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Urban Railway System for Sustainable Development in Urban Area

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<p>The aim of this thesis was to study an urban railway system for sustainable development of a metropolitan area. The thesis studied a basic type of municipal railway and its implementation by, first, studying two well-developed urban railway systems, and second, applying an observation to an area struggling with unsustainable, insufficient public transportation.</p> <p>The two developed areas studied were Helsinki and Singapore, both with successful public transport systems that have brought sustainability to the community. The thesis studied how the system were built and run, collecting information about the technical solutions and passenger services.</p> <p>The thesis applied the data learned from the two developed systems to a plan drafted for an urban railway system for Cebu island in the Philippines. An implementation plan, a plan for running and future expansion of the system, and an analysis of how the system would contribute to the development of the area were analysed. It was established that an urban railway system would improve the living quality of the residents there and help Cebu island, a hot point of tourism, attract more tourists.</p> <p>The thesis can be used as a starting point when planning an urban railway system for an area with insufficient public transportation.</p>	
Keywords	urban railway, sustainable development

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List of Abbreviations

HSL	Helsinki Region Transport
MRT	Mass Rapid Transit
LRT	Light Rail Transit
LTA	Land Transport Authority
PTC	Public Transport Council
BIM	Building Information Modelling
CAD	Computer-aided Design
CBTC	Communications-Based Train Control
AC	Alternative Currents
DC	Direct Currents
BRT	Bus Rapid Transit

1 Introduction

1.1 History of urban railways

An urban railway system is basically a renovated version of a regular railway, adjusted to be used in municipal regions as a means of public transport. The first railway was invented for more than 2000 years ago. The horse and wagon combination wastes energy. Therefore, a stable path with two parallel lines for wheels was built. It was called a *wagonway*. This way, a bull or a horse could pull a wagon or cart easier. One of the oldest wagonways still exists in Greece. [1.]

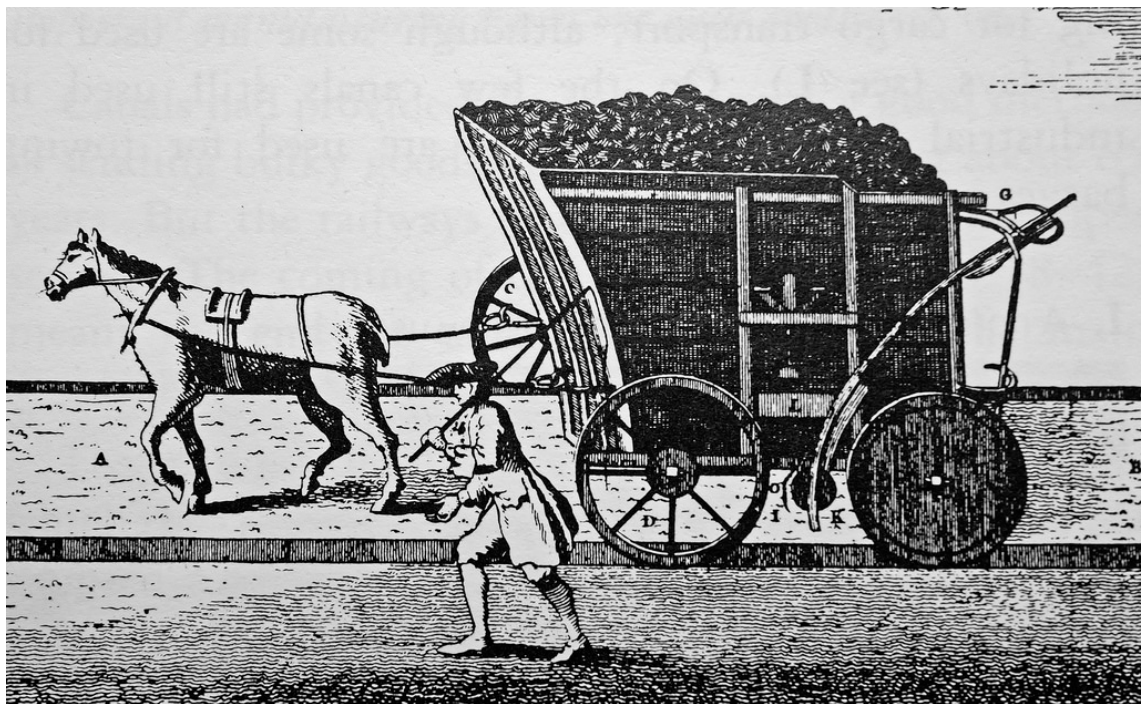


Figure 1. Example of Wagonway [2]

In 1803, the first 14-km public railway was opened to transport goods, run by horse. The first railway was launched in England running a 12.9-km route between Stockton and Darlington. The engineers of this project were George Stephenson and Edward Pease. The main purpose was to experiment replacing the horse which was still being used widely at that time, with a steam engine system running on railway. [1.]

The first locomotive railway was launched in 1825 in Britain, followed by the US. In 1881, with the development of electricity industry, a tram system was opened initially in Berlin. After nine years, London was the first city in the world to have an underground railway system. [1.]

Now, a railway system has become one of the most important means of transport. Furthermore, the speed of a train has increased dramatically through the times. The maximum speed of an electric train was 515 km per hour in 1990. The largest urban system with 278 stations is in Shanghai. [1.]

1.2 Types of urban railways

In general, there are four types of urban railway systems. The first type is a tram which can run along a street. A tram system is operated in a metropolitan area with short distances, and the speed must be under 50 km per hour. The tram system is widely used around the world, especially in Europe and North America. Since it is operated in crowded cities, a tram only carries 1 or 2 units. [3;4.]

The second type of urban railway systems is a Light Rail Transit (LRT). The LRT has multiple units and a higher speed than a tram. Therefore, its capacity of carrying passengers is also larger. The LRT operates in urban centres at a longer travel distance than a tram. The LRT is connected with long distance trains. The LRT is more common in Asia and North America. [3.]

The next urban railway system is a rapid train. It has different names in different countries such as metro or MRT (mass rapid transit), and operates mainly in the city centre. The speed of the rapid train can exceed 100 km/h. The rapid train system can run about 20-30 trains per hour and its total hourly capacity is 20,000 to 50,000 passengers. It can carry multiple units together, and it has its own separate railway. A rapid railway is usually located underground in the city centre and goes up in sparse areas. [3.]

The final type of urban railway systems is the commuter train. The commuter train operates from an urban centre to a remote area. It can connect with a long distance train to

another region. The commuter train has multiple units and can carry large amounts of passengers. [3.]

2 Implementation of urban rail system

The implementation plan of an urban rail system is seen as one of the highest investment costs in a city. The plan plays a crucial role for the development of a whole region once the construction is completed and put to use. An urban rail project has to be calculated carefully on the basis of four key considerations: improved accessibility, economical aspects, environmental and social benefits. These key elements are based on the concept of sustainable city standards for transport. A plan for the urban rail system has three main steps:

- Evaluate and adjust the project, according to passenger demand, future development, and social impacts in order to optimize the operation of the system.
- Create a management plan to monitor and process the construction from beginning to ending, including the launching of operations.
- Assign civil work to construction. This step is related to the decision of the structure and design of the urban rail system, i.e. the rail system, stations, and internal design. [5.]

2.1 Evaluation of urban rail project for a city

An urban rail is a huge investment for the urban area, not only as a public transport system but also as a long term development of the whole area. Therefore, the project plan has to be considered carefully before it is processed. The project will carry on together with the development of the municipal region. The plan needs to be adjusted according to 5 key factors: population density, city growth plan, environmental status, local geography and local transport system. The factors will affect the success of the project directly. [5.]

In every large city such as Singapore, Shanghai or Hong Kong, it is necessary to estimate the potential number of passengers correctly based on 3 factors which are socio-demographic characteristic of population, geography, and urban plan of land policies.

The sociodemographic characteristics include the density of population, living costs, income, employee situation, gender, age and even the transport culture. These factors are used to estimate the number of travelers. Then, a planner needs to define different segments of passengers and see their demand in order to decide the types of trains, railway, stations and distances for traveling. Understanding a social situation will help the planner decide a suitable strategy to maximize an operation of railway system. For instance, when it comes to employee preferences, when a railway system is ready, it has to offer a competitive travel time for the railway and public transport system compared to the regular method of transport such as a car or motorbike. By defining common traveling destinations of passengers, a planner can decide the right location and distances for the urban rail system. In case of density, urban system planners have to outline where the highest density of population is in order to fulfill a capacity of the train running through that area. To sum up, the sociodemographic characteristics of the population are one of the most important factors to improve the efficiency of the operation in an urban rail system. [5.]

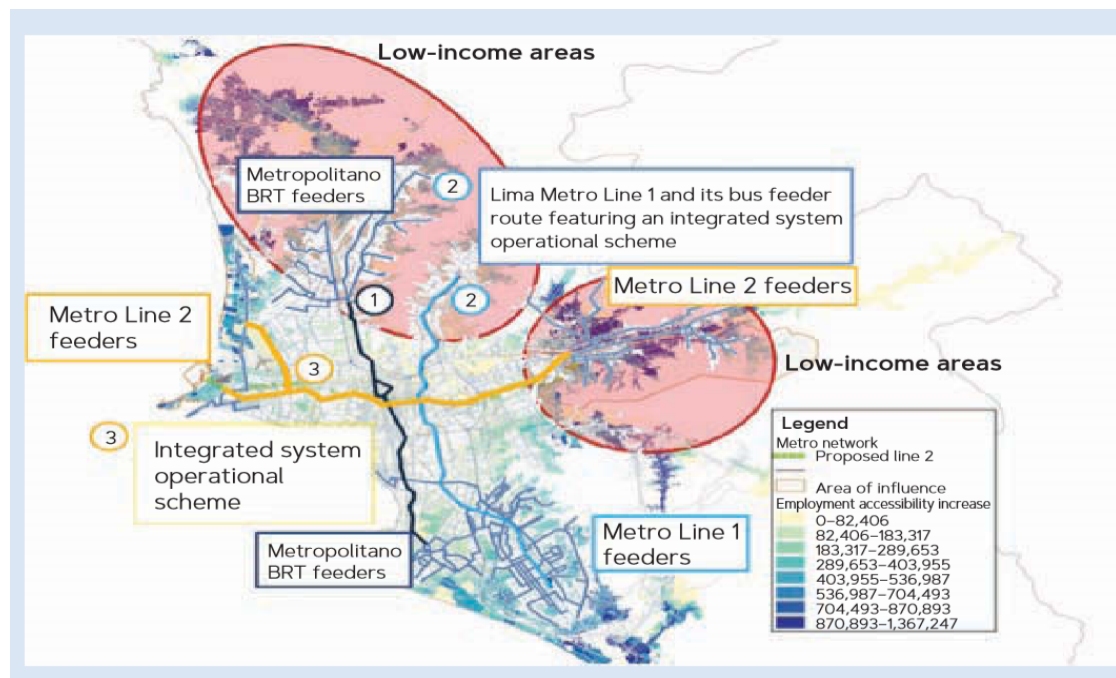


Figure 2. Metro system in Lima, Peru [5]

Figure 2 above shows that the metro lines 1 and 2 in Lima, Peru have been designed and divided into various branches. The purpose is to reach high population density areas. The map displays a significant increase of low income area usage. [5.]

The second factor to consider is geography. It includes the infrastructure, location of the urban area, soil structure, etc. Due to the large investment on the project, the geography of the project needs careful consideration for sustainable purpose. In urban areas, the infrastructure is the main problem when locating a railway. Because most urban land has often been used for buildings and roads, it is difficult to have extra space for railway. Therefore, it needs to be planned meticulously. A new system must not affect or damage the present infrastructure. Some urban railway project runners decide to replace old infrastructure with a new railway system. An underground railway system is widely used to avoid unnecessary replacement of infrastructure, especially in crowded urban central area. [5.]

An urban location has its own geographical problem, especially the weather and natural disaster. For example, Japan is located along the pacific ring of fire. That leads to a problem with possible disasters such as earthquakes or tsunamis. The planner is required to use the right technology for a railway system in order to reduce risk due to disasters. [5.]



Figure 3. Earthquake damage in Japan, 1995 [5]

The damage, caused by an earth quake in Japan in 1995 (figure 3), is worth 100 billion US dollars. Because of this disaster, Japan launched a new law for building standard with two levels, life safety and damage limitation. The law is to ensure life safety against annual earthquakes in Japan. In 1998, all railway systems in Japan had adopted a performance-based design code. [5.]

The last factor that must be taken into consideration when planning urban railway systems is city council plan and land policies. In developed areas, the urban railway should be located along important social structures, such as hospitals, schools or stadiums. Planners choose the location for stations and construct railway based on those social structures , together with a number of demands. Furthermore, every urban railway has its own extension plan that follows the population growth. Therefore, the urban rail expansion plan always sticks to the city's future development project. The purpose of the railway is to help the residents reach social places easily. [5.]



Figure 4. A bridge crossing Tagus river in Lisbon, Portugal [5]

A bridge across Tagus river in Lisbon, Portugal was launched as part of the city's project of distribution population (figure 4). The bridge was first used as a highway, but in 1999, a new railway system was added below the highway system. The bridge was strong enough to carry both railway and highway. The project helped the city reduce the cost for railway expansion because no new bridge has to be built for the railway. [5.]

The evaluation of urban railway project will be carried out for final decision. Moreover, it helps the project and its construction team choose the right method to run the process. It also reduces the cost significantly, prevents risks and other damages which might affect the structure of the city, especially some cities with cultural values such as Rome, Paris or Beijing. [5.]

2.2 Management plan

In some developing and low-income countries, an urban railway project could be among the biggest in the country's history. The cost might take a large portion of the country's budget; some countries even have to loan money to complete the project. That is why the role of managing group is very important. The real cost of some urban projects has been more than 50% higher than the budget forecast. For example, the estimated cost of the Virginia railways in the US connecting Washington DC to Washington Dulles International Airport were around 975 million US dollars. However, when the project was completed, the total cost reached 3.14 billion US dollars. This extremely high cost resulted from an inexperienced projector leading to a delay of the process [5.]. As many troubles could happen during a project such as cost increasing, schedule delay or change in scope, requirement for experienced manager is compulsory.

Well-organized management is the first factor that needs to be considered. Because an urban railway project requires a high investment, it is imperative to have experienced and skilled managers, advisors, engineers, and architects. Each group in the project team must be highly responsible for their work. However, in a complex project such as an urban railway, unexpected problems cannot be avoided. That is why the whole team always needs to communicate openly. Engineering and management are totally different fields, and the manager does not always have enough knowledge to solve an engineering problem. On the other hand, engineer works directly at a job site, and can give advice to manager about their professional matters. The communication between the involved parties will aid the project to run successfully. A project should follow the planned schedule and be ready to solve any unexpected problems that may happen. [5.]

To optimize processing time of a project tools like BIM can be used. *"BIM is the process of designing civil engineering works collaboratively using one coherent system of*

computer models" [5.]. By applying BIM to a project, the efficiency of the work load during the project can be improved. All information about the physical structure, structural elements, schedule, and work changes are always updated and shared between all stakeholders of the project who are project manager, architects, engineers or contractors. BIM is an open process that allows all involved parties of a project to contribute their ideas and improve the quality of the construction. BIM helps stakeholders to find and solve any errors due to information loss or wrong estimation. Stakeholders can redo the work to optimize the project process in the fastest way. The use of BIM includes both new technology and a collaborative process. The level of collaboration can be calculated on a scale from 0-4 level. [5.]

- Level 0. There is no collaboration. The 2D CAD draft is used and distributed by normal paper or electric prints. Most construction companies passed this level. [5.]
- Level 1. 2D and 3D CAD are used together. 2D is used for statutory documentation and 3D for concept work. There is a common data environment where all the data is submitted and controlled by a contractor, but it is not shared to other team members. This is the most common level at the moment. [5.]
- Level 2. All parties use their own standard 3D model and share through a common file format. It allows all parties to combine and test the design based on this collaborative and standardized data. [5.]
- Level 3. An opened BIM. A centralized repository is created in order to collect the models of all disciplines. All parties have a right to access and modify the model. [5.]

With a good management plan, a project is well organized and runs on time, preventing extra cost and time consumption.

2.3 Designed features and options for urban railway system

The designed work load of an urban railway system includes civil works, rolling stock options and general system during an operation which is signaling, telecommunication or ticket control and fare collection. The design work collects the data from the first evaluation survey analyzed by experts from the technical team in order to decide which design would be suitable for the urban area. The decision is made and adjusted carefully by all involved parties. All factors are considered and discussed for the final design. The final design is supposed to be not only suitable for the present demand, but also flexible for a long term. As an urban rail system has a lifetime at least 100 years, it should be possible to increase passenger capacity according to a future need or a connection with future infrastructure of the city. Furthermore, the design needs to ensure its endurance for maintenance and expansion. A flexible urban railway design will contribute to the development of the urban region in the most economical way. [5.]

2.3.1 Infrastructure and Civil work.

On stage, the civil engineer needs to cover numerous aspects like alignment of urban rail system by horizontal or vertical, track, station and terminal, railway yards and support facilities before moving on the next stage [5].

Alignment

The urban rail system alignment has two features, vertical and horizontal. The horizontal design covers the route through the city to desired destinations as planned. The vertical alignment means the location of railway system either at ground level, elevated or underground. Each option has its own advantages and disadvantages (table 1) depending on the project's characteristics, such as budget, city plan or present infrastructure, so that the engineer can decide which alternative is the most suitable.

Table 1. Advantages and disadvantages of alignment options [5]

Options	Advantages	Disadvantages
Ground level	<ul style="list-style-type: none"> - Cheapest. 	<ul style="list-style-type: none"> - High land acquisition cost. - Most disruptive to surface traffic (vehicles and pedestrians). - Creates noise, vibration and some visual impacts. - Requires plenty of land for operation.
Elevated	<ul style="list-style-type: none"> - Typically more expensive than ground level option, but cheaper than tunneling. - Less disruptive to surface than ground level. - Less vibration. - Requires lower land than ground level options. 	<ul style="list-style-type: none"> - Requires extra method for vertical access. - Higher cost of maintenance than ground level option. - Noise impact.
Underground	<ul style="list-style-type: none"> - Offers flexible operation and expanding. - Does not affect the surface area. - Less noise. Smooth operation. - Reduce weather effects. 	<ul style="list-style-type: none"> - Highest construction, maintenance and expansion cost. - Costly operation due to extra equipment such as ventilation, lighting or elevator system.

In most crowded urban centres, the underground system is the most common since it does not require land for construction. It is completely suitable for an old European city. For an area outside the centre with less infrastructure and density, the ground level and elevated options are likely to be more suitable. [5.]

The horizontal design of a railway has to be calculated carefully. The horizontal alignment creates a router network for urban rail. The urban rail network needs to be well connected in order to shorten the distance from each station and to be available for expansion in case of required development of the city. Furthermore, it has to avoid areas that may require substantial environmental mitigation. For example, an urban rail system through an existing gas station would cost highly for the remediation of contaminated soils. [5.]

Track

The track layout is another factor that needs to be considered carefully. Because the urban railway project lasts long and the system is used for a long time, the track layout is the key to the success of the operation. Moreover, a right track layout can help the future expansion. There are three types of track layout which are track gauge, auxiliary track and track bed. A track gauge is the space between two inner faces of load-bearing rails. An auxiliary track is used to change the direction of a train or to give the train more running options. A track bed is the ground floor for railways, it aims to reduce stress on the subgrade. Table 2 below shows the advantages and disadvantages of options of each type. [5.]

Table 2. Advantages and disadvantages for track options [5]

Feature	Options	Advantage	Disadvantage
Track gauge	Standard UIC gauge (1,435 mm)	<ul style="list-style-type: none"> . Popular around the world. . Various choices for off-the-shelf rolling stock and equipment. . Reduce cost. 	<ul style="list-style-type: none"> . Not suitable for a development of greenfield projects.
	Nonstandard gauge	<ul style="list-style-type: none"> . Flexible to expand. 	<ul style="list-style-type: none"> . High cost. . Expensive in maintenance.
Auxiliary Track	Pocket tracks	<ul style="list-style-type: none"> . Easily merge all with a system that could adapt high operational capacity. . Flexible to distribute shift in case of incident. . Offers temporary free space for disabled trains. 	<ul style="list-style-type: none"> . Higher cost for implementation.
	Passing track	<ul style="list-style-type: none"> . Increases flexibility during operation by allowing two trains in the same or opposite direction to pass each other on the same railway line. 	<ul style="list-style-type: none"> . High cost and creates possibility of accidents.
Track bed	Ballasted	<ul style="list-style-type: none"> . Highest cost with wood material . Lowest cost with concrete 	<ul style="list-style-type: none"> . Maintenance cost, concrete more expensive than wood.
	Fixed slab	<ul style="list-style-type: none"> . Widely applied in tunnels. . Reduces vibration during operation. 	<ul style="list-style-type: none"> . Higher cost than Ballasted option. . Short life cycle. . Need extra path in case of emergency
	Floating slab	<ul style="list-style-type: none"> . Less vibrated than fixed slab 	<ul style="list-style-type: none"> . Highest cost

The application for each type has to be flexible. For example, with track bed options, a designer needs to choose a mixed solution. When a train runs fast and needs to pass a crowded living area, a floating slab is required in order to reduce noise. In contrast, ballasted tracks are ideal for low speed trains. The right solution for track layout could help a project reduce cost but also to improve its efficiency during operation. [5.]

Stations and terminals

The design of station platform is to be done so that it serves passengers in the most convenient way. The total time for an urban railway travel is calculated from the point when a passenger reaches the station to the point the passenger gets out of the destination station. The most convenient station platform layout reduces the walking time for passengers. There are 4 typical types of platform as seen in figure 5: center, side platform, split platform and flow through platform. [5.]

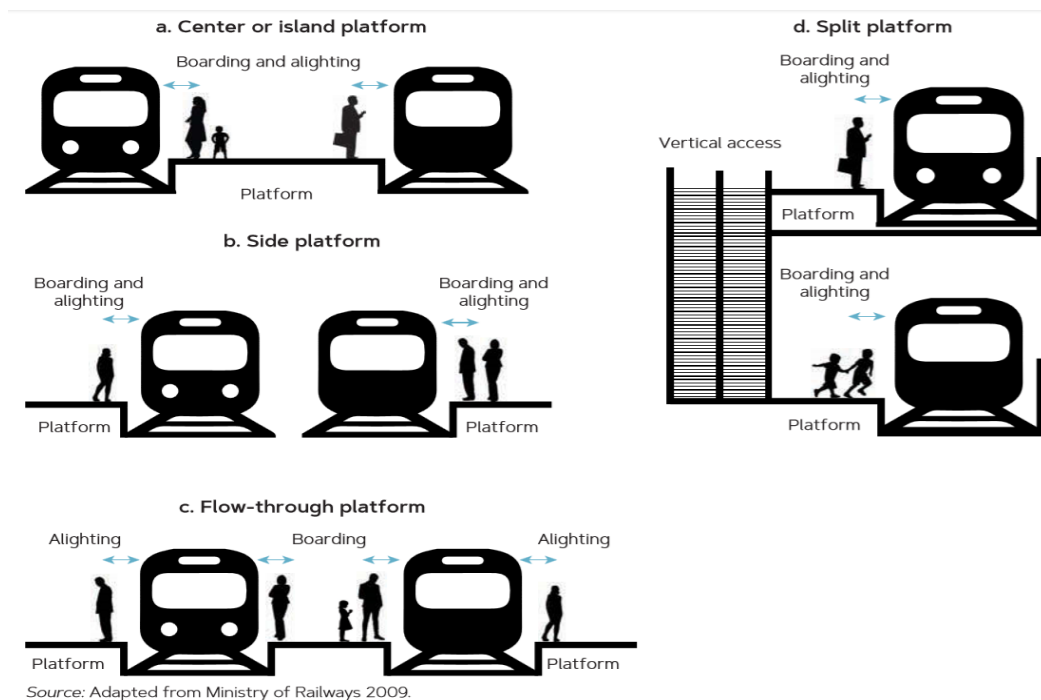


Figure 5. Types of station platform layouts [5]

The most popular types of platforms are the center and side platforms. The center platform design especially allows system to serve an unbalanced number of passengers who get in to and out of the train. Passengers can easily go directly to the next train

rather than the other options. However, in general, the design depends on the requirements of the project so that all functions of the system are maximized and the cost is reduced. [5.]

Platform shape, platform screen doors and other activities at the station of each type of vertical access are different (table 3).

Table 3. Features of station and terminal design [5]

Vertical access	Platform shape	Platform screen doors	Other activities at the station
Escalator	Shorter platform	Half height	Joint development
Elevator	Longer and wider platform	Full height	In-station commercial space

Vertical access is a part of transferring the flow of passengers. The most important rule when choosing the right method for vertical access is that it has to contribute towards efficient circulation. The role of vertical access is especially important for underground station so that a passenger can quickly access the target train. Nowadays, escalator and elevator methods are applied to underground railways. Most of passengers use the escalator while an elevator is available for disabled persons, passengers with heavy things to carry, or baby trolley to push, etc. [5.]

Rail yard and support facilities

The purpose of them is to serve rolling stock maintenance facilities and to accommodate the service of rolling stock [5]. The rail yard is primary location for train maintenance and it serves as industrial area. Hence, it should be located properly according to two demands: firstly reducing the negative impacts on residential areas such as noise, vibration or traffic, and secondly having an ability to expand in the future. The location can also be constructed underground. The location of a rail yard should be

decided thoughtfully for a long time project that can supply all the demands of urban rail system development. [5.]

2.3.2 Rolling Stock

For a design of rolling stock, the train has to rely on various features of standard. Table 4 below lists the most important options that needs to be considered and calculated so that the rolling stock is suitable for the project. [5.]

Table 4. Components and their standard in rolling stock design [5]

Components	Standards
Car width	Wider car (3.2 meters)
Number of Cars per train	Greater number of cars per train
Doors	Wide Doors
Type of connection between cars	Gangway or continuous corridor
Climate control	Air-conditioning and heating
Propulsion systems and regenerative brakes	Regenerative brake or power accumulation systems
Front end design	Aerodynamic front end
Car frame materials	Stainless steel or Aluminium
Maximum speed and acceleration	80-100 km/hour or 100-110 km/hour
Wheels	Rubber tires or Steel wheels
Advanced monitoring and maintenance systems	Train control and monitoring system

Table 4 shows the standards for rolling stock designs. The design team has to choose the most suitable options to apply on rolling stock. For example, rubber tire and steel wheel, each of them has its own advantages and disadvantages. Rubber tires help the train operate smoothly, with less noise and easily acceleration; however, it costs more in maintenance and power to operate the train. On the other hand, a steel wheeled train requires less power to operate and has lower cost of maintenance, but its track gradient is limited to 3%. [5.]

To sum up, there are many aspects that affect the design of urban rolling stock, such as location, the project's budget or future plan. The designer has to choose the best option for the rolling stock in order to optimize the operation of the whole system.

2.3.3 General operation system

An urban rail system has a centralized control system that decides the smoothness of the rail operation. It controls the train flow with number of passengers checked and stored in the system for all the stations. [5.]

Signaling and Control

A signaling and control system determines the design capacity of the system. In the peak hour, a metro system may require more than 30 trains per hour. In order to maximize the operation ability, most urban railway systems have applied communications-based train control (CBTC). CBTC reduces the safe distance between each train. The purpose is to increase the number of train operations during peak hours. The train's data is monitored by the control center. The implementation of CBTC proves the automation on 4 levels. From level 1, where a CBTC has automation ability to reduce crash and improve accident protection between two trains, to level four, where the auto ability is maximized so that there is no need of human control. The efficiency of the operation is enhanced and higher safe guaranty is confirmed. [5.]

Electrification power

Due to the high demand for electric supply during the operation of trains including facilities such as lights, air conditioning, the electrical system for an urban railway system has

to be set wisely. There are two options for the electrifications, overhead wires and a third rail together with two power supply options, AC and DC. The power installation should reach the safety requirement and be suitable with system infrastructure. [5.]

Telecommunication

There are three main options for telecommunication, Wi-Fi, cellular telephone network, and on-board communication system. An on-board communication system in a railway system should always be available for any circumstance which could be a short notice of delay from the operator or alarm from passengers. It is required for safety and security during operation. Each one of the numerous options has its own advantages and disadvantages, it is up to the designer to choose which one is the most suitable for the project.

Ticket control and Fare collection system

There are two types of ticket controls, a barriers-free design and a tap-in/tap-out design. In the barriers-free design, passengers can easily access the train. Some cities, such as Helsinki and Prague have applied it widely. The tap-in/tap-out design, on the other hand, requires passengers to input their ticket to open the entrance door and access the trains. That can reduce the number of passengers in peak hours. The tap-in/tap-out is used in densely populated areas like Paris and Brussels. [5.]

3 Contribution of urban railway to sustainable development

3.1 Helsinki region

The Helsinki metropolitan area is part of Helsinki region which covers areas such as Hyvinkää, Vihti, and Espoo. The total area of the Helsinki metropolitan area is 719 km², and the area of the Helsinki region is 5,523 km². In 2017, the total population of the city of Helsinki was 635,181 people and that of the Helsinki region was 1,456,619. The population density of Helsinki metropolitan area and Helsinki region are 2,934 and 379 people/m², respectively. [6.]

The urban railway system in the Helsinki region consists of three main systems, which are the metro, tram and commuter train. [6.]

The metro program was first discussed in 1955 based on the demand of long-term development in the city. The program was aimed to make the city's public transport more flexible and meet the requirement of city development plan. The city studied the transport system of other countries such as Germany, Sweden, and Denmark. The metro building started in 1969, and first stations were opened in the central of the Helsinki metropolitan area in 1982. [5.]

By this date, 25 metro stations have been launched. Of the 25 metro stations, eight were opened in 2017 to connect the Western part of the Helsinki metropolitan area to the network. [8.]



Figure 6. Metro line in Helsinki metropolitan area in 2018 [8]

There are five more metro stations currently under construction in Espoo [8].

The tram system of Helsinki was first opened in 1891 and it was run by horses until 1917. In the beginning of 1900, the first electrical tram was launched with journey from Töölö to Hietalahti [18]. There are 10 tram lines in the Helsinki center. [9.]

A railway was first used in 1862 from Helsinki to Hämeenlinna. The commuter train, developed from that very first railway, now becomes an important means of transport in the Helsinki region's public railway system. It serves more remote areas such as Vantaa, Espoo, Kauhajoki and even Tuusula and Kerava. In 2016, a railway to the Helsinki airport was completed. This not only increases the convenience and reduces the travel time for

Helsinki residents but also supports tourists with the simple yet cost and time effective method in travelling from the airport to the city. [18.]

Improving efficiency on public transport operation

In the end of 2017, the eight metro stations that were opened connected the Helsinki metropolitan rail transportation system to the Southern Espoo area. Together with the railway system, the metro system has linked the three most crowded areas in the Helsinki region. Moreover, the purpose of expanding the urban railway system is to maximize all the functions of public transport. According to a report by HSL, most buses in Helsinki, Vantaa and Espoo were linked to at least one metro or train station in the area in 2017. [9.]

Table 5. Number of passengers by mode of transport using HSL system in 2015 and 2017 [9;10]

	Bus	Metro	Train	Tram	Ferry
2015 (million)	182	62.9	56.5	55.2	1.9
2017	180.1	67.5	64.8	60.2	2.1

Table 5 shows clearly that in two years, the number of customers using public transport increased significantly. Especially the number of passengers travelling by metro and train increased, by five and ten million, respectively. The result shows the positive effect of new commuter trains and Länsimetro railway.

Keeping the passengers loyal to using the public system is a result of hard and constantly updated work by the HSL. HSL has provided the passengers with several easy methods of purchasing a ticket by both mobile and traditional ways for the metro, tram, bus, and train alike. The mobile ticket application is constantly updated to attract more users, and in 2017, more than 700,000 people used mobile ticket [9]. Every tram, metro and train station have automatic ticket machine for case passengers who want to purchase their ticket with cash or credit card. The central feedback system is constantly updated to receive the opinion of passengers as fast as possible by mobile or paper. In 2017, 60% of the feedback was positive. [9].

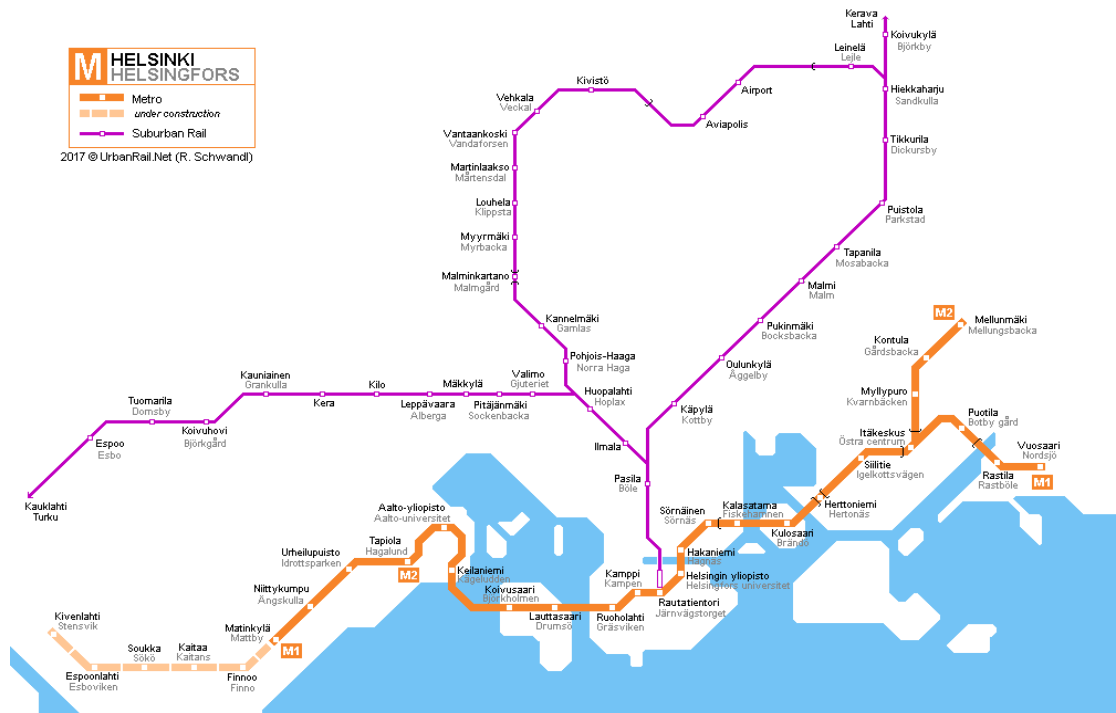


Figure 7. The urban railway system on HSL's map is main travel method in Helsinki metropolitan area. [13]

In the Helsinki metropolitan area, the urban railway systems (figure 7) had the main role in travelling. According to the HSL annual report of 2017, the metro, tram and train systems had a reliability level of more than 99%, and the satisfaction ratio was over 90% [9]. For example, according to the Direction function of Google Maps service, it takes 22 minutes to travel from Kamppi to Mellunmäki by metro, and 25 minutes by car without any traffic jams [14]. The long-term purpose of the Helsinki council is to expand the metro system, which belongs to the urban railway network, further, to the Espoo area within the Helsinki metropolitan area where there are more than 80% of residents living currently [6].

Environmental effect

Helsinki has become one of the leading European cities in eco-friendly travelling. Helsinki region reached its target on environmental quality due to the low increase in the number of cars registered during three years from 2015 to 2017 [11].

Table 6. The number of vehicles registered from 2011 to 2017 [11]

Vehicle stock by area on 31 December by Vehicle class, Area, Traffic use and Year

		Number of all vehicles registered						
		2011	2012	2013	2014	2015	2016	2017
Passenger cars	WHOLE COUNTRY	2,978,729	3,057,484	3,127,399	3,194,950	3,257,581	3,346,005	3,422,792
	Espoo	120,957	124,412	127,105	130,274	133,359	134,798	138,005
	Helsinki	240,175	244,178	248,583	249,158	253,528	260,301	264,901
	Vantaa	103,130	105,692	107,781	110,661	114,344	119,125	122,998

Table 6 above shows the strong effect of a railway and public system on the travelling habits of the people. The total number of cars increased slowly during the period 2011-2017 with the total number of cars in 2017 being 525,904 [11], compared to the population of Vantaa, Espoo and Helsinki which is 1,129,105 [6]. This number of cars per 1000 inhabitants is 465. Although the population of Helsinki, Espoo and Vantaa is 20,4% of the total population of Finland, only 15.3% of the total car stock is there. [11]

More than 190 million passengers used the metro system in 2017. The new metro line has contributed a significant amount to that. For instance, the Matinkylä metro station had in average more than 16,900 passengers daily. The new railway system has reduced the amount of bus users by more than 2 million passengers in 2017. Carbon emissions dropped by 2,800 tons in the same year, equal to 1,590 cars running. [9.]

An urban railway system has zero carbon emissions. Therefore, it improves the air quality in the whole area. Based on the website World Air Quality, the air quality index in the Helsinki metropolitan area is 42-53, reaching the safest level (<50) for breathing, according to air quality criteria. In London, the air quality index is 50-78, and in Frankfurt this number reaches 55-81 [15]. Those cities have been ranked in the top 10 on the list of best public transport in the world [17].

Social and economical effect

The five new more metro stations connected Espoo directly to the Helsinki city centre. The project links the regions closer together in all aspects.

Espoo was ranked as the most sustainable city in Europe two years in a row in 2016 and 2017. The metro connection between Helsinki and Espoo makes travelling between the two much faster. [16.]

A fast and reasonably priced transport system is beneficial for residents as it connects 3 of the most crowded areas: Helsinki, Vantaa and Espoo. It also has an economic effect because it encourages companies to choose the area for expansion, and gives more options for inhabitants when choosing workplaces with a short travel time.

3.2 Singapore.

Singapore is a small island located south of the peninsula of Malaysia, with a total area of 719.9 km². The population of Singapore in 2017 was almost 6 million people. Due to the small size of the area, its density is extremely high, more than 8,000 people per square meter. 100% of the population lives in the urban area. [19.]

The urban railway system in Singapore is divided into two parts, the mass rapid train system (MRT) and light train system (LRT). The LRT runs at low speed with short distances, and in high railway line. [25.]

The first railway system in Singapore was launched in 1869 [20]. In 1967, the first electrical railway system was planned and proposed to the City council. The purpose of this project was to connect the city centre, the working areas, and the residents' living areas in the easiest and most convenient way, and also affect positively to the environment [21]. In 1987, the first 6-km electrical MRT was completed and put in use [22].

In 1990, the construction of all stations was completed on schedule, and the North-South line as well as East-West line connecting all parts of the island were officially put in use. In 1999, LRT system was launched with 14 stations. The purpose of LRT was to shorten the travel distance and reduce the burden of the MRT. Figure 8 displays the MRT and LRT railway system in Singapore. All LRTs connect to MRT stations [36]. Nowadays, the total station number in the island is 52 [24].



Figure 8. The MRT and LRT railway system in Singapore [23]

Improving efficiency on public transport operation

When the first MRT was launched in 1987, Singapore public transport council aimed the MRT, or urban system, to be the core method of transport in Singapore. Other methods, like buses and taxis, were taken as a supporting solution to improve the quality of MRT. [25.]

To do that, the Singapore Land Transport Authority (LTA) department, apart of the Ministry of Transport in Singapore, was established in 1995. The LTA department is in charge of all transport issues in Singapore, including planning, maintenance, design and building. The LTA department has planned to double the length of the railway system in Singapore, and to reduce the demand of using a bus. In 2017, four new MRT stations were put in use, extending the MRT railway and reducing the time traveling by bus from the Joo Koon MRT to the Tuas link. The total travel time was reduced from 60 minutes by bus to 35 minutes by the MRT between Clementi and Tuas Crescent, and from 100 minutes by bus to 65 minutes by MRT between Ang Mo Kio and Tuas West Road. Futhermore, during the period of 2019 - 2024 and 2026 - 2028, the Thomson - East Coast line and Jurong Region line will be constructed to reduce the total travel time by 20 - 35

minutes. The purpose of the plans is to minimize travel times and to reduce the high demand of bus use. [26.]

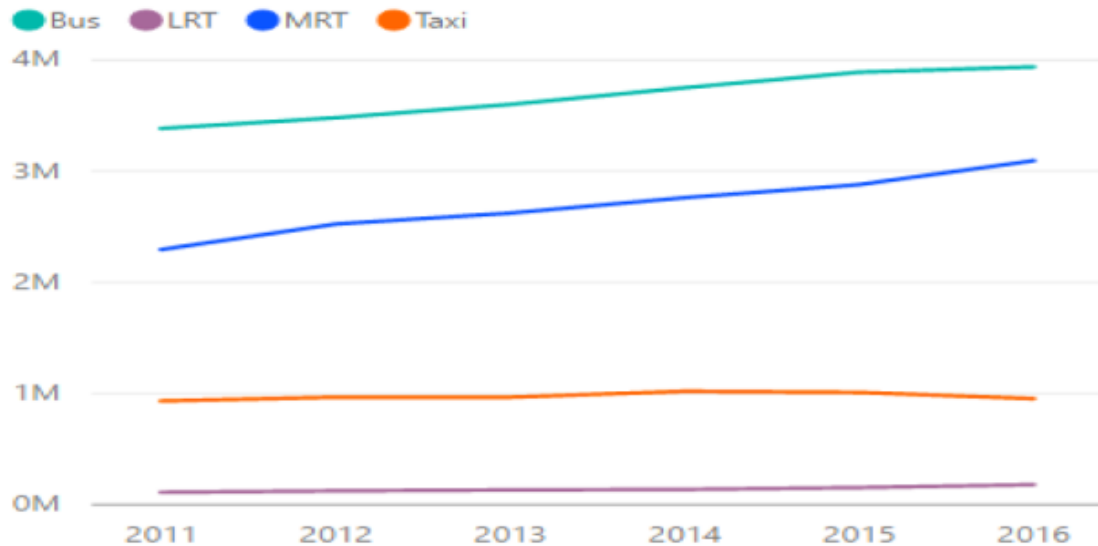


Figure 9. Average Daily Public Transport Ridership in Singapore [27]

As seen in figure 9, the most daily rides average in Singapore are done by bus, followed by MRT. The bus network only serves passengers for short distance travels and runs as a feeder system for the MRT and LRT network.

In order to help passengers to use the transport services easily, the Public Transport Council (PTC) offers more than 1000 ticket selling points including automatic selling machines and kiosks that accept both cash and card, around the city. Feedback from customers in 2017 was 94,5% satisfied with the service and hoped to use the service again and reports showed that 1,6 case out of 1000 found evading fare. Those numbers proved the success in management of the PTC and the satisfaction of the residents. Travelling distance of the MRT system was increased from 174,000 km in 2016 to 393,000 km in 2017, means 10 times around the earth at the equator, and travelling distance of the LRT system was increased from 49,000 km in 2016 to 65,000 km in 2017, which mean 6 times distance from Singapore to London. [25;26.]

The system was expanded with 200 new trains and 1000 buses between the years 2012 and 2017. Furthermore, the system ensures that the passengers have the most

convenient rides by applying near field communication software, electrical plug for charging phones on each train. [24.]

Environmental effect

Even though the GDP per capita of Singapore is in top 10 countries in the world (61,000 USD) [28], the number of private car owners in Singapore was one of the smallest of the world, with only 151 cars per 1000 inhabitants [29]. Table 7 below compares Singapore with 3 other cities with a very good urban railway system.

Table 7. The comparison between Singapore and other developed cities in April 2018. [28;30;31;32]

	Singapore	London	Seoul	Paris
Income USD per capita	61,000	44,200	32,000	45,000
Car per 1000 inhabitant	151	356	338	464

As seen in table 7, although Singapore has a higher income per capita, the number of car owners is only half of that in the other cities because of the high population density. Another main reason for this low ratio is the effective transport system with urban railways. In 2007, the total number of vehicles in Singapore was 850,000 and after 10 years, the total number was 961,000, which means an annual growth rate of only 1.1% [41].

Apart from a flexible service with various options in the urban railway systems, PTC aims at reducing the cost of the public transport service. All the cost for public transport in Singapore decreased slightly despite expansion of railways (figure 10). In 2018, Singapore public transport system was ranked as the best urban transportation system in the world and stood as the fourth lowest fare in the world. [33;34.]

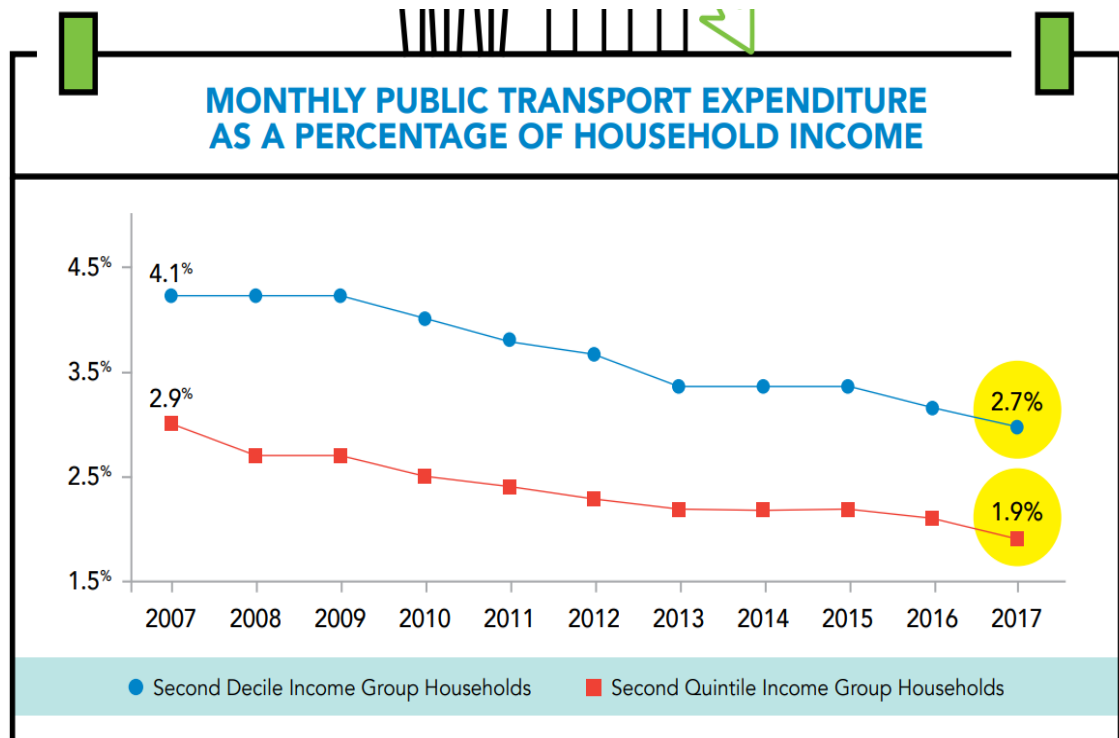


Figure 10. The monthly spend for household [25]

PTC's effort to focus on renovating the urban railway system has brought a positive result, as the main transport method in Singapore is public transport. As the result, the air quality index of Singapore mostly stays below 30 and rarely reaches 50 (<50 is considered a healthy air quality), compared to Jakarta (104) or Beijing (140-168) [15]. Just like the Helsinki urban railway system, the MRT and LRT have reduced the carbon emissions in Singapore significantly, resulting in the positive ratios above.

Social and economical effect.

The expansion of urban railway industry has created plenty of jobs. The LTA understands the demand on workforce in all aspects of their project including planning, maintenance, construction, etc. The requirement for labour will increase from 10,000 jobs in 2018 to 15,000 jobs in 2030 [26]. The urban railway industry will contribute at least another 5,000 jobs in Singapore in 12 years. In 2016, the LTA completed a training program for 1,000 trainees and granted professional degrees.

In 2016, Singapore was ranked as the top global center region, this resulted from tourism, economic development, connectivity, employment, ease of doing business and transport infrastructure index. Singapore was also ranked as the second in the

comparison of sustainable cities in the world. Its high ranking is due to the good index for mobility and connectivity in the city through MRT system and its expansion plan. [35.]

The LTA plans to extend the urban railway system to connect with their neighbour, Malaysia. The implementation of this project started in 2016 and it will be ready to launch in 2026. Passengers can travel directly to Kuala Lumpur, Malaysia with a new line from the Singapore MRT railway system. [26] With the new line connecting to Malaysia, Singapore will get more business opportunities and develop the economy of the country.

4 Urban system in Cebu

4.1 Cebu city

Cebu is an island which belongs to the Philippines with a total land area of 4,865 km² (figure 11). There are 3 large cities on the island, the capital Mega Cebu, Lapulapu, and Mandaue. In 2015, the population of Cebu island was 4,632,359 people and the density was 952.3 people/km². Cebu is one of the top developed regions in the Philippines with an economic system based mainly on commerce, trade, education, heavy industry, shipping. In the last 20 years, it is known as an attractive place for tourism with more than 2.5 million tourists per year. [37.]

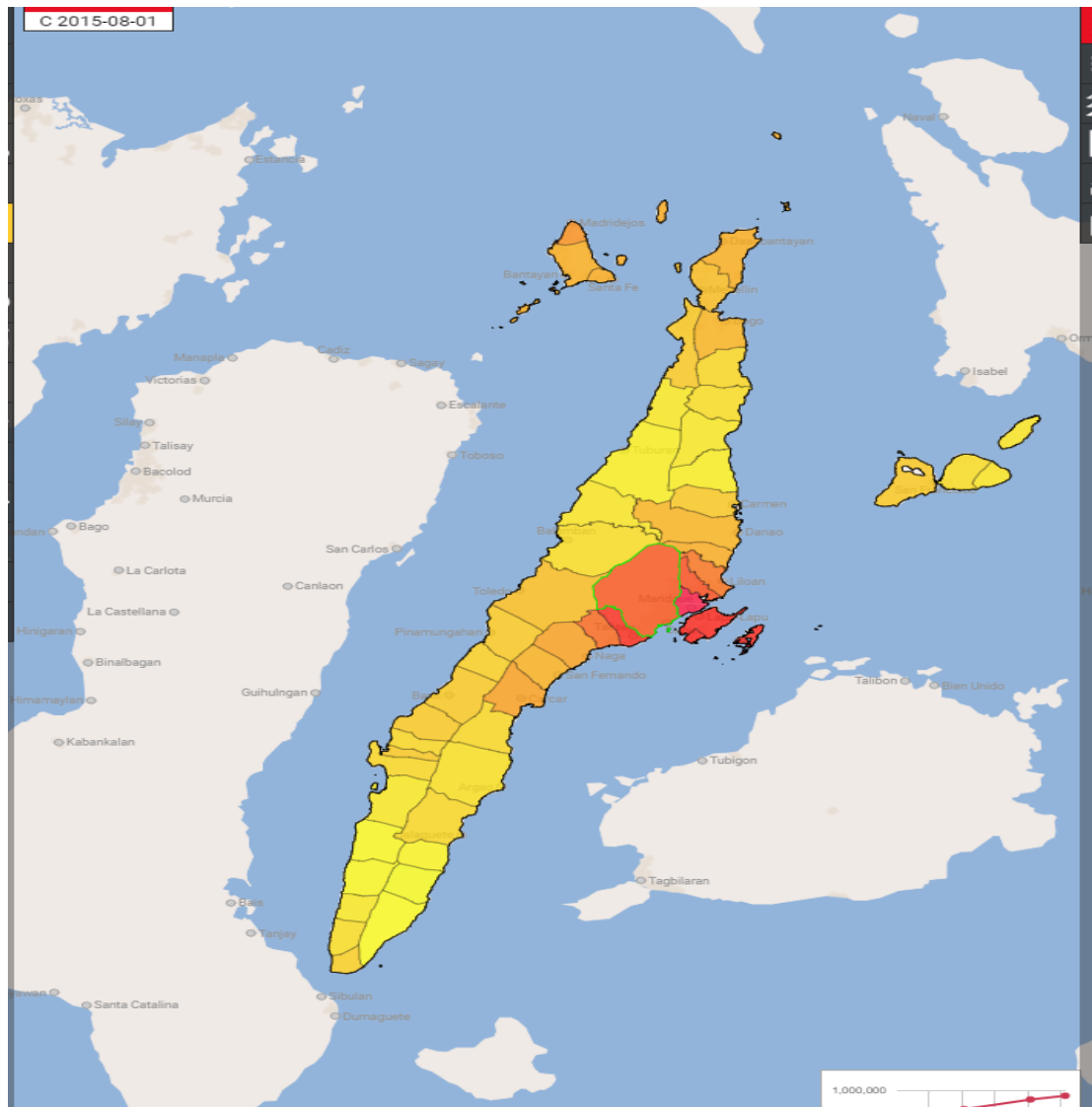


Figure 11: Cebu Island locate in the middle of the Philippines [37]

Cebu, as a large part of the Philippines, is divided into many small and isolated islands. The city governor is voted for in an election and controls all the power of the island. In general, the citizen of Cebu can speak the local language and English. [37.]

4.2 City Transport in Cebu

High population growth rate

The total population of Cebu island has increased rapidly from 2.6 million in 1990 to more than 4.6 million in 2015, an increase of 77% after 25 years with an average growth rate of 5.1% per year [37] compared to world population annually change always under 1,8% [38]. Despite the fact that the population density in total area of Cebu island is quite sparse, only 952 residents per km², most of the population lives in Mega Cebu city, Lapulapu, Mandaue, Talisay, and Toledo. The population density in these areas is a lot higher than in other places of the island: in Mega Cebu city 3,172 people per km² and in Talisay 5,406 people per km² in 2015. The reason is understandable. The residents tends to move to urban areas which account for under 20% of the total Cebu island area [37].

Traffic situation

The rapid urban population density growth rate and poor public transport lead to the problem that the traffic system mainly relies on private cars and motorbikes. The Mega Cebu transport infrastructure has been used for 30 years without any renovation. Besides the high population growth rate, the traffic jam rate has increased rapidly with the ineffective traffic signs and lights. All the streets of the urban area are designed lack of sidewalk vendors and alternative road; resulting in illegal parking. This lead to slower travel time. Cebu urban region's transport system is overcrowded. In 2016, Cebu was ranked as the worst urban driving area. [40.]

In conclusion, there are some main reasons for the traffic situation in Cebu. The first one is the high population density in the central island. The population has increased rapidly along with a massive growth in the number of registered vehicles annually (more than 150,000 in 2016). The second reason is the outdated transport infrastructure, especially as the quality of the urban infrastructure is deteriorating. The third reason are poorly educated drivers, due to the inadequate driving license requirements. [39.]

4.3 City plan for Mega Cebu urban railway

4.3.1 Forecast

In April 2015, Cebu council presented a long-term development plan for the Cebu region called "*Cebu development vision in 2050*", based on four aspects: population, economics, employment and urban land. The purpose of the project was to renew the city to become sustainable by 2050. The Cebu council was aware that they might face many challenges such as a high population growth rate, an unfair education system, and unbalanced distribution of urban areas in order to identify right function for each area depending on the different purposes: residential area, industry, economics and education. The Cebu council has agreed to organize the Mega Cebu as an urban central in the future. Cebu central or Metro Cebu will become a major urban area in the Cebu island, with the population now at 2.5 million, anticipated to be 3.8 - 5 million in 2030 and 2050, respectively. [42.]

An urban railway system has been presented as a major method for the future sustainable transport system. In 2050, the expected GDP per capita is 20,000 - 25,000 US dollars. The goal of the project is quite reasonable with the Cebu Island situation right now, when the total export rate constantly grows despite the period of economy downturn. The amount of tourists in 2015 reached 2.5 million and was forecasted to be more than 4.6 million in 2024. Cebu tried to attract well educated workers from other areas in the Philippines [38]. However, the goal will not be reached in 2050 without completing transport system and a reasonable contribution plan for urban areas. [38.]

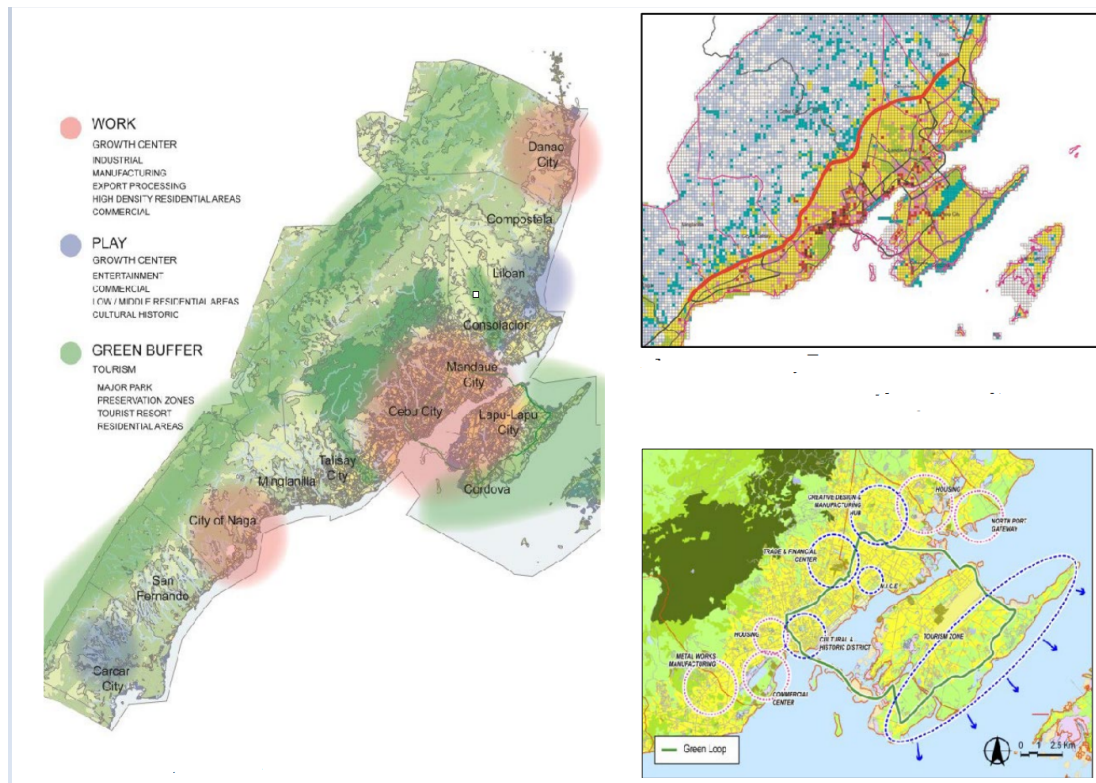


Figure 12: The urban mega Cebu map in 2050 [43]

The map in figure 12 shows the distribution of Mega Cebu in 2050 when Cebu city is expected to be the central of Mega Cebu, together with two supportive cities. This kind of city is polycentric. An urban Mega Cebu will be limited and organized logically. [43.]

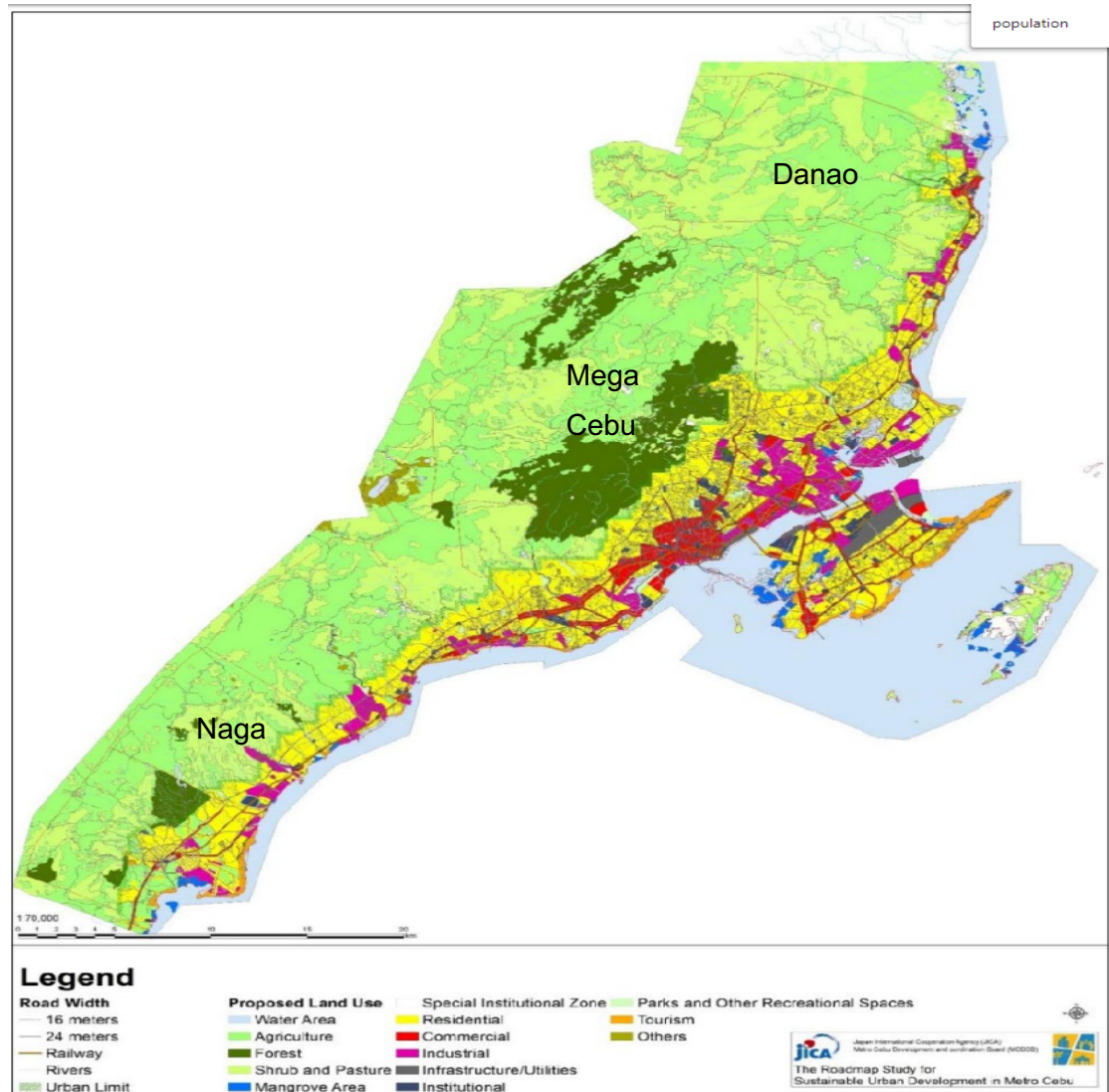


Figure 13. The distribution of Mega Cebu based on land use purposes [41]

The purpose of the polycentric cities, Danao and Naga (figure 13), is to help Cebu city in commercial and industrial ways by attracting more residents and therefore distributing the population density equally while Cebu city would still be the central area for residents in 2050. [43.]

4.3.2 Urban transport system plan

With the right project plan, residents will spread out equally as in figure 13. The goal is to link all the parts of the Mega Cebu together. In figure 13, Cebu city would easily be seen as a major central point for a railway system and expanded to two lines further

Eastern and Southern, a number of stations and length of the railway have to be calculated prudently in order to co-operate effectively with the road system and to maximize the transport system efficiency. [43.]

A future of traffic road.

The plan also covers the road traffic of the Cebu city. It will be shared by two new central cities. At the present, the Cebu city has to handle a huge number of vehicles. The MRT project will be launched in 2050 with Cebu city as the central of the system. [43.]

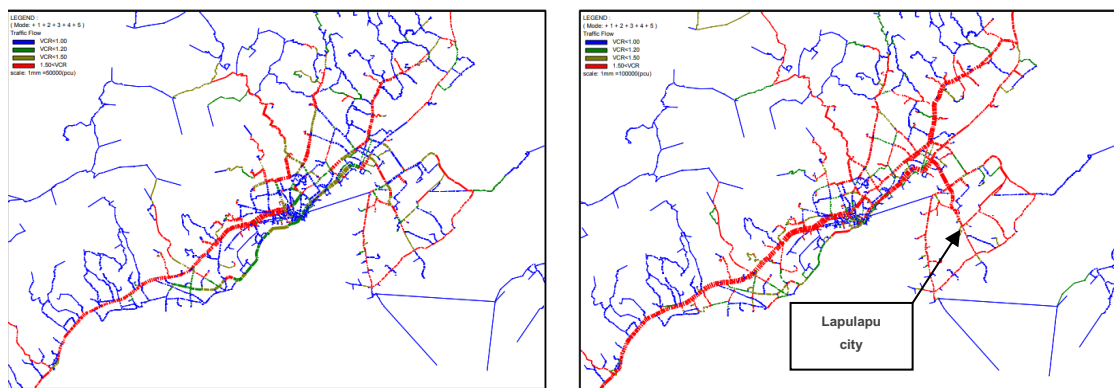


Figure 14. The Mega Cebu's demand of highway in 2014 and 2050 (blue is normal smooth traffic flow and red line is heavy traffic flow) [43]

The demand for future transport is understandable as in 2050 the population in Mega Cebu will be doubled. As seen in figure 14, there are three main crowded points in the centre, two ways heading to North and South and one heading to Lapulapu city where Cebu Airport is located. The reason for the existence of three crowded points is that Cebu city will be both a large service centre and a major commercial area. It is why the old road system no longer handle the demand for present traffic anymore. The solution is to build two alternative highways heading to the North and South in order to reduce the traffic flow on an old road. The new highways use the free land on the west side of Cebu city. The problem with the traffic flow to Lapulapu city is more complicated because it is connected to Cebu city with two main bridges close to the North. One of the bridges could be overcrowded in 2020. The solution is to build another alternative bridge close to the old highway in the South and connect it to a new MRT station. [43.]

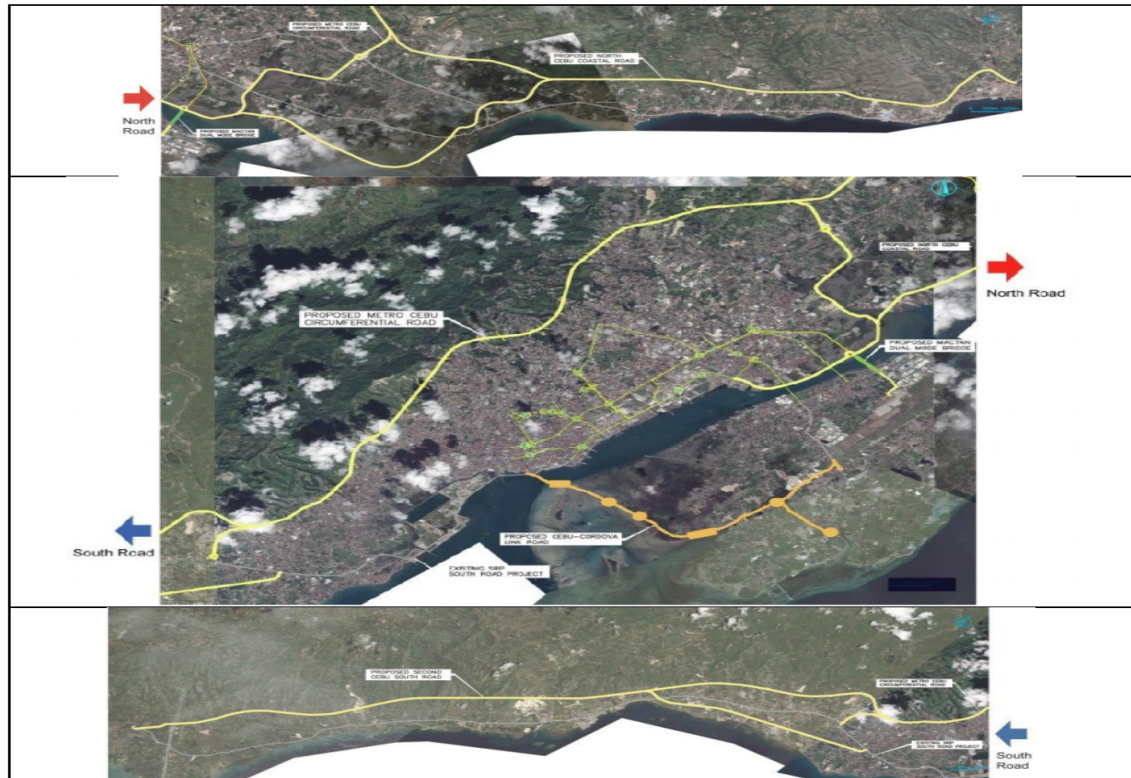


Figure 15. The future solution for highway demand in 2050 [43]

As seen in figure 15, from the centre of Cebu city, new highway line system will be launched and cover all the Cebu city. By 2050 the new highway will be completed close to the residential area, solving the traffic situation of the whole city. [43.]

Implementation of urban railway.

The *"Cebu development vision in 2050"* maintains that an urban railway construction is compulsory. The implementation of an urban railway system has been planned carefully and divided into different steps until 2050. [43.]

The first phase of the urban railway project is to create an LRT and a bus rapid transit (BRT) line. The new lines will be located in Cebu city centre and connect to two other areas next to Cebu, Lapulapu city and Mandaue city. The purpose of the project is to create lines in the most crowded urban areas in Mega Cebu region. The project will start in 2019 and be ready for use in 2020. [43.]

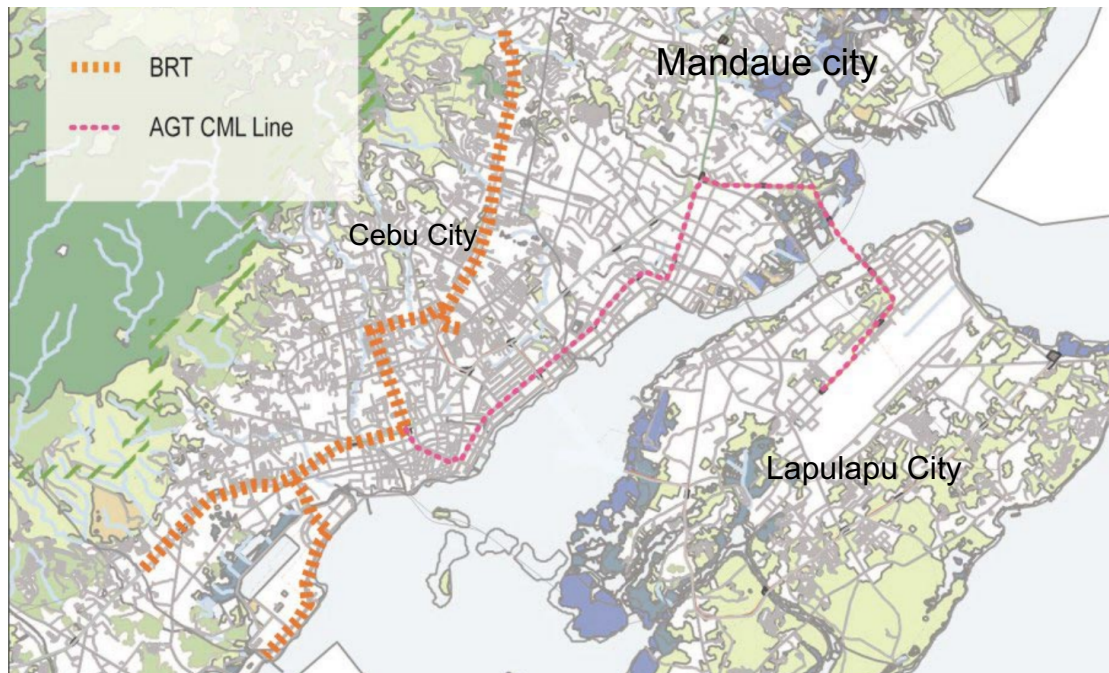


Figure 16. An LRT and BRT line in 2020 [43]

LRT connects Lapulapu city, where Airport is, via Mandaue city to Cebu city. LRT railway can carry 20,000 passengers per hour in one direction, and become the main public transport system. This is the first effort to relieve the burden from bus, jeepney (a local means of transport in the Philippines) and taxi. This will reduce the number of cars from Lapulapu to Mandaue and Cebu centre. [43] The total length of the LRT router will be 21 km and it is predicted to be ready by 2022. BRT line in Cebu city will be prioritized to serve passengers in the North and the South. [43.]

The second phase of the railways project is the MRT railway system. The project runs from 2021 to 2030. The second phase of the project plays a key role in transferring the whole Mega Cebu transportation system because the number of private transports will be reduced by LRT and BRT systems. During the second phase of the project, a new alternative highway system and an extra bridge connecting Lapulapu city to Cebu city will be constructed together with MRT railways. The first MRT railway system will be opened in the Cebu centre which is the intersection of three big cities Cebu, Mandaue and Lapulapu city. [43.]

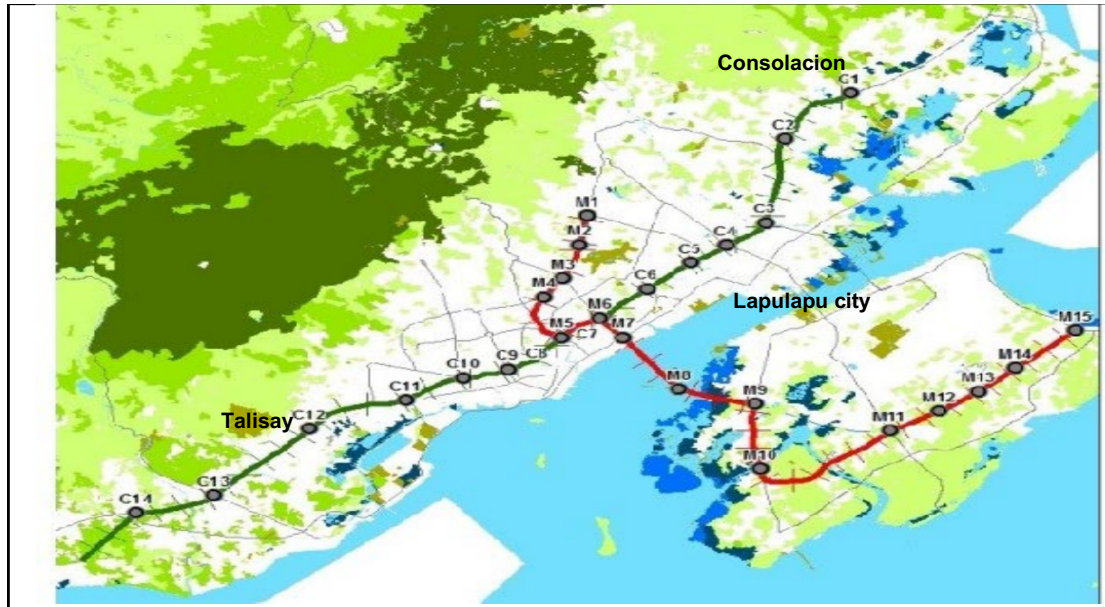


Figure 17: The first MRT line of Central Mega Cebu [43]

The red and green lines in figure 17 show the new lines in Central Mega Cebu. The green line (central MRT line) will cross Cebu city and connect Consolacion to Talisay city with a total length of 21.2 km. The red line (named Mactan line) will connect Lapulapu city to Cebu city and continue to the Eastern side of Cebu city with a total length of 21.5 km. The Mactan MRT line will be constructed together with the new bridge from Lapulapu city to Cebu city. [43] The Central and Mactan MRT line will be taken to use in 2030. [43.]

The final stage of the project is 2031-2050. During this period, the project will begin to construct the two final MRT North and South lines which will head to Liloan and Carcar city. [43.]

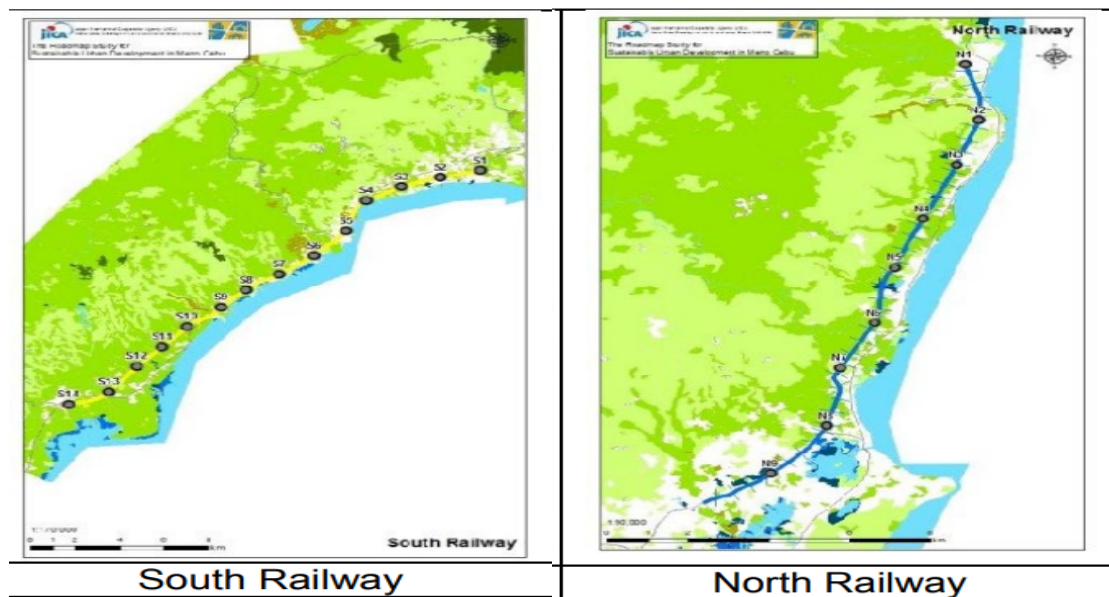


Figure 18. MRT line to South and North side of Mega Cebu [43]

The construction plan for the rest of MRT system will be started in 2030. The Northern line will link Danao City to Lioan city and connect directly to the Consolacion MRT station. The total length of the Northern line will be 24.7 km. The Southern line will link Carcar city, via Naga city, which will be projected as one of 3 cities in Mega Cebu, to Minglanilla city and connect to Talisay MRT station. The total length of the Southern line will be 29.2 km. [43.]

When the final stage of MRT project is done, the new highway infrastructure will also be completed with alternative roads and old roads running together. Moreover, the project aims to reduce the influence of local public transport vehicles such as taxis, jeepneys and buses. The purpose is to make sure these vehicles are used as a supporting method for the MRT system. They will run mostly in short distance journeys and help to connect some places where the MRT cannot reach due to low demand. By connecting all the public transport factors together, Cebu could create a stable network for public traffic and be controllable in traffic issue. The whole complete MRT network will be used in 2050. [43.]

4.4 Discussion.

Reason of MRT project stages

The MRT project in Cebu is divided into three stages of time and will be ready to use in 2050. The plan has predicted many challenges that Mega Cebu will face and design goals to achieve. The first and second stages of the MRT railway plan focus on Mega Cebu centre due to population growth, economic reasons and the need to renew the road system. [42.]

The population of the three cities is predicted to increase rapidly by 1.2 million people in Cebu city, 0.7 million people in Lapulapu city and 0.583 million people in Mandaue city. The population of those three cities will equal half of population in Mega Cebu by 2050 [41]. Therefore, the development of the central urban area of Cebu city, Lapulapu city and Mandaue city require a high-quality transport system throughout all three cities.

Economically, the Cebu Council has defined that the cities will be promoted as a core service center in 2050 together with large number of residents and travellers [42].

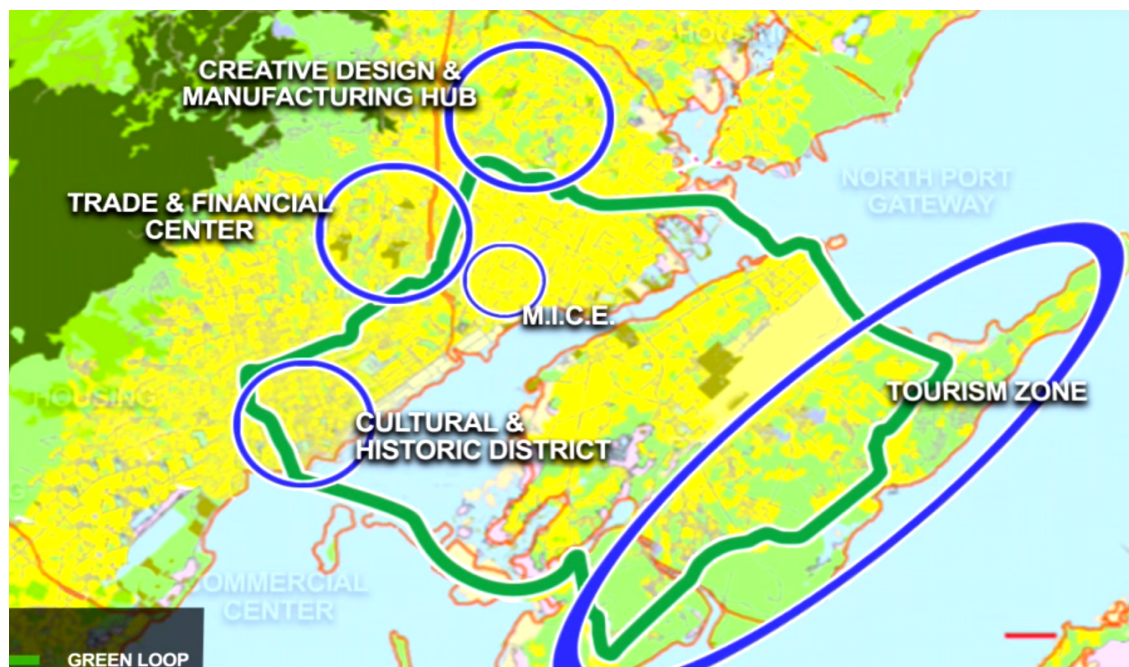


Figure 19. The function of Mega Cebu centre [44]

Figure 19 shows that Mega Cebu centre is the core of all functions in the urban Cebu region. It could cover 60% of the total GDP of the urban area. Together with the Airport of Cebu, the only airport of the Island, Cebu will welcome 4.6 million tourists in 2024, an increase of 75% over the 2.5 million tourists in 2015 [37]. That could be a heavy burden on the whole centre area if the transport renewal project is not carried out by 2030. Despite the two new polycentric cities, it will not be easy to reduce the demand of travelling in the city centre.

The new road system is the third reason to focus on the Cebu centre. Together with an innovation for the highway and LRT/BRT system, the implementation of MRT in centre area is the first priority. In 2019, the new LRT and BRT will be constructed. The systems will be apart from the road system. Moreover, a new bridge connecting Lapulapu to Cebu city will be constructed in order to serve the demand of travelling from Lapulapu city, and also to become a part of the MRT line. [43.] If the MRT line is not finished in Mega Cebu centre as scheduled, the new bridge cannot maximize its function.

The implementation for the MRT line to the Northern and Southern areas will be the last stage that will complete the Mega Cebu urban public transport system project.

Future success

The MRT stages and new highway system changer the Mega Cebu public transport system profoundly because it would arise the awareness of the residents, increase the efficiency of the transport system, and allow for the population growth. According to a survey conducted prior to the Cebu transport project, more than 90% of 6,000 answers supported the renewal of the transport system. [42.]

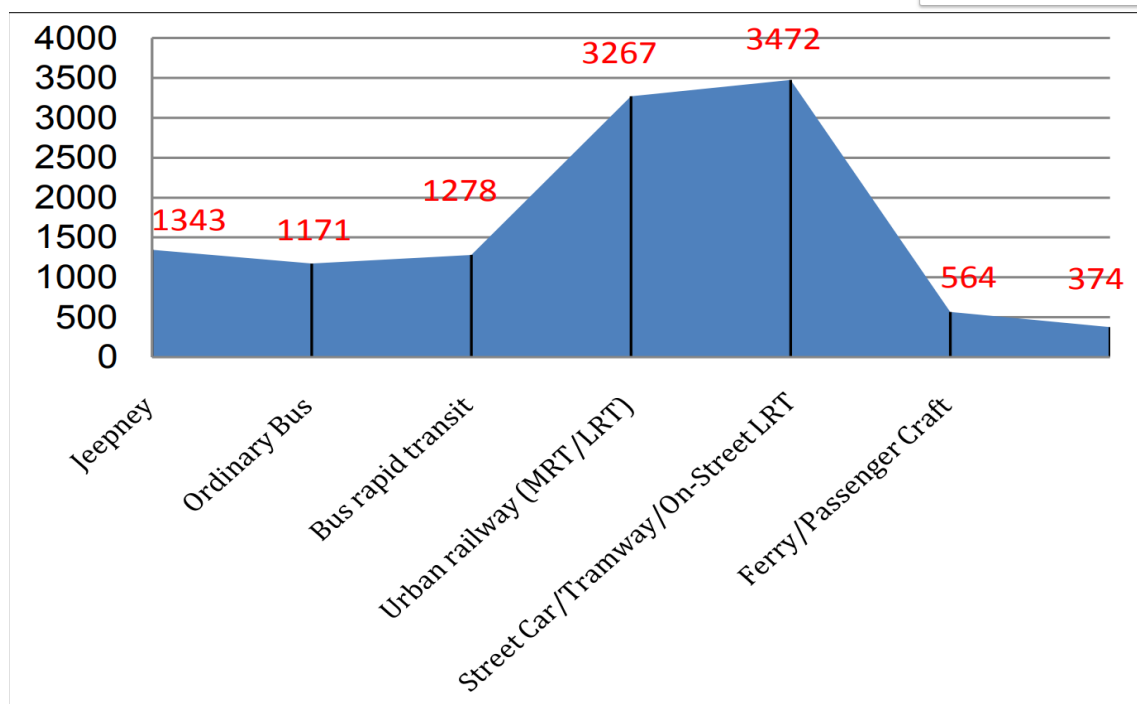


Figure 20. Choice of public transport service. [43]

The survey also shows (figure 20) that the residents had strongly desired a new transport system to replace the old one. The jeepneys and buses which are the major public transport method for now are seen as a good choice by very few residents as more than 75% would prefer an urban railway system. [43.]

The high efficiency of the new urban railway would benefit the city in the same way as in Helsinki and Singapore. Those cities have a completed public transport system and an urban railway plays a main role in the success of those cities. The MRT in Cebu could carry 50,000 passengers/hour/direction and the LRT could carry 20,000 passengers/hour/direction together with operation of BRT system. At the moment, the most popular modes of transport in Mega Cebu are the car and motorbike. However, the rail system are expected to replace them as the favorite transportation in Mega Cebu. [42.]

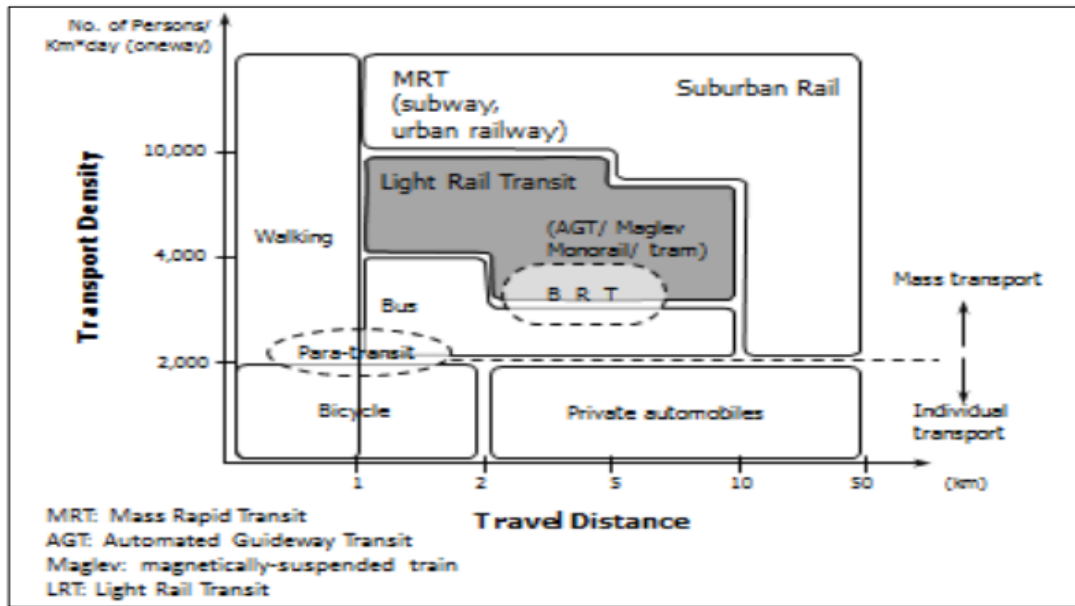


Figure 21. The prediction of percentage transport method in 2050 in Mega Cebu [42]

The prediction of the council for 2050 is showed in the figure 21. The residents is expected to use public transport such as the urban railway rather than private transport. Buses, bicycle and walkings are also alternatives. Private cars might be used for longer journeys above 50km. [43.]

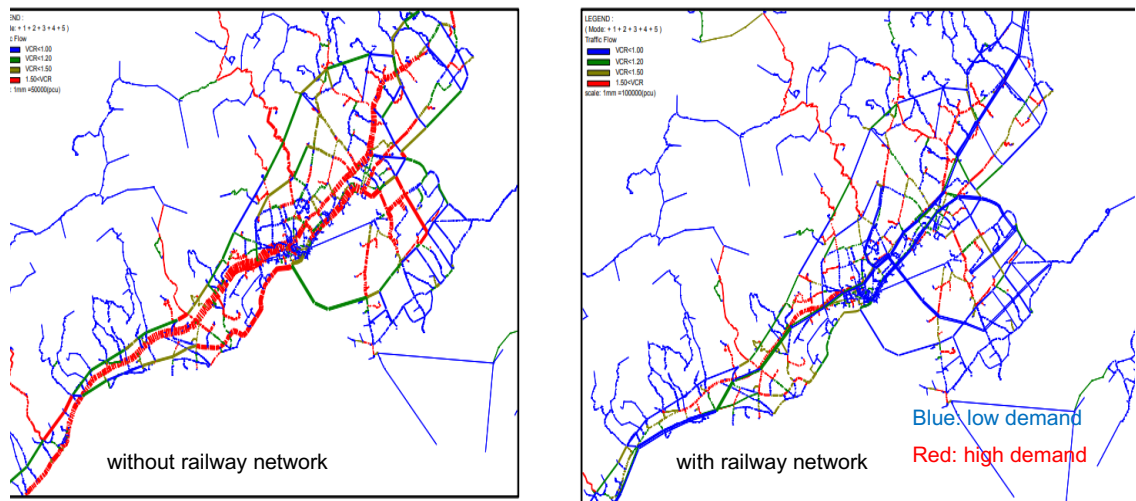


Figure 22. The demand on future in 2050 without and with railway network [42]

As shown in figure 22, there will be a low demand for highway travel with the new urban railway system in 2050, despite the high growth of population. The implementation of the new urban railway has a major effect on the traffic flow, reducing the number of private vehicles, lowering the carbon emissions, as well as improving the quality of the environment. The urban railway is based on the project of Cebu vision 2050 which will play a major role in the sustainable development of the Mega Cebu in the long term.

5 Conclusion.

The urban railway system is one of the most important methods of travelling around the world, especially in developed urban areas. The urban railway system has a major advantage compared to other methods such as buses and private cars. The competitive travelling time and the environmentally friendly characteristics with no carbon emissions during operation contribute to a better air quality. The positive results that a railway system brings to Helsinki and Singapore are shown clearly in the report, especially interesting was that Helsinki has a lower number of car owners per capita than the country in whole, and that Singapore has the lowest car ownership per capita in the world. [29]

Because of the long construction time and need for human resources, the budget for a railway system is large. However, compared to its life cycle, the project will bring benefits of transport services that could last for 100 years or even longer. An urban rail system has proved to be a solid solution for crowded urban areas such as Singapore, Seoul, and Tokyo.

Nevertheless, the implementation of a railway system in an urban area needs to be well estimated. The project runners have to compare the disadvantages and advantages of various options in order to minimize the cost and time, and to ensure the efficiency of the operation as well as the future development.

The urban railway systems around the world are classified into different types depending on the characteristics of the area. For example, in Helsinki, the rail-based systems are tram, metro and train, whereas in Singapore, the MRT and the LRT are the main means of transportation. The type of urban rail system chosen for a country depends on the distinctive factors of that nation, such as local infrastructure, type of society or local public

transport system. An urban rail implementation plan has to be studied prudently before processing it. Once the urban rail system is constructed, it not only contributes to maximize the efficiency for the urban transport system, but also improves the air quality and social development creating more chances for economic development, job opportunities and various other benefits.

In developing countries, with a rapid population growth rate and inevitable development of technology, the requirement for a sustainable public transport solution, such as urban rail system, is always needed. An urban railway not only can help those countries to solve the problem of traffic jams, but also creates more a sustainable plan in the long run. The urban railway project in Cebu will gain those benefits once it is implemented. The project will be processed together with the present infrastructure and the city's development plan like density distribution, new alternative infrastructure and economical growth prospects. The long term vision of Cebu needs a stable development and efficient improvement. With a long life cycle of more than 100 years, the urban rail system is believed to play an important role for the sustainable development of the world, both present and for the future.

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