking at 3 possibilities options, which are minimum cost, medium cost, and highly cost improvement. Those scenarios are analyzed by considering the current condition rolling stock and infrastructure of current public transport, look at the possibility improvement to accommodate travel demand during peak hour.

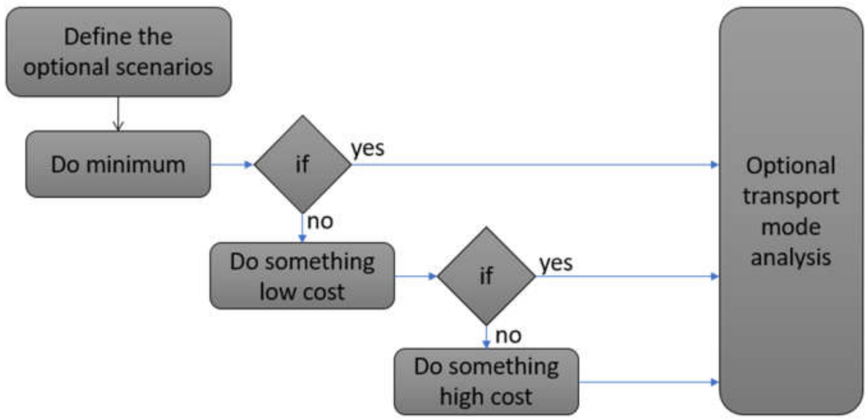


Figure 4.13 Scheme to decide the which scenario to be analyzed

The scenario analysis based on the current conditions rolling stock and infrastructure condition. use Scenario 1 – Do minimum is assessed, if the improvement can be done by managerial improvement only, if not possible goes to another option Scenario 2 – Do something low cost, in the scenario 2 is supposed to have better performance of public transport by improving the number of rolling stock or infrastructure avoiding build completely new public transport system, if the scenario 2 is not possible to be implemented move to the scenario 3 possibilities analysis to be implemented.

The public transports available around industrial area are bus, train, and minibus. The performance of those public transport should be reviewed to decide which scenarios can be implemented on the study area. The trivial way is used to decide the which scenario is the most suitable one, by looking at the capacity of each vehicle, and compares to the travel demand generated during peak hour.

Transportation mode	Performance Indicator		
	Capacity [passenger/vehicle]	Travel/hour	Max speed [kmph]
Minibus	11	N/A	60
Bus	60	N/A	120
Train [8 cars, 72 pass/cars]	576	0.25	80

Table 4.8 The performance comparison during peak hour

The current transport mode performance comparison. Minibus being used fir short travel distance, with capacity only for 11 passengers/vehicle, while the travel time not available for desired route (study area – industrial area). The bus currently favorite public transport for intercity journey since the travel time and the accessibility are acceptable. The train has very low level of service, since the headway of the train is more than 1 hr.

Scenario 1

The minimum improvement on the managerial (new route, timetable management, etc.) only is not possible, since the transport capacity is very low compare with the travel demand generated, the very huge number of rolling stocks is necessary for the minibus and the bus, while the head way is not possible to be maintained with the current number of rolling stocks on the route.

Scenario 2

The scenario 2 is about the improvement of the current public transport, by looking at the availability of infrastructure accessing industrial area, the similar scenarios already applied on the other province, which is the sub urban train adoption as new short-distance public transport by using existing railway line.

Scenario 3

Scenario 3 can be implemented by considering new public transport with very low capital cost, for example tram, but the tram has major weakness which has very low speed compare with other existing public transport.

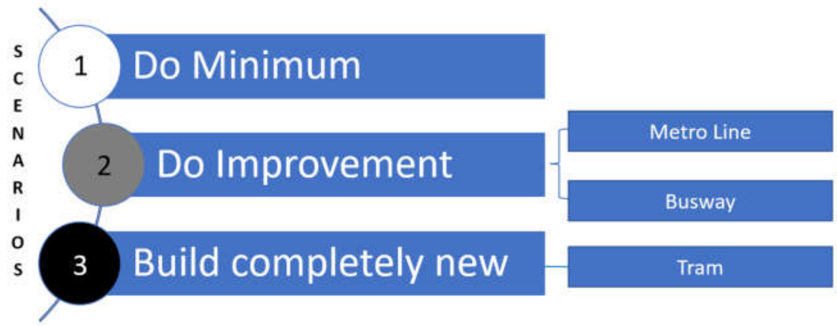


Figure 4.14 Scenario options

The infrastructure available only for sub-urban train line and busway, since sub-urban train line can use existing railway line, while the bus can use the highway, both infrastructures need improvement to accommodate the travel demand from the study area into industrial area. Tram has history in Indonesia, it operates since 1869 and stop in 1960s in capital city Indonesia, the low capital cost of tram is the strong point to be considered, but the low speed of tram is also the main concerns, the slow movement.

Transport Mode		Infrastructure		Rolling stock	
		New	Improvement	New	Improvement
BRT	Scenario 2		V	V	
Sub-Urban Train	Scenario 2	V	V	V	
Tram	Scenario 3	V		V	

Table 4.9 Optional Scenarios of new public transport

Different transport mode, give different plan. BRT is one of the most successful public transports in Indonesia, since adopted on 15 January 2006, it serves an average of 1006 million passengers daily[5], since it uses road and at some sections, build completely new infrastructure is not desired, the improvement in some section to make it as dedicated way and build the stop station are necessary to adopt BRT in the study area, while the rolling stock is not available, the rolling stock procurement is mandatory. Sub-Urban Train is commuter rail system which already adopt in the Indonesia capital city Jakarta, adopting this transport mode, electrification of the existing railway line is desired, and need to completely build new railway in some section with floating design, since it will crossing highway and resident area, the rolling stock procurement use the used rolling stock from Japan, for free with only pay for delivery process. The tram system adopts similar route as BRT, while the completely new infrastructure is desired, and the rolling stock procurement can be done by buying local product or import product.

The current infrastructure available in study area are railway line and highway, the public transport that operates in the study area mostly for long distance, so short travel is not accommodated very well. The bus operates in the highway through study area is inter-city bus, while for the train operates only for intercity and inter province journey. Building new public transport by using existed infrastructure leads to overlapping route between current public transport and proposed public transport. Overlapping would happen if we implemented new public transport in study area, Malvika observs that “partial overlap of public transport routes is preferred by travelers, since there are more that option for travel in case of disruption.”[6]

The proposed tram/bus route location is overlap with the long-distance public transport both bus and train. The railway line only has one stop station in the study area, while the bus has not fix timetable, the long-distance bus also provides short distance service, with adjusted ticket cost based on the minimum distance. As tropical country, Indonesia only has two seasons, which are summer and rain season, during rainy season, flood often happen in the study area, especially in some section of highway, while for railway have higher construction so it safe from flood. Flood should be considered on the consideration of new public transport to be adopted, diesel bus has no problem since current bus rolling stock is diesel and has no issue during rainy season, but for new proposed public transport which area electric rolling stock, has no data regarding flood reliability.

4.4.1 Scenario Analysis

a. Scenario 0

Scenario 0 means we do nothing related with the current conditions, neither improvement in managerial, rolling stock, infrastructure, or build completely new public transport in study area to accommodate mobility of industrial employees. The land use will happen once the economic growth due to the expansion of industrial area attract people to immigrate nearby it, higher population, means higher mobility. With current condition, which the public transport that cannot accommodate the mobility, while considering the future with higher population in the study area, without good public transport, the private vehicle will rapidly grow. The growth of private vehicle which is internal combustion (IC) vehicles, the emission will be higher, and the accident rate will increase. The private vehicle ownership grows every year, especially motorcycle, east java is the province with the most motorcycle users in Indonesia, the economic level, the geographical location, and spatial layout are the reason behind the high number of motorcycles.

b. Scenario 1

The improvement of current public transport to accommodate the current potential demand is the most economical way, but we must look at the rolling stock and infrastructure conditions. The current rolling stock is used to serve long distance journey, which is there is no rolling stock that allocated to provide service from study area into industrial area, especially to accommodate the current mobility level during peak hour.

c. Scenario 2

The improvement with the low cost as possible, by looking at current condition, which there are two infrastructures available in the study area which area railway and the highway, by optimizing the infrastructure with new transport mode is the idea, since the available infrastructure are railway and the highway, the sub-urban train and BRT is the option for this scenario.

d. Scenario 3

The scenarios 3 is to provide public transport by building completely new transport system, which are the infrastructure and rolling stock. The option is to build new transport way with new land use or by installing the transport line in the existing infrastructure. The options for this scenario are LRT (Tram) or cable car, by choosing the most sustainable way, the tram is more potential to improve the mobility in industrial area.

4.4.2 Public transport option analysis

a. Optional public transport

The zonation of study area based on the resident location pattern, and the location of the sub district relatively to the public transport infrastructure, by considering the demand generated by home-factory travel. Based on the shape and availability of infrastructure, BRT, TRAM, and Sub-Urban Train has same potential to be implemented on the study area, but those three transport modes have different capacity, which is main point to be considered. specification comparation can be seen as table below.

Transport mode	Product	Rolling stock Cost [EUR/Rolling Stock]	Capacity [passengers/unit]
Sub-Urban Train	Indonesia	N/A	N/A
	Import New	N/A	N/A
	Import Ex used	525,000	1320
TRAM	Indonesia	1,310,000	75
	Import New	3,500,000	220
	Import Ex used	N/A	N/A
BRT	Indonesia	327,000	50
	Import New eCITARO	500,000	140
	Import New ANKAI	400,000	120
	Import Ex used	N/A	N/A

Table 4.10 The cost and the capacity comparison of train, bus, and tram

The sub-urban train has the highest capacity and followed by TRAM and BRT with the lowest capacity. The rolling stock for each mode transport has many optional suppliers, with the lowest one is Sub-Urban Train rolling stock, since Indonesia has bilateral relation with Japan, Indonesia can get free ex-used train, and only pay for the delivery process. BRT has only one option since we only consider electric bus, and the tram has two options for rolling stock supplier buy import or local product.

Infrastructure cost comparison show different result than rolling stock cost comparison, consider the lowest cost scenario possibility, BRT has the lowest infrastructure cost/km, since it possible to use the existed highway, and build a barrier to make some section to be dedicated way. The completely new tram way is necessary, but the location will be the same as highway/the route of BRT to be considered, the cost is higher than BRT since the construction is more complex. The sub-Urban train has the highest infrastructure cost, even though there is already installed railway, but electrification of the railway is mandatory since the rolling stock is electric cars, while to provide the new public transport accessing industrial area, elevated railway should be built.

b. Infrastructure availability

The infrastructure availability related with how much capital cost of the new public transport implemented, so comparing the potential performance of infrastructure accessibility by look at the relative location refer to the peripheral line of study area, by means look at the accessibility of the furthest user.

		Railway line	Highway
Distance [km]	Average	1.87	1.92
	Maximum	4.52	3.94
	Minimum	0.48	0.49

Figure 4.15 The comparison relative position of highway and railway location

From those data both railway line and highway have similar location relatively to the study area. so based on current infrastructure, both mode of transport has same potential since it has similar relative location of infrastructure. the maximum distance user willing to walk to access train stop station is 1259 m[7], but considering the phenomena in Indonesia, which has a lot of motorcycle user, and by looking at the KRL Jakarta user, the potential user which live more than 1 km away from stop station will use their motorcycle and park in station area, while the user that has no private vehicle, they will use daring transportation. The accessibility of bus is the main point to be considered, since it uses the highway that will be mixed up with the other transportation, the travel performance will be not as good as train. The acceptable walking distance to bus stop station is around 524 m is much less that train station.

c. Performance comparison

Describing the potential user based on each zone, refer to how the distribution of road user in east java based on the Government data released in 2020 (BPS 2019), to define how many private vehicle user on each zone, and the route choice is generated based on the gravitational model between each zone and the highway route, this step to define how many toll user use private vehicle, since, the toll gives very good accessibility to industrial area, so the possibility of toll user to shift to new public transport will be very low. The result of distribution potential demand for each zone as table below.

The gravitational model is used to analyze the distribution of potential demand for each stop station, for both cases tram/bus and sub-urban train line. the stop stations placement of all scenarios considers the maximum walking distance, since bus/tram stop station has similar characteristic regarding maximum walking distance, the location for both tram and bus are in the same location, while for sub-urban train line has fewer stop station in the study area. The walking distance of bus is lower than train/sub-urban train, with the willingness to walk into bus stop station with maximum distance around 524 m, while for rapid mass transport/sub-urban train it around 1259 m, it commonly happens that the user willing to walk further for faster public transport.[7]

	Stop station								
Bus/Tram	a	b	c	d	e	f	g	h	i
Potential Demand	437	3,440	2,430	692	1,172	1,784	5,483	3,291	7,110
Metro	A	B	C	D	E				
Potential Demand	3,877	3,883	7,554	3,531	7,110				

Table 4.11 Peak hour daily potential demand distribution for each stop station

The attractiveness value for each stop station assumed all the same, so the relative distance contribute more in the distribution, result of gravitational model application, potential demand distribution can be seen in the table 4.11, the calculation based on the study area demographical data in 2019, it shows some variation but there is no pattern, since the result affected by resident distribution on the zone, the bus and tram have similar characteristic regarding the desired accessibility and based on the existed infrastructure the route will be the same, so the option is either bus or tram will be chosen, and then will be compared with the sub-urban train line.

The peak hour happen depends on the working hour and the travel time, the working pattern can be seen as figure 4.17, based on the commonly working hour in Indonesia, since there are 3 shifts in one day, the proportion of working hour and the peak hour as Figure…, with the peak hour happens on both direction, origin (study area) and the destination (industrial area), considering the travel time 20 – 45 minutes no congestion happens, the peak hour happen in 2 hours before working hour in study area and 1.5 hours after working hour in industrial area.

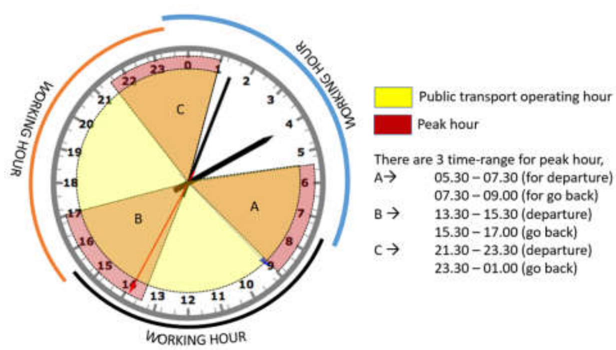


Figure 4.16 Timetable illustration of industrial employees

1. Sub-Urban Train

The sub-urban train scenario adopts 5 stop stations to accommodate potential demand in study area, while 2 more for the area between study area and the stop station in the industrial area. considering the maximum willingness distance to walk, the number of stop station inside the study area is 4 stop station, while to accommodate people from zone 10, stop station E is to be considered, the stop station placement has no other consideration than the walking distance.

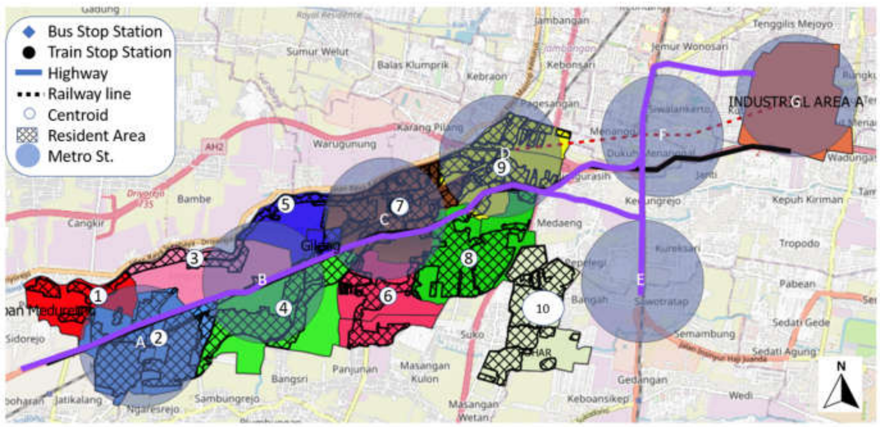


Figure 4.17 The map for the train stops stations

The distribution of train stop station can be seen as figure 4.18, with the orbs represent of the service area, the number of stop station along the line is 7 stop stations, the stop station placement considering the resident and the service area based on the maximum distance of willingness to walk to access the stop station.

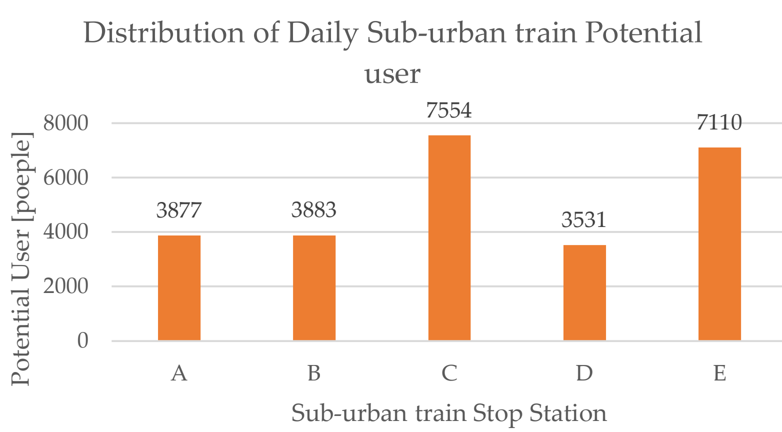


Figure 4.18 The sub-urban train potential user

The daily distribution of transport demand calculated based on the demographical data in 2019, before pandemic covid-19, starting from 2020 the mobility significantly decreases. The distribution of potential user has no pattern related with the distance from industrial area. The highest number of potential users in station C, station C has more resident inside the orbs (as service area considering max walking distance), and then followed by station E, since the gravitational model used in this case, there is no other station which closer to the zone 10, so mostly the user generated by zone 10 will attracted to station E.

Sub Urban Train Potential Demand	%	Stop Station					
		A	B	C	D	E	Total
		3877	3883	7554	3531	7110	25955
		15%	15%	29%	14%	27%	100%
Demand/hr [Passengers/hr]	05.30-06.30	1292	1294	2518	1177	2370	8652
	06.30-07.30	2584	2589	5036	2354	4740	17303
Demand/metro [Passengers/Trainset]	05.30-06.30	108	108	210	98	198	721
	06.30-07.30	215	216	420	196	395	1442

Table 4.12 Potential user distribution for each sub-urban train station during peak hour

The distribution demand along the route line of proposed sub-urban train as above, there are 5 stop stations in the study area, the placement considers the accessibility and the resident area distribution in study area. The distribution analysis based on the gravitational model from centroid to nearby stop station. Sub-urban train-line has 5 minutes headway time, since the labor working time of mostly start at 07.30 morning, while the travel time 20 – 45 minutes, the considers the duration of peak hour in the morning is 1.5 hr, with proportion 30 % for time range 05.30-06.30, while the rest for time range 06.30-07.30. The calculation result as table 4.12, the maximum number of passengers is in the 2nd time-range, with 1442 passengers/sub-urban train, based on the sub-urban train technical specification, it's not possible to accommodate the demand.

2. Bus/Tram transport mode

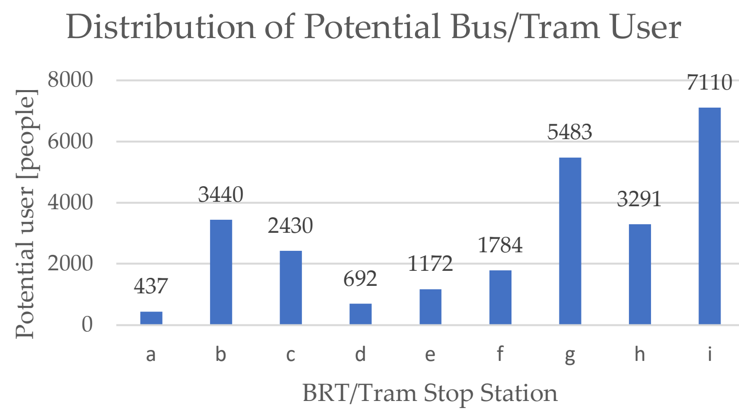


Figure 4.19 Daily potential demand distribution for each station

The distribution of potential user has no pattern related with the distance from industrial area. The highest number of potential users in station g, station g has more resident nearby the orbs (as service area considering max walking distance), and then followed by station i, since the gravitational model used in this case, there is no other station which closer to the zone 10, so mostly the user generated by zone 10 will attracted to station E.

			Stop station									
	Bus/tram		a	b	c	d	e	f	g	h	i	Total
	Potential Demand		146	1147	810	231	391	595	1828	1097	2370	8613
	%		2%	13%	9%	3%	5%	7%	21%	13%	28%	100%
	Demand/hr [passengers/hr]	05.30-06.30	73	573	405	115	195	297	914	548	1185	4306
		06.30-07.30	73	573	405	115	195	297	914	548	1185	4306
Demand/bus [passengers/bus]	6 bus/hr	05.30-06.30	12	96	68	19	33	50	152	91	198	718
		06.30-07.30	12	96	68	19	33	50	152	91	198	718
	10 bus/hr	05.30-06.30	7	57	41	12	20	30	91	55	119	431
		06.30-07.30	7	57	41	12	20	30	91	55	119	431

Table 4.13 Peak hour distribution of potential demand per station

The distribution demand along the route line of proposed bus line as above, there are 9 stop stations in the study area, the placement considers the accessibility and the resident area distribution in study area. The distribution analysis based on the gravitational model from centroid to nearby stop station. considering two headway duration, which are 5- & 10-minute headway time, and the duration of peak hour in the morning is 2 hours, with proportion half of potential users go to work for time range 05.30 - 06.30, while the rest for time range 06.30 - 07.30.

The max number of passengers between those two time-range is same, assumed the demand is evenly distributed during peak hour, table 4.13 shows that highest potential demand is 718 passengers/travel for headway 10 minutes, while for the for the 5 minutes headway have potential demand as 431 passengers/travel. There are some options of bus available, articulated electric bus with capacity 146 passenger/travel manufactured by Mercedes, while electric double-deck bus has 120 passengers/travel, while for the tram has more optional capacity, Alstom CITADIS can carry up to 220 passengers/travel, Hyundai's tram can carry up to 240 passengers/travel, both tram and bus cannot satisfy the potential demand during peak hour.

4.4.3 Economic analysis

Economic analysis refers to the method to determine the value of project or program proposed. The important component of project planning. The economic analysis process includes information collection, capital cost analysis related with rolling stock and infrastructure based on the requirement, operational cost analysis of the operation on the proposed route, user advantages, environment impact, operator benefits analysis and cost benefit analysis.

a. Capital cost

1. Rolling stock

Capital cost analysis to be done related with the cost for purchasing the rolling stock, cost for infrastructure either improvement or build complete new, and the house of maintenance cost. The data collected from some previous research, the report of previous project, or the statement regarding on going project.

Transport mode	Product	Rolling stock Cost [EUR/Rolling Stock]	Capacity [passengers/unit]
Sub-Urban Train	Indonesia	N/A	N/A
	Import New	N/A	N/A
	Import Ex used	524,000[8]	1660[9]
TRAM	Indonesia	1,320,000[10]	75[10]
	Import New	3,600,000[11]	220[12]
	Import Ex used	N/A	N/A
BRT	Indonesia	327,000[13]	50[13]
	Import New	500,000.00[14]	140[14]
	Import Ex used	N/A	N/A

Table 4.14 The cost related with the available rolling stock option

There are some options related cost of rolling stock, purchase local product, import new or used one, the detail related capital cost option for each scenario as table 4.14. The sub-urban train that will be used should be compatible with the track gauge of existing railway line in Indonesia, since the ticket price of same public transport is very low in capital city Indonesia, the option to purchase ex-used Japan is the choice for lower capital cost, since there is bilateral cooperation between Indonesia and Japan, "the ex-used sub-urban train can be got by free, the cost only for shipping process which cost IDR 1 Billion" said Vice President Corporate Communications PT KCI Eva Chairunisa[8].

Tram has history in Indonesia, it operates since 1869 and stop in 1960s in capital city Indonesia, in some regions the tram railway still available. The options for rolling stock purchasing are purchase local product (battery base) with capacity only 75 passenger/travel and purchase from other country which are from Alstom (ground power supply) with capacity 220 passenger/travel and Hyundai with capacity 240 passenger/travel, Hyundai is cheaper price since it powered by catenary and has higher capacity than Alstom's tram, looking at far future, the catenary-free tramway is better, so Alstom's Tram is chosen for economic analysis.

BRT is very famous public transport in Indonesia. BRT already adopted in Indonesia capital city and has very good performance and response from user. Since it has good response from the user, the success story wants to be followed by others region as well. Considering green public transport, only electric bus is considered, the electric bus is more expensive than diesel bus. The electric bus option available are local and import, with the local product have lower passenger capacity and lower cost, while the import bus available is from China or from Germany, there is not many data related with electric bus from China so the data refers to the bus from Mercedes Daimler eCitaro with the passenger capacity around 140 passenger/travel and more expensive compare with the local product, with the capacity comparison the Daimler bus has reasonable price, so Daimler bus is chosen for cost analysis.

2. Infrastructure

Infrastructure cost of each scenario is analyzed based on the data from previous research, project report, and statement of on-going project. The BRT/Tram proposed scenarios has same route, the BRT scenarios need some improvement in the highway to make in some section to be dedicated way, while for the tram it's need big improvement in the highway since the construction of tram way need more modification on the current highway condition. The proposed route of sub-urban train use exists railway line, while in some section completely build new railway line is necessary since there is infrastructure that give access to industrial area.

Transport Mode	Infrastructure Cost [EUR/km]	
	Improvement	Complete New
Sub-Urban Train	3,300,000[15]	41,000,000[16]
BRT	1,200,000[17]	N/A
Tram	15,000,000[18]	

Table 4.15 Infrastructure cost comparison

The infrastructure cost for each scenario is showed in table 4.15. The sub-urban infrastructure considering the electrification the line by installing power transmission for pantograph on the line, this improvement was done in the other region, so the price for electrify the line is refer to that project, which is electrification railway line in West Java Indonesia, it costs 3,300,000 EUR/km, to adopt sub-urban train as new public transport, and no more modification of exist railway line, while build completely new railway line is necessary since, the current line doesn't connect the industrial area with the study area, and the cost to build complete new with floating construction is 41,000,000 EUR/km. Considering less land use, the floating construction is considered, the cost is based on the previous project in Indonesia, while the route following Waru-Juanda toll route.

The BRT system proposed is not possible to be fully dedicated way, since in some section regarding the width of road it is not possible to build dedicated, so the dedicated way only can be built in some section with at least has 3 row capacity. The cost of construction is based on the dedicated way scenarios, which cost 1,200,000 EUR/km, while there is no additional cost required for the section without dedicated way, the additional cost only on the stop station. The tram system proposed has same route as BRT scenario, while the infrastructure cost of BRT counted only in dedicated way, while the tram is need track for along the route, in additional tram system uses pantograph system so the installation of power transmission line is necessary.

The tram infrastructure cost is between Sub-Urban Train and BRT, free catenary tram is the one to be considered, with the infrastructure cost around 15,000,000 EUR/km, so the power supply options are UC storage with fast charging at each station (US-FC) or battery storage with slow-charging at starting and final station (BS-SC), choosing one of those technology is a trade off in economic point of view, BS-SC has better performance with cost saving 34.23% and weight reduction over 40%, so BS-SC scheme is the one chosen for economic analysis[19]. The cost for infrastructure is the cost build on surface, not elevated, and the route same with BRT proposed idea, the completely build new tramline is necessary and some modification on the road should be proceed.

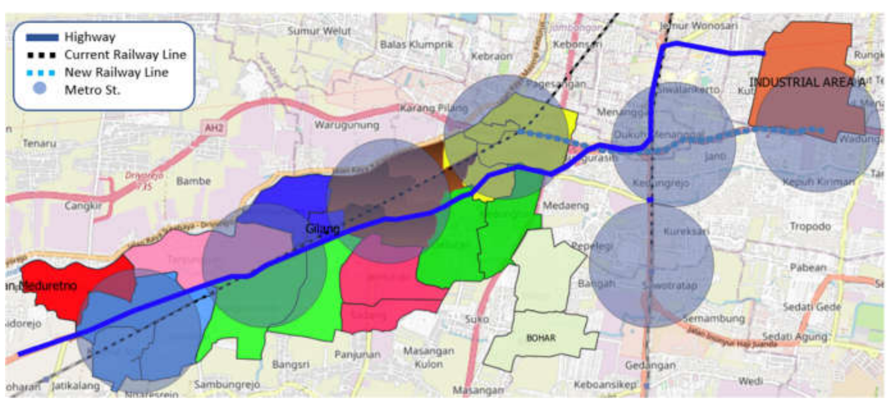


Figure 4.20 The route of each proposed public transport scenarios

The other capital components are maintenance house and charging stations. The maintenance house will be used for parking and charging during off-duty periods. The maintenance house between BRT and tram is different, the additional track to access the maintenance house should be built, so the location of tram maintenance house should be nearby from tram line, while BRT has more flexibility regarding the location of maintenance house, and the capital cost of BRT depot is lower.

		Charging Station Cost [EUR/Station]	
Transport mode	Depot Cost [EUR/Depot]	Slow Charging	Fast charging
Sub-Urban Train	36,000,000[20]	N/A	N/A
BRT	10,000,000[21]	40,000[22]	82,000[22]
Tram	25,000,000[23]	40,000[22]	82,000[22]

Table 4.16 Capital cost related with Depot and Charging station data

The other capital cost for new public transport area depot cost and the charging station, table 4.16 shows the depot cost varies for each scenario, with the cheapest one is the BRT depot cost 10 million euro, and the most expensive is the sub-urban train with 36 million euro, while the tram depot cost is 25 million euro. The charging station only installed in BRT and Tram scenarios, since the sub-urban train use powered by catenary. The technology of battery between tram and bus is similar, so assuming the charging station cost is same with slow and fast charging station cost respectively 40,000 euro and 82,000 euro.

b. Operational cost

Operational to be analyzed consisted by energy consumption of rolling stock and stop stations, maintenance cost, man-power cost. The data obtained from previous project, related paper, and statement from related figure. The data is proceeded to obtain the performance of operational cost of each public transport mode.

Energy consumption of rolling stock obtained from some papers, while the electricity cost based on previous research related with the outage cost, from the research known that the electricity cost in 2015 is Rp. 483 per kWh, assumed that there is no change related with the fare, and it's equal with 0.031 EUR/kWh. While the energy consumption for each rolling stock and the stop station can be seen as table 4.17.

Transport mode	Energy Consumption [kWh/km]	Travel Distance [km/year]	Total Energy Consumption [kWh/year]
Sub-Urban Train	7.3[24]	1,971,000	14,368,590
Tram	0.9[25]	1,357,319	1,273,267
BRT eCitaro	2.0[26]	1,218,436	2,436,873
BRT Ankai	1.35[27]	1,218,436	1,644,889

Table 4.17 Annual Rolling Stock Energy Consumption

Sub-Urban train has the highest rolling stock energy consumption, while followed by the eCitaro electric bus with energy consumption 2 kWh/km, based on the Mercedes claim, while for the BRT Ankai, due to new product, there is no data regarding the energy consumption of the bus, so the data refer to other research about non trolley electric bus energy consumption 1.35 kWh/km. The tram has similar characteristic with the bus, as research resulted that tram has lower energy consumption than electric bus due to lower rolling resistance due to railway system.

Transport mode	Rolling Stock Energy Cost [EUR/year]	Stop Station Energy Cost [EUR/year]	Energy Consumption Cost [EUR/year]
Sub-Urban Train	321,697	551,363	873,059
Tram	42,033	1,358	43,391
BRT eCitaro	87,578	1,358	88,936
BRT Ankai	59,115	1,358	60,473

Table 4.18 Annual Energy cost by Rolling Stock and Stop Station

The annual energy consumption as table 4.18, the stop station energy consumption of sub-urban train is significantly higher than 3 others transport mode, the metro energy consumption is equal to 520000 kWh/year-station[28], since the data related with the station of sub-urban train cannot be found, by assuming that the sub-urban train station has same level of energy consumption with metro station, the data is used to analyze the energy cost.

Tram, and BRT has similar characteristics of stop stations, the station installed is simple station, so the energy consumption is very low, since there is no electric facilities in the station except the light, the energy consumption is comes from light, with the light power is 50 Watt, and active between 18.00 – 06.00, since the day and night duration doesn't changes much like in European countries, the information board related only with the timetable which is manual board, so doesn't consume any energy.

The maintenance cost between IC vehicle and electric vehicle is different. Energy on board vehicle need more maintenance, since the battery has limited charging cycle, transport mode proposed that use battery on board are tram and BRT, the battery has significant maintenance cost, so it can be neglected, the battery maintenance cost 600,000 EUR per 10 years[29], since assuming the project lifetime is 35 years, so the battery change will three in the project lifetime, the maintenance cost for each scenario as table 4.19.

Transport mode	Maintenance Cost [EUR/unit-km]	Battery Maintenance Cost [EUR/unit-hr]
Sub-Urban Train	2.44[30]	N/A
Tram	1.14[31]	16.86
BRT eCitaro	0.32[32]	16.86
BRT Ankai	0.32[32]	16.86

Table 4.19 Maintenance Cost

Therefore, the total maintenance cost for each public transport can be seen as table 4.20, the sub-urban train has more maintenance cost even though has less rolling stock but has more travel distance for each rolling stock unit. The missing part is the maintenance cost of stop station and the fix assets like railway in sub-urban train, or tram way in tram scenarios, barrier for dedicated way in BRT scenarios.

Transport mode	Maintenance Cost [EUR/year]
Sub-Urban Train	3,468,948
Tram	2,271,545
BRT eCitaro	1,247,900
BRT Ankai	1,079,708

Table 4.20 Maintenance cost for each transport mode scenarios.

The other component in operational cost considerations is the energy consumption and the manpower needed. The energy consumption based on the energy spend of rolling stock and the stop station during operation hour, while the manpower cost based on the number of manpower needs to operate the transport system. The manpower consisted by driver for each transport mode, the vigilantes for each stop station for ticket counter, and the supervisor for to make sure the operation of system, while the technician for daily control the rolling stock.

Transport mode	Driver	Supervisor	Technician	Vigilantes
Sub-Urban Train	12	6	9	18
Tram	30	6	6	30
BRT eCitaro	24	6	6	30
BRT Ankai	24	6	6	30

Table 4.21 Number of employees on each public transport mode

The Salary of each manpower profession is different since the skill required is vary. Sub urban train has the highest level of salary in driver, since it has special school for it, and the salary is same as salary of driver sub-urban train in capital city. The tram salary level has not been found for Indonesia, since the tram is abandoned idea, so the tram salary put it in the same level as BRT manpower. Technician on the 2nd place of the salary level, since it need high skill related with high end technology of the rolling stock and the infrastructure. The vigilantes as the lowest of salary level, since it need very less skill, and simply job, all the salary mentioned is above level of minimum salary settled by government. The salary will be paid monthly and considered there are bonuses which is equal to two-month salary for each profession. The list of salary can be found as table 4.22.

	Manpower salary [EUR/month-employee]			
Transport mode	Driver	Supervisor	Technician	Vigilantes
Sub-Urban Train	642	415	642	281
Tram	514	313	578	281
BRT eCitaro	514	313	578	281
BRT Ankai	514	313	578	281

Table 4.22 Manpower cost [33]

The Annual manpower cost calculated by considering 14-month salary for each profession, this way of salary payment is based on the police of Trans-Jakarta as the operator of BRT in capital city. Therefore, the annual cost for manpower is obtained for each transport mode. The annual manpower cost as shown in table 4.23, with tram has the highest cost and followed by BRT, this is because the BRT and need more rolling stock compare with sub-urban train scenarios.

	Manpower cost [EUR/year]				
Transport mode	Drivers	Supervisors	Technicians	Vigilantes	Total [EUR/year]
Sub-Urban Train	107,935	34,841	80,951	70,759	294,486
Tram	215,863	26,275	48,571	117,932	408,642
BRT eCitaro	172,691	26,275	48,571	117,932	365,469
BRT Ankai	172,691	26,275	48,571	117,932	365,469

Table 4.23 Annual cost for Manpower

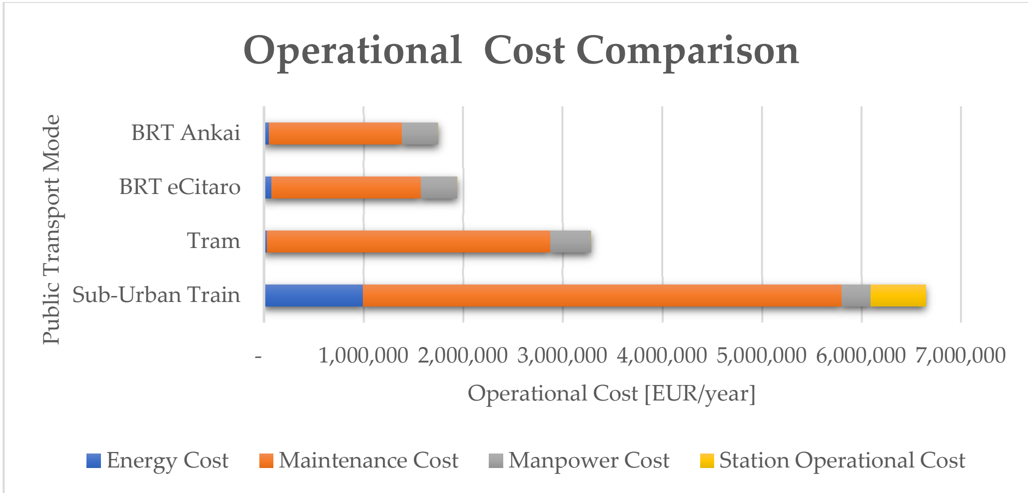


Figure 4.21 Total operational cost for each transport mode

The total operational cost for each transport mode is obtained as Figure 4.22, operational cost consisted by annual manpower cost, maintenance cost, energy consumption for both rolling stock and the stop station. The sub-urban train station has higher energy consumption since it has more equipment for operational than the other transport mode.

1. Cost benefit Analysis

Cost benefits analysis executed by analysis the level of benefit obtained by users (transport user), environmental and operator. The user benefit defines as how many generalized prices for each travel by using private vehicle and compare with the public transport generalized cost. The environmental benefits based on the emission emitted by private vehicles and calculate how the effect if there is public transport intervention, the benefits calculated based on the well to wheel method and assumed that public transport is fully green energy. The operator cost benefit by reviewing the operational cost, and the cost for travel per passengers compared to the expected cost by potential user, the expected cost value which is the current ticket cost of public transport in the study area.

I. User

The user benefit defines as how many generalized prices for each travel by using private vehicle and compare with the public transport ticket cost. The non-public transport considered are motorcycle and MPV car, the daring car considered use motorcycle in used. The generalized cots of private vehicle come from the fuel spend per travel, parking cost, and value to time. The emission calculated based on the most used type of motorcycle and car, which are for motorcycle dominated by Honda Beat 125cc, while for car dominated by Toyota Avanza 1300cc.

	Fuel Consumption						
	km/lt	lt/100km	Fuel Cost [EUR/lt]	Travel Distance [km]	Travel time [min]	Average Speed [km/h]	Generalized Cost [EUR/travel]
Motorcycle	60.6	1.7	0.57	20	40.00	30	2.1
Car	14.8	6.8	0.57	20	60.00	20	2.7

Table 4.24 Generalized cost of private vehicle for work travel

The generalized cost for travel to industrial area from study area, considering the furthest centroid, the result can be seen as table 4.24. The data of Honda Beat fuel consumption from Astra Honda Motor website (manufacturer website), while the Toyota Avanza fuel consumption based on the Automotive reviewer website. Considering that car and motorcycle use same route, which is non toll route, with travel distance 20 km. while the average speed is obtained from google map. While for daring option assuming that the transportation type is same as in motorcycle user, but with cost Rp 3000 per km, which is equal to 0.19 EUR/km in 2022, So the total generalized cost for each transport mode can be calculated.

The generalized cost compared with proposed new public transport and the different travel time involving the value of time. The value of time calculated based on the country, since the value of time analyzed based on the research by Lasmini Ambarwati with income approach[34], which is from GDP of the desired area refer to BPS data of East Java in 2021, and obtained that value of time for each person is 0.033 EUR/min. Therefore, the cost benefit analysis can be carried out and the result can be seen as table below.

	Annual Surplus shifting to [EUR/year]			
	Sub-Urban Train	Tram	BRT Ecitaro	BRT ANKAI
Motorcycle	11,347,098	2,734,039	7,140,908	5,869,239
Car	2,456,894	2,422,403	1,147,671	943,291
Daring	1,024,826	1,949,339	501,807	412,444

Table 4.25 Annual surplus cost by shifting to new public transport

The cost benefits analysis shows positive result for car and daring user by shifting to the all optional public transport mode as table 4.25, while for motorcycle users shows different result, the users obtain benefit in shift to the sub-urban train and BRT, while for shifting to the tram, assume that the tram has average speed as 30 km/h, so the travel time of tram is longer than motorcycle user, the travel time of tram by considering 30s idling time for each station, is 45.5 minutes, while for motorcycle travel time from the furthest centroid is around 40 minute based on google map on the normal condition (no congestion), so the motorcycle users don't get the benefit in terms of travel time and monetary cost per travel for tram scenario.

II. Environment

The environmental benefits analysis based on the emission emitted by private vehicles and calculate how the effect if there is public transport intervention, the benefits calculated based on the well to wheel method and assumed that public transport is electrical vehicles, so the emission in tank to wheel is zero, while the emission source is on the well to tank process.

Transport	Annual energy consumption [kWh/year]	Annual energy consumption [MJ/year]	Emission CO2 [kg/year]	Emission Cost [EUR/year]
Sub-urban Train	14,368,590	51,726,924	15,124,953	60,500
Tram	1,273,267	4,583,762	1,340,292	5,361
BRT eCITARO	2,480,673	8,930,422	2,611,255	10,445
BRT ANKAI	1,688,689	6,079,281	1,777,582	7,110

Table 4.26 Annual Emission Cost

The Well to Tank emission analysis is based on the emission of power plant to generate electric energy, the calculation result is shown is table 4.26, since the majority power plant in Indonesia is coal power plant therefore the emission calculation based on the coal power plant emission, with the level of emission 292.4 g $CO_{2equivalent}$/MJe stated by Robert Edward in JRC Technical Report 2013, therefore zero emissions public transport still not possible, but with the new public transport can reduce the number of emissions. The number of emissions for private vehicles can be seen as below table.

	Emission Level [gram/km]		
	CO	HC	NOx
Motorcycle	0.143	0.042	0.031
Car	1	0.1	0.08

Table 4.27 Emission data of motorcycle and car

The emission level in study area assumed as table 4.27, since motorcycle data based on the emission of most used motorcycle, which are Honda Beat 125cc injection, while for car data emissions coming from emission limit, meanwhile mostly car used is Toyota Avanza but there is no information regarding the data of emissions, the car is already EURO IV, therefore the emission data following emission limit of EURO IV. Assuming the annual emission of private vehicles based on the number of accommodate potential user per year for each public transport mode, can be seen as table 4.28.

Private Veh. Mode	Sub-Urban Train	Tram	BRT eCITARO	BRT ANKAI
Motorcycle	15,739	12,125	8,366	6,614
Car	1,640	1,263	838	689

Table 4.28 Private vehicle number accommodated by public transport in peak hour

Sub-urban train can accommodate more user during peak hour than other scenarios, as shown in table 4.28, and followed by tram, then BRT. The emissions cost to quantify the value of pollutant refer to the research by Laura Reviani Bestari, about the estimation of diesel vehicles tax value related with the air pollution loss, the research result can be seen as table 4.29.

Pollutant	Cost [Rp/kg]	EUR/kg
CO	62	0.004
NO2	124	0.0081

Table 4.29 The Emission Cost[35]

The cost estimation tax related with the air pollution is used for analysis of public transport intervention impact to environment especially air pollutant. The emission analysis carried out by well to wheel method, analyze the emission generated by power plant and by vehicles, then comparing the emissions of new public transport and the private vehicles, since the proposed public transport is electrical, therefore the public transport do not generate any emissions, but based on the Indonesia country conditions, which is most of power plant is coal power plant, so the emissions of public transport is from energy generation in power plant. The emission by coal power plant based on the Robert edward in JRC technical report is about well to tank appendix analysis.

The emissions by power plant to generate energy is used to analyze the emissions generated by public transport proposed, since the power plant is coal power plant, so zero emissions of public transport is not possible yet, the result emission of each public transport based on the energy required can be seen as Figure below.

Transport	Annual energy consumption [kWh/year]	Annual energy consumption [MJ/year]	Emission CO2 [kg/year]	Emission Cost [EUR/year]
Sub-urban Train	14,368,590	51,726,924	15,124,953	60,500
Tram	1,273,267	4,583,762	1,340,292	5,361
BRT eCITARO	2,480,673	8,930,422	2,611,255	10,445
BRT ANKAI	1,688,689	6,079,281	1,777,582	7,110

Table 4.30 Annual emission cost for each scenarios

Sub-urban train scenario has the highest emission because it needs highest energy based on the table 4.30, while the tram has the lowest emissions cost because the low level of emissions, since the energy consumption of tram is the lowest one, while BRT has different result since the energy consumption of two electric vehicle is different, eCITARO requires more energy since it can accommodate more passenger than Ankai's bus.

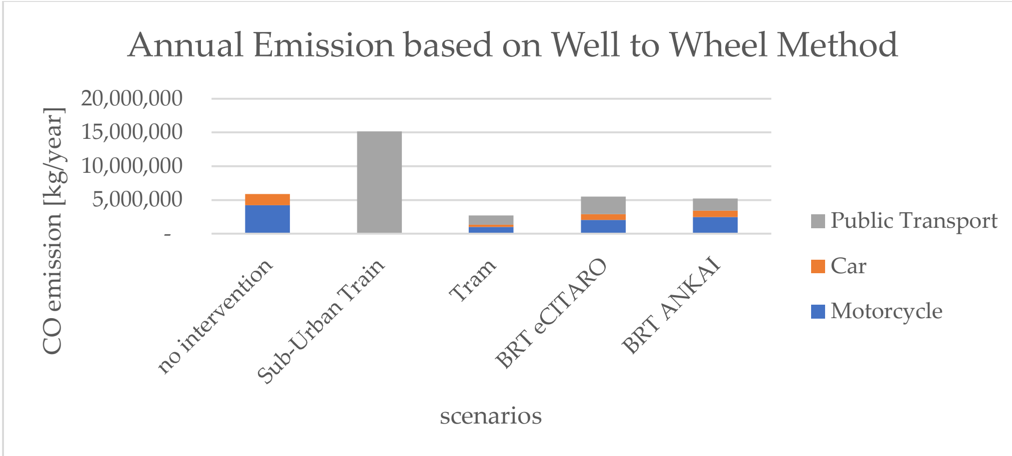


Figure 4.22 Annual emission comparison before and after intervention of scenarios

The intervention scenarios in study area not shows good results for all public transport, by looking at figure 4.31, the sub urban train can accommodate all the potential user, so the emission purely caused by the sub-urban train, it has higher emissions since greater energy required, even though the accommodate passenger is higher, but since the energy produced by coal power plant, the emissions of coal power plant is very high, so in general the emissions of public transport is depend on the energy required, higher energy required, higher emission generated by power plant, only tram and BRT with Ankai's bus has lower emission after intervention. Therefore, for environmental point of view the tram is the best options, in scenarios Tram and BRT there is still private vehicle emissions since the transport mode cannot fully accommodate the demand. The road user considered only the industrial employees, while the others road user profession is not considered. The emissions considered

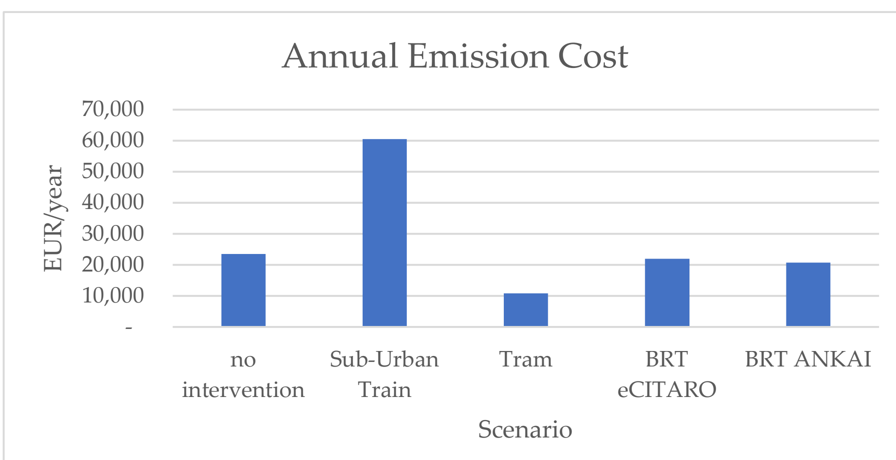


Figure 4.23 Annual cost emission for each Scenario

Tram shows the best result in emissions term among those scenarios, the comparison as figure 4.23, with the annual emissions cost around 10,790 EURO, while the highest annual emissions cost by sub-urban train with 23,523 EURO. This result only considers the population which work as industrial field, while there is more private vehicle user that work in other sectors, therefore the emission annual cost of non-intervention scenario is higher.

III. Operator

The operator cost benefit by reviewing the operational cost, and the cost for travel per passengers compared to the expected cost by potential user, the expected cost value which is the current ticket cost of public transport in the study area.

Transport Mode	Ticket Price [EUR]	Expected Ticket Price [EUR]
Sub-Urban Train	1.82	0.35
Tram	0.93	0.2
BRT eCitaro	0.38	0.2
BRT Ankai	0.42	0.2

Table 4.31 The comparison of expected ticket price and the ticket price based on the operational cost

The scenario ticket will follow the scenario ticket price of region that already has the same public transport. The sub-urban train scenario adopts same ticket price as KRL Jakarta, which is Rp 3,000 for first 25 km, and will add Rp 1000 km for next every 10 km, while for Tram and BRT adopt the ticket price like BRT Transjakarta ticket price based on the hour, with the price Rp. 2000 in 05.00 – 07.00 am, and the other hour as Rp. 3500, this different price by means to distribute the user in the morning time / peak hour. Based on the expected ticket price, from operator point of view, the expected ticket price is too low, and it a loss for operator, but in term of government, increasing quality of life in term environmental conditions, tram and BRT Ankai is good solution, so the subside is an option to implement new public transport.

IV. Safety Impact

The safety impact analysis by quantifying the accident number based on the level of injury or impact after accident, the paper by Gito Sugiyanto, about the lost due to accident based on the casualty severity of accident, which are fatal injury, severe injury, and property damage only[36]. The accident cost include cost to repair the vehicle, loss of productivity, medical expenses, administrative expenses, etc., the cost of each casualty severity accident shows in table 4.34.

Casualty Severity	Fatal Injury	Severe Injury	Minor Injury	Property Damage Only
Cost [EUR]	17,273	792	125	100

Table 4.32 Loss Cost Due to Accident [36]

The data related accident number come from Indonesia Police data in 2019, the accident data is national data, to obtain the number incident data in study area, by assuming that the proportional of accident rate for casualty severity is same with national data, so the data related how many cases can be obtained. Based on the loss cost data, the current condition without any intervention, the lost due to accident cases is 46,443,358 EUR, by intervention new public transport, the lost percentage reduction due to accident cost can be seen as figure 4.24.

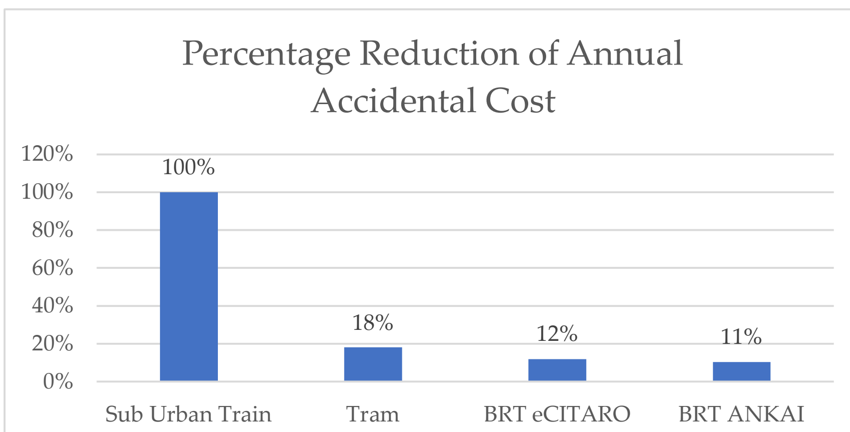


Figure 4.24 The intervention effect to the accident lost in study area

The loss reduction due to accident shows variation for each public transport mode, the level percentage depend on the how is the performance of public transport can accommodate the potential demand per day. Sub-urban train has highest passenger capacity and can fully accommodate the demand per day, while the tram and BRT unit, has limited capacity and headway, so it's not possible to accommodate all the demand.

4.5 NPV and Cashflow analysis

The project economic analysis carried out by NPV analysis and the cashflow analysis. NPV can be defined the value of the project in certain time as the result of summation discounted benefits and cost of project. Cash flow is part the NPV component, the discounted benefits in NPV are the one used in cash flow analysis. Net present value (NPV) refers to the difference between the value of cash now and the value of cash at a future date. NPV in project management is used to determine whether the anticipated financial gains of a project will outweigh the present-day investment, meaning the project is a worthwhile undertaking. Generally, an investment with a positive NPV will be profitable and therefore given a green light for consideration, while an investment with a negative NPV will result in a financial loss and may not be undertaken.

The cash flow is the result of discounted total benefits of scenario, the benefit value is the summation of the benefit received by ex-private vehicle & daring user, operator, environment, and safety of travelers, all the benefits from the project has been analyzed in previous sub chapter. The discount rate by Asian world bank state that the value should between 10-12%, in this research the discount rate used is 12%, and assuming that the general lifetime of all components of project are 35 years, while used by 30 years, by using straight-line depreciation method, obtained the residual coefficient as 14.29%. so, the cash flow analysis for each scenario can be seen in Figure 4.25.

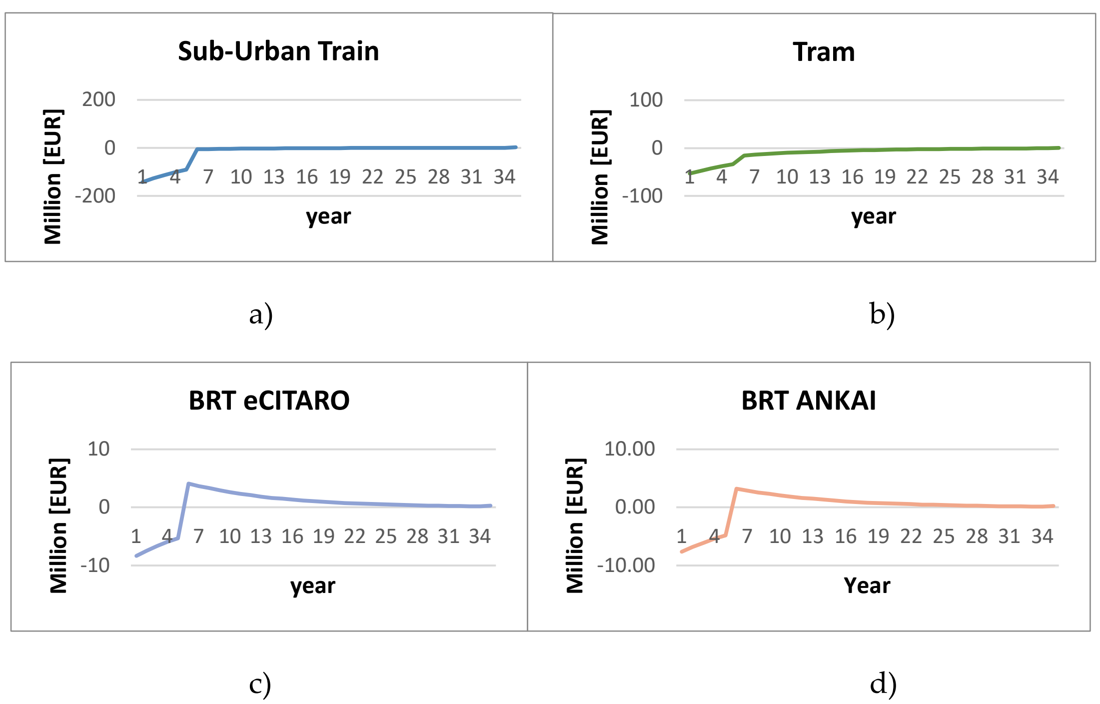
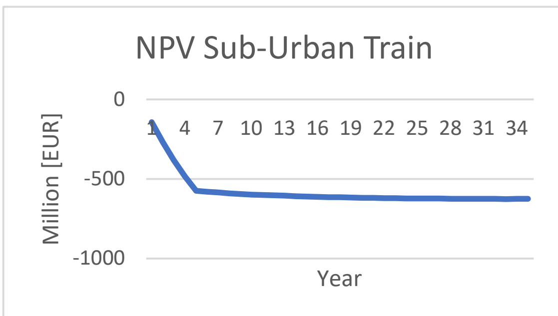


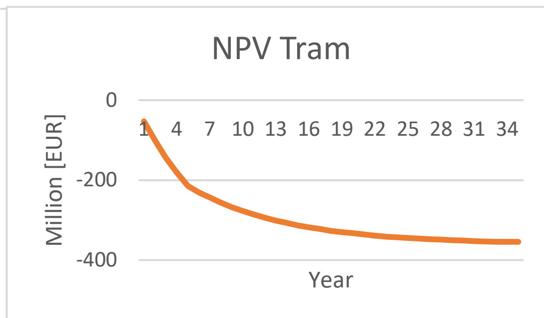
Figure 4.25 a) sub-urban train, b) tram, c) BRT eCITARO and d) BRT ANKAI, the cash flow of project in 35 years

The cash flow graph shown that the sub-urban train has negative cash flow, since the operator has big loss due to expected cost is much lower than the ticket price based on the operational cost, the benefits from safety and environment is not high enough in this project, while the BRT scenarios for both type bus has positive cash flow even though the operator has loss but the benefits of environment and safety is comparable to the loss of operator, so can give positive cashflow.

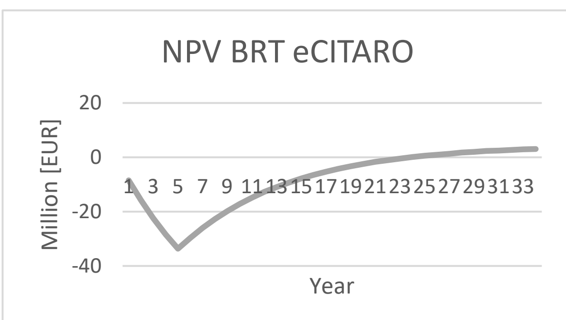
The net present value calculated by multiply the discount factor with the benefits obtained for each year and considering that there is residual value in the end of project lifetime, since assume that the project lifetime is lower than actual. The NPV can be seen as Figure below.



a)



b)



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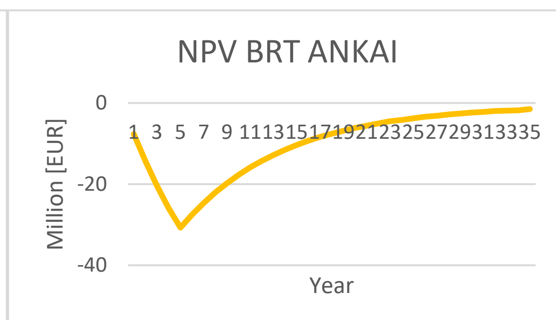

d)

Figure 4.26 The NPV of each scenario, a) Sub-Urban Train, b) Tram, c) BRT eCITARO, d) BRT ANKAI

The NPV from all the proposed scenarios can be seen on the above Figure, only BRT eCITARO has positive NPV, while the other scenarios have negative NPV, the negative NPV shows that the project will have loss in the future if adopts the project. The BRT eCITARO has positive NPV after 24 years project lifetime, or after 19 years project operation, which is only has 11 years of positive NPV considered the project lifetime 35 year, the biggest lost mostly due to ticket price, there is possibilities to have earlier NPV if the government subside the ticket price, so the biggest (Operator loss due to higher ticket price).

5 CONCLUSION

The idea to solve mobility problem from study area into industrial area by proposing some scenarios as solutions. Furthermore, the scenario only solves the mobility problem, the new public transport expected to improve the safety and the environment conditions, based on the analysis in the previous chapter, can be conclude as each proposed idea as below.

Sub-Urban train has very high capital cost even though the rolling stock use the ex-used from Japan, which is totally free, only pay for the delivery cost. The operational cost of Sub-Urban Train is very high compare with the other scenarios, which mostly caused by high energy consumption. Beside has high operational cost, the service performance (the level of accommodated passenger) is 100%, in term of industrial employees in peak hour, with this service level the accident cost benefits is very high, since can accommodate more the ex-private vehicle user, in other hand the environment has big issue in this scenarios, by analyzing with Well to Wheel method, instead of gives reduction related with the emission level, it has higher emission level, since the emissions of the power plant to generate the energy required is very high, so the good point of sub-urban train is on the user mobility only, by providing better access to industrial area.

Tram has capital cost similar with sub-urban train, since the new rolling stock is considered, while the operational of tram is lower than sub-urban train. The significant component in tram operational cost is the energy consumption. The level of service of tram is 27.5%, so the effect of safety by reducing the number of road user is low, but in term of environment, it reduces the total emissions generated, combining by the non-accommodate passenger and the tram emission, is lower than scenarios 0, the reduction of emissions is 54% from scenario 0, while the accident cost level which is depends on the level of service, it show 18% reduction, higher service level show higher accident cost reduction, even though in term of emission tram show very good performance but the high capital cost has significant effect, since the NPV never be positive until and of project life.

BRT shows very low capital cost compare with tram and sub-urban train scenario because the infrastructure cost much lower. The rolling stock has two option which has similar characteristic related with rolling stock cost and passenger capacity, the options area eCITARO electric articulated bus and ANKAI electric double deck bus. BRT eCITARO has higher service level which is 20.9% while ANKAI's is 17.17% due to has higher passenger capacity. The accident cost reduction aligns with the service level, with lower than tram and sub-urban train service level, accident cost reduction is low, which are 12% for eCITARO and 11% for ANKAI. The environmental effect of BRT scenarios with eCITARO shows the affect 7% emission reduction from scenario 0, while ANKAI's is 12%. The NPV of BRT eCITARO is positive in year 24th, from the first-year construction, while for ANKAI's NPV never become positive, in other hand ANKAI has better performance in reducing the emission.

All the proposed scenarios have negative NPV except for BRT eCITARO. Meanwhile in operator point of view, all the proposed scenarios have no benefits. Consider The accident cost reduction, Sub-Urban Train has the best performance. In other hand Tram is the best in terms of emission reduction, but for the far future when the Indonesia has green power plant, in term of environmental and safety, Sub-Urban Train is the best option. Furthermore, if the government want to implement one of the proposed scenarios, subside in ticket price is mandatory.

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List of Acronyms

Acronyms	Description
BPS	Badan Pusat Statistik (Central Bureau of Statistics)
DIMI	Deltf Deltas Infrastructure & Mobility Initiative
BRT	Bus Rapit Transit
LRT	Light Rail Transit
SIER	Surabaya Industrial Estate Rungkut
SiRIE	Sidoarjo Rangkah Industrial Estate
NIP	Ngoro Industrial Park
EPZ	Export Processing Zone
KCI	Kereta Cepat Indonesia (Indonesia High Speed Train)
IC	Internal Combustion
GDP	Gross Domestik Product
MJe	Mega Joule Electric
JRC	Joint Research Centre
KRL	Kereta Rel Listrik (Electric Train)
NPV	Net Present Value

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