

Acknowledgement

The Study of Traffic Management and Public Transport Development Master Plan in Nakhon Ratchasima Urban Areas was produced by the Office of Transport and Traffic Policy and Planning of the Ministry of Transport in association with Suranaree University of Technology (The Consultant). The project was successfully completed and its targets were fully achieved with cooperation and support from a number of agencies and individuals concerned.

The Consultant would like to extend our gratitude to the Monitoring Committee for the Study of Traffic Management and Public Transport Development Master Plan in Nakhon Ratchasima Urban Areas for all of the useful advice and suggestions relating to the study of the project as well as for the assistance in facilitating and coordinating the Consultant's discussions with agencies and individuals concerned. We would also like to thank the representatives of all agencies involved for the provision of the information needed to complete the study and for their cooperation in organizing seminars, for brainstorming and the exchange of views essential for the successful completion of the project.

In addition, the Consultant wishes to thank the representatives of organizations, their organizations, entrepreneurs, people concerned in the operation of the public transport system and others for taking part in meetings and interviews, participating in the seminars and providing useful information and suggestions for the benefit of the study.

The Consultant would also like to thank the management team of the Office of Transport and Traffic Policy and Planning and all other officials who contributed to the study for their advice, cooperation and facilitation of all aspects of the study.

Finally, the Consultant would like to extend deepest gratitude to the Office of Transport and Traffic Policy and Planning for the trust and opportunities given throughout the study of the project.

The Consultant

Table of Contents

	Page
Acknowledgement	
1. Introduction	1
1.1 Problems confronting the Urban Areas of Nakhon Ratchasima City	1
1.2 Objectives and Goals of the Study	1
2. Results	4
2.1 The Development of Public Transport in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs	4
2.1.1 Direction of Urban Development Trends and City Centre Expansion	4
2.1.2 Overview of the Existing Public Transport Interchange in Nakhon Ratchasima City and Surrounding Areas	5
2.1.3 Travel Demand	6
2.1.4 Development of the Public Transport System in Nakhon Ratchasima City and Surrounding Areas	7
2.1.5 The Main Public Transport Route proposed as the Pilot Project	11
2.1.6 Technology for Public Transport in Nakhon Ratchasima City	12
2.1.7 Fares	14
2.1.8 Ridership	14
2.1.9 Process for the Main Public Transport System Development	15
2.2 Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs	19
2.2.1 Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs: Prior to the Launch of the Main Public Transport System	19
2.2.2 Traffic Management in Nakhon Ratchasima City and Surrounding Areas with the Travel Demand Needs: After the Launch of the Main Public Transport System	20
2.3 Master Plan for Public Transport Development, Master Plan for Traffic Management and Urban Development Plan for Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs	25
2.3.1 Master Plan for Public Transport Development in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs	25
2.3.2 Master Plan for the Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs	26
2.3.3 Development Plan Consistent with the Integration of Public Transport Links	29
2.4 Pilot Project for the Development of the Main Public Transport System in Nakhon Ratchasima City	33
2.4.1 Conceptual Design	33
2.4.2 Environmental Impact Study and Public Relations and Public Participation Process	38
2.4.3 Areas Development around Stations or Public Transport Terminals	39
2.4.4 Economic and Financial Appraisal	42
2.4.5 Investment Analysis	43
2.5 Recommendations to Drive the Development of Public Transport and the Traffic Management System in Nakhon Ratchasima City and Surrounding Areas to Achieve the Goals and Success	45

List of Figures

		Page
Figure 1	Key Success Goals of the Study	2
Figure 2	Overview of the Study Process	3
Figure 3	The Areas of Influence on Traffic and Surrounding Areas with Travel Demand Needs	4
Figure 4	Relationship of Urban Development Trends with the City Centre	5
Figure 5	Overview of Existing Public Transport Interchange in Nakhon Ratchasima City and Surrounding Areas	5
Figure 6	Travel Desire Lines in Nakhon Ratchasima City in year 2016	6
Figure 7	The Proposed Main Public Transport Network (LRT) including Extensions	8
Figure 8	Interchanges for the Three Main Public Transport (LRT) Routes	9
Figure 9	Feeder Public Transport Network (Bus) System	10
Figure 10	Public Transport Technologies	12
Figure 11	The Main Public Transport Technology Proposed in Nakhon Ratchasima City	13
Figure 12	Flood Areas in Nakhon Ratchasima City	13
Figure 13	Zonal Fare System Concept	14
Figure 14	Trends in Public Transport Use	15
Figure 15	Comparison of Passenger Numbers Using Public Transport Bus and the Main Public Transport System (LRT)	15
Figure 16	Project Overview of the Main Public Transport System Development in Nakhon Ratchasima City	16
Figure 17	Administrative Structure for Development of the Main Public Transport System in Nakhon Ratchasima City	17
Figure 18	Management in the Form of Specialized Organization	18
Figure 19	Outer and Inner Ring Road Construction Projects	20
Figure 20	Location of Junction Improvements	21
Figure 21	The Four-lane Road Expansion Project (to accommodate Traffic before the Outer Ring Road is completed - Sections 3 and 4 on the South)	21
Figure 22	The Proposed Road Projects to handle Traffic Congestion for the Main Public Transport System	22
Figure 23	Areas where Traffic Signals / Traffic Signs and Law Enforcement must be Improved before the Service of the Main Public Transport System	23
Figure 24	Areas where Traffic Signals / Traffic Signs and Law Enforcement must be improved when the Main Public Transport System is Operational	24
Figure 25	Master Plan for Public Transport Development in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs	27
Figure 26	Master Plan for the Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs	28
Figure 27	The Urban Development Concept in Nakhon Ratchasima City	29
Figure 28	Area Development Plan Consistent with the Integration of Public Transport Links	30
Figure 29	Area Classification for Urban Planning Measures for Area Development on the Integration of Public Transport Links	30
Figure 30	Area Development Plan Consistent with the Integration of Public Transport System	32

List of Figures (continued)

	Page
Figure 31 Park and Ride, Interchange/Mode Change and appropriate Access Points for Phase 1, Phase 2 and Phase 3	33
Figure 32 Overview on the Main Public Transport System proposed as a Pilot Project	36
Figure 33 Overview on the Main Public Transport System proposed as a Pilot Project (General)	37
Figure 34 Study Areas for Environmental Examination	38
Figure 35 Public Relations and Public Participation Processes	39
Figure 36 Schematic Layout of the Transit Oriented Development (TOD) at Nakhon Ratchasima Railway Station or "Korat Railway Station"	40
Figure 37 Schematic Layout of the Transit Oriented Development (TOD) at Nakhon Ratchasima Bus Terminal No.2 or "Bus Terminal 2"	41
Figure 38 Key Factors in the Development of Public Transport and Traffic Management in the Nakhon Ratchasima City and Surrounding Areas to Achieve the Goals and Success	45

List of Tables

	Page
Table 1	7
Table 2	11
Table 3	12
Table 4	25
Table 5	25
Table 6	26
Table 7	31
Table 8	34
Table 9	38
Table 10	42
Table 11	42
Table 12	43
Table 13	43
Table 14	43
Table 15	43
Table 16	44
Table 17	44
Table 18	45
Table 19	46

1. Introduction

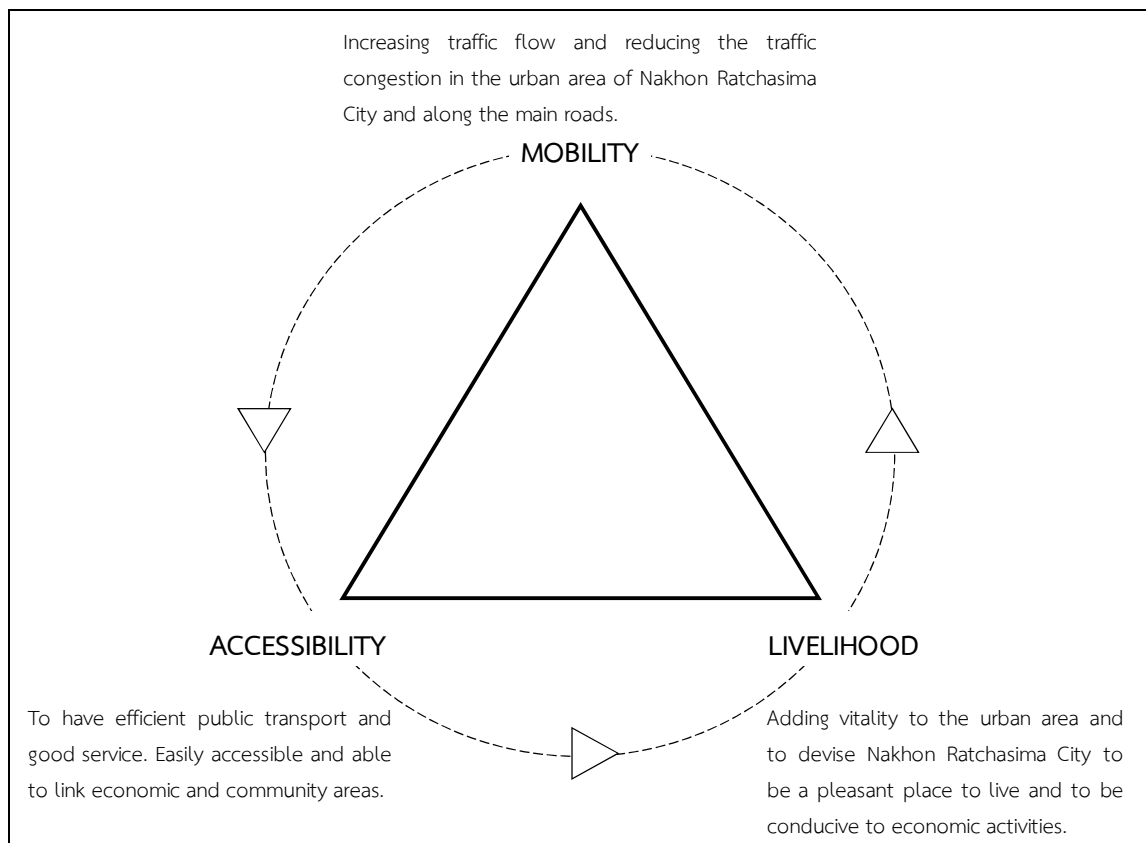
1.1 Problems confronting the Urban Areas of Nakhon Ratchasima City

- 1) The expansion of the business and trade zone has caused an economic downturn to the old town areas of Nakhon Ratchasima City, the traditional commercial center. As a consequence, the areas needs to be revived in a timely manner in order to restore its trade and service competitiveness as well as its status as a hub of commercial networks, lifestyle, and traditional culture.
- 2) The urban area of Nakhon Ratchasima City is confronted with a severe traffic problem that requires an immediate solution in order to improve journey safety and efficiency.
- 3) The future growth prospects of the city will be enhanced when it is connected to the high-speed rail system and when the double rail track project on the metre gauge railway is implemented. Nakhon Ratchasima City needs a step change in its public transport system, and improved circulation for road traffic, in order to gain the full benefits from the major investment in high speed rail and the double rail track project.

1.2 Objectives and Goals of the Study

In response to the above problems, there is an urgent need to devise Traffic Management and Public Transport Development Master Plan in Nakhon Ratchasima Urban Areas, including an Urban Development Plan. Such plans will serve as an effective mechanism for solving traffic problems and restoring the livability of the old town areas, the traditional commercial center. As illustrated in Figure 1, the main objectives of the study are as follows:

- 1) Livelihood: to stimulate economic activity within Nakhon Ratchasima City and transform the city into a thriving and dynamic community with all of the facilities needed to support economic activity,
- 2) Mobility: to reduce traffic congestion in the inner city areas and along main roads in order to increase convenience, travel safety and the mobility of people living in Nakhon Ratchasima City by providing additional options for more convenient and reliable travel,
- 3) Accessibility: to elevate the effectiveness and service standard of the mass transit system in order to ensure its accessibility and connection with economic and community areas.

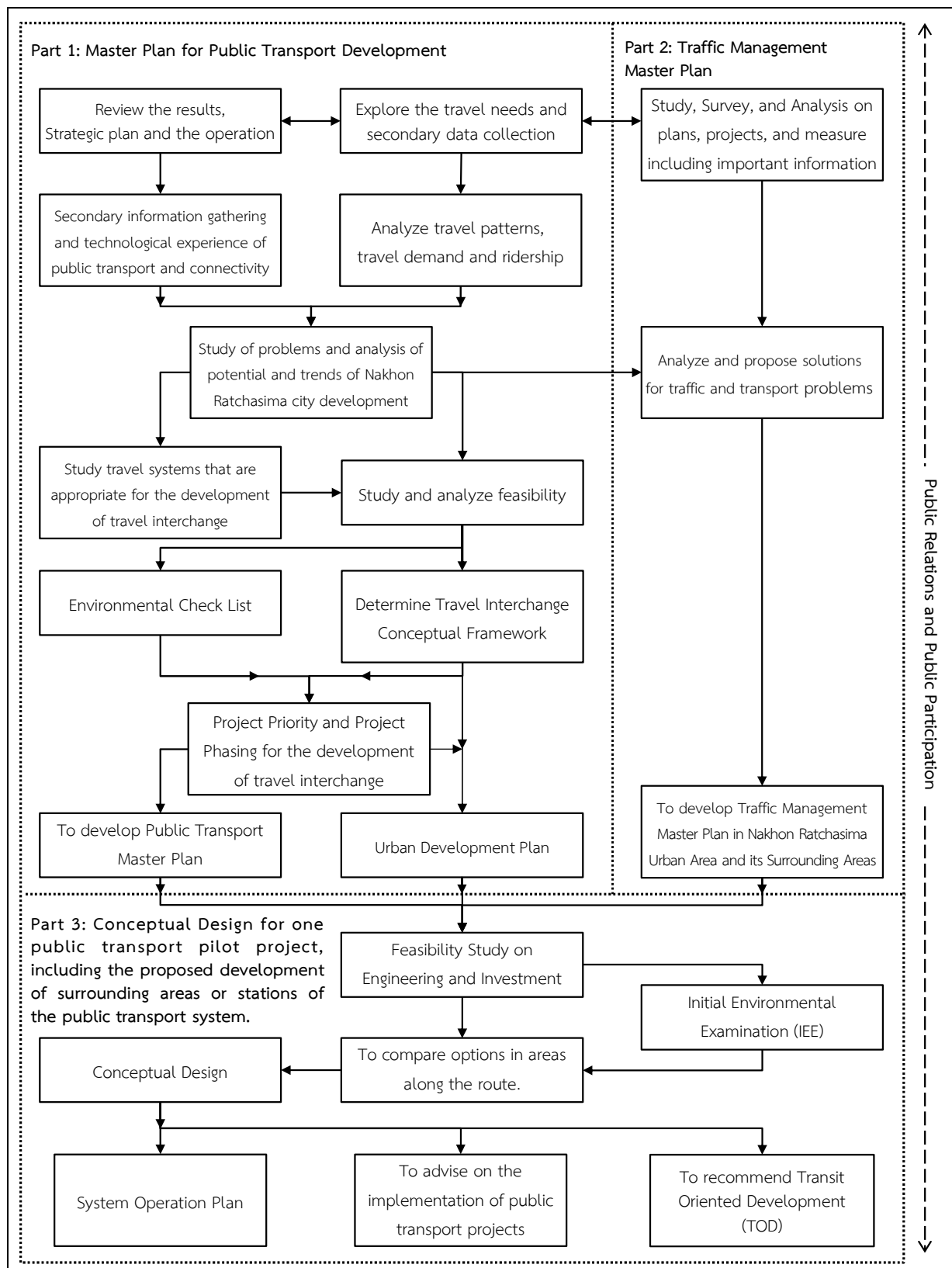


Source: The Consultant

Figure 1 Key Success Goals of the Study

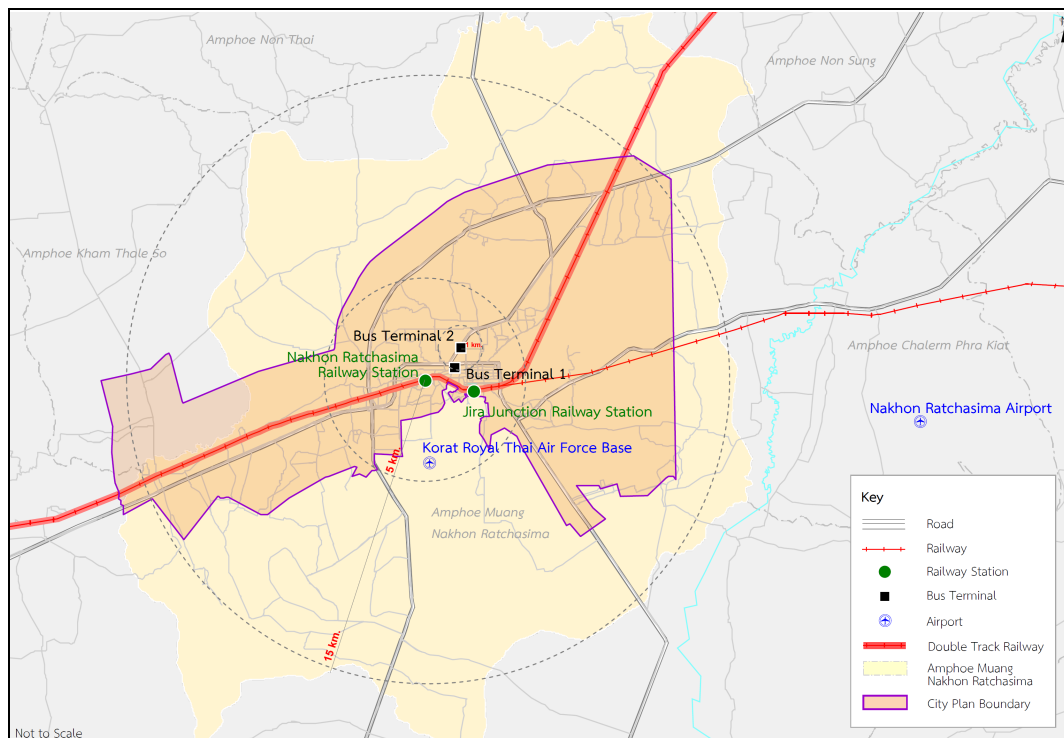
The scope of the study is divided into three main sections: (i) The Master Plan for Public Transport Development in Nakhon Ratchasima Urban Areas and surrounding areas with travel demand needs, e.g. Nakhon Ratchasima Airport, (ii) The Master Plan for Traffic Management in Nakhon Ratchasima Urban Areas and surrounding areas with travel demand needs, and (iii) The Conceptual Design Study – a pilot project for the Main Public Transport System in Nakhon Ratchasima City, including the proposed development of the areas around the railway station, including the park and ride facility.

The process overview and guidelines for the study are shown in Figure 2. It outlines the process applied to the study, integrated planning and development of public transport, the road traffic system and urban development in Nakhon Ratchasima Urban Areas and the surrounding areas. Figure 3 shows the areas of Nakhon Ratchasima under consideration in the Study including external areas of influence.



Source: The Consultant

Figure 2 Overview of the Study Process



Source: Modified from Department of Highways and Nakhon Ratchasima Province Comprehensive Plan

Figure 3 The Areas of Influence on Traffic and Surrounding Areas with Travel Demand Needs

2. Results

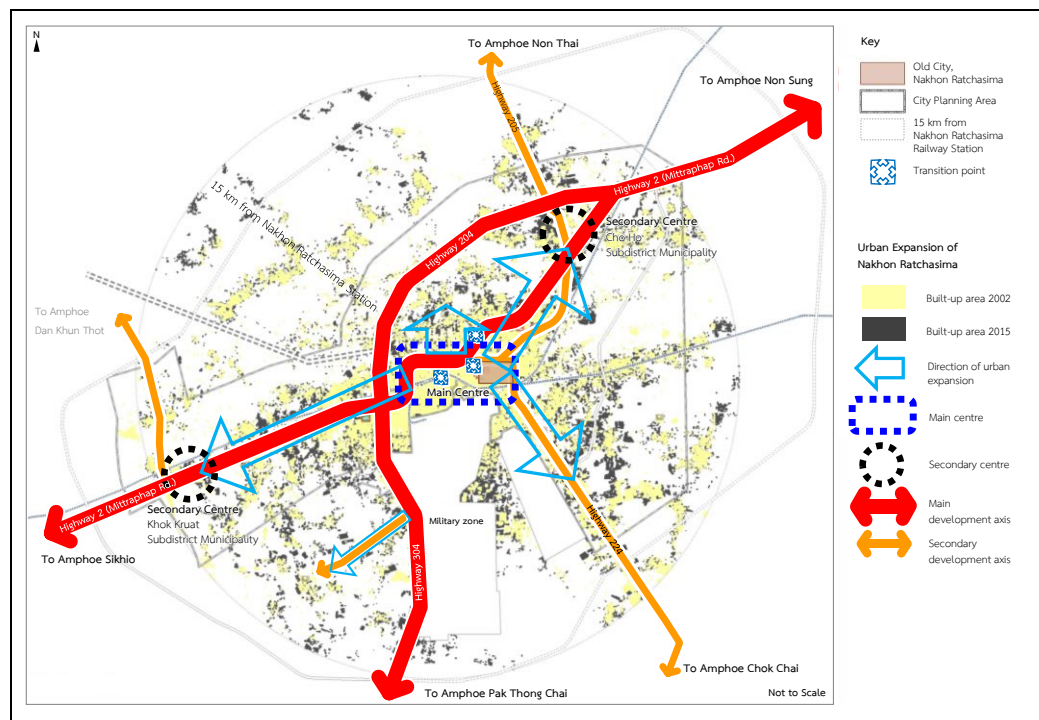
In summarizing the results of the Study based on the project objectives, it can be divided into 5 main areas: (i) the development of public transport in Nakhon Ratchasima City and surrounding areas with travel demand needs; (ii) traffic management in Nakhon Ratchasima City and surrounding areas with travel demand needs; (iii) Master Plan for Public Transport Development, Master Plan for Traffic Management, and Urban Development Plan for Nakhon Ratchasima City and surrounding areas with travel demand needs; (iv) pilot project for the development of the public transport system in Nakhon Ratchasima City; and (v) recommendations to drive the development of public transport and traffic management system in Nakhon Ratchasima City and surrounding areas to achieve the project goals, and successes. The summary is as follows:

2.1 The Development of Public Transport in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

This work encompasses 9 major issues: (i) direction of urban development trends and city centre expansion; (ii) overview of the existing public transport interchange in Nakhon Ratchasima City and surrounding areas; (iii) travel demand; (iv) development of public transport system in Nakhon Ratchasima City and surrounding areas; (v) the main public transport routes proposed as the pilot project; (vi) technology for public transport in Nakhon Ratchasima City; (vii) fares; (viii) ridership; and (ix) process for the main public transport system development. The results are summarised as follows:

2.1.1 Direction of Urban Development Trends and City Centre Expansion

It is assumed that Nakhon Ratchasima City is likely to develop and expand in all directions along main routes from the traditional centre (city moat areas). The development trend is linked to the main industrial zone clustered around the City of Nakhon Ratchasima and especially along the axis of Mittraphap Road to the Districts of Sungnoen, Sikhiu and Pak Chong in the direction toward Bangkok (Figure 4).

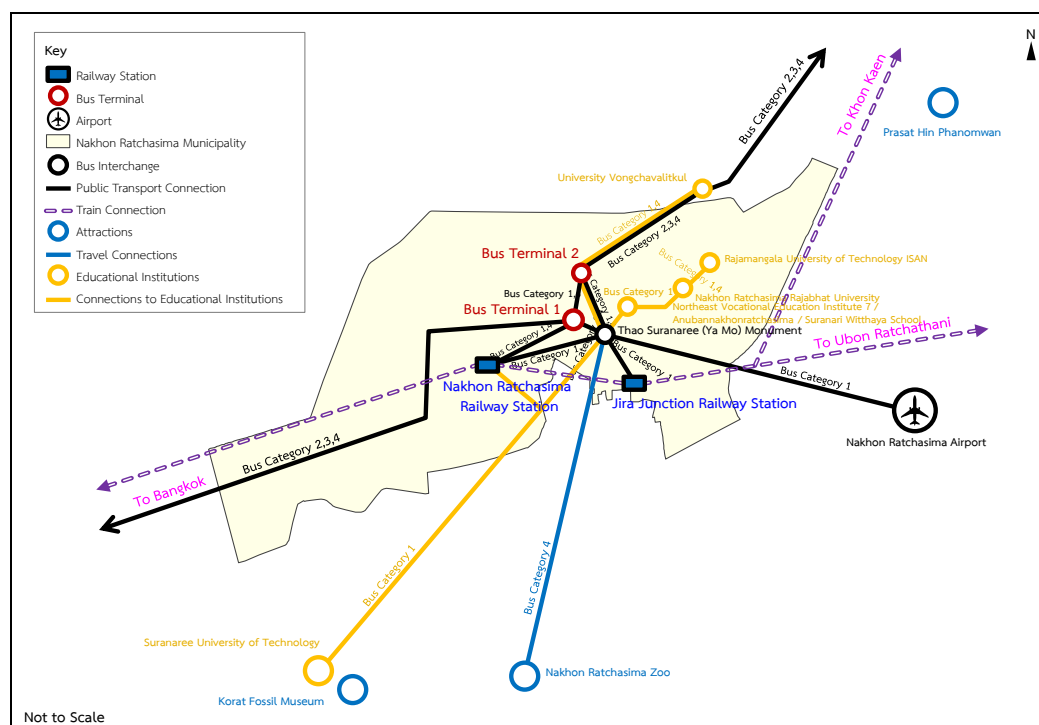


Source: Modified from Draft Nakhon Ratchasima City Comprehensive Plan and Google Maps

Figure 4 Relationship of Urban Development Trends with the City Centre

2.1.2 Overview of the Existing Public Transport Interchange in Nakhon Ratchasima City and Surrounding Areas

Figure 5 provides an overview of current public transport interchange in Nakhon Ratchasima City and surrounding areas, including public transport on roads, rails and air.



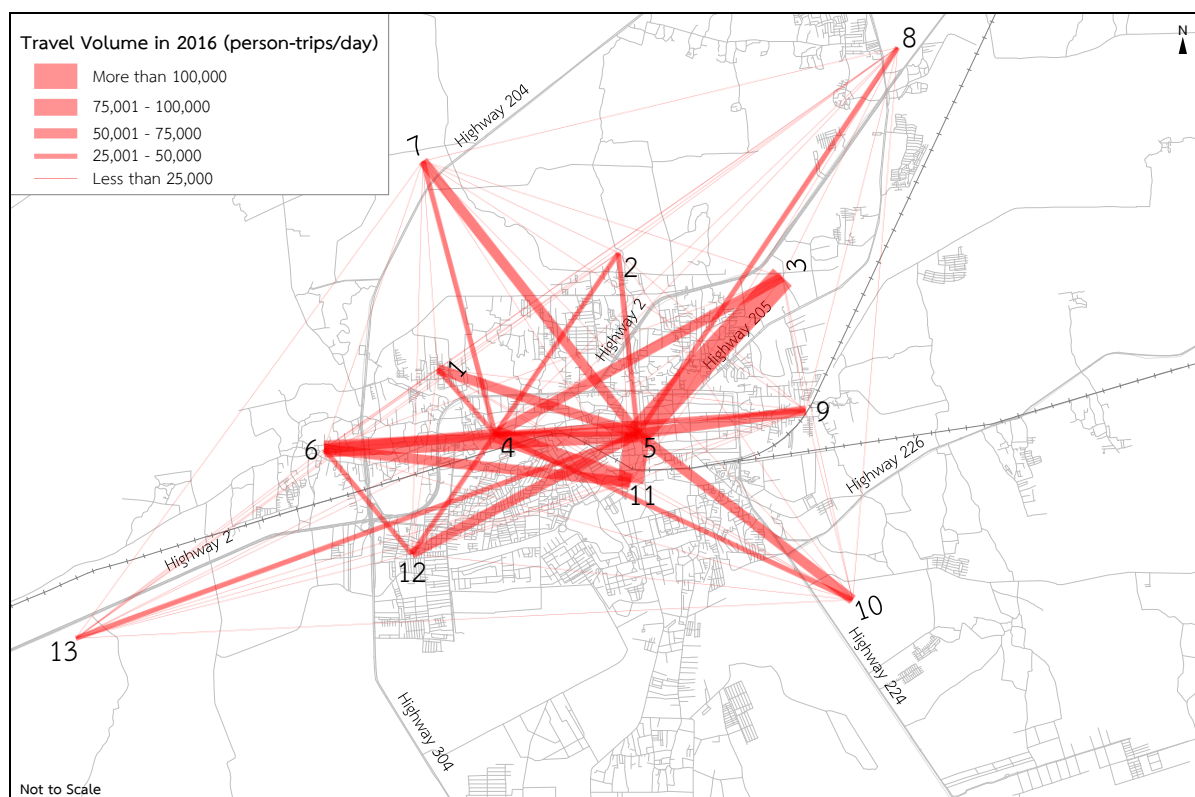
Source: The Consultant

Figure 5 Overview of Existing Public Transport Interchange in Nakhon Ratchasima City and Surrounding Areas

Public transport plays a central role in linking the city centre with outer parts of the city and surrounding areas. It consists of (i) intracity bus routes in urban areas (or Songthaewa) (Bus Category 1); (ii) intracity bus routes linking Nakhon Ratchasima urban areas with other cities within Nakhon Ratchasima provinces (Bus Category 4); and (iii) local public transport, e.g. taxis, tuk-tuks, tricycles and motorcycle taxis. The Study has found that the city bus service: (i) is inefficient, discontinuous and outdated, with low capacity and low frequency; (ii) is radial with no cross-city routes, with the result that passengers wanting to travel across the city have to change vehicle in the city centre, pay a second fare and spend longer journey time; and (iii) there are many bus routes for Bus Category 1, which run along the same routes (overlap). The main public transport hubs for connecting the surrounding areas (including Bangkok and other nearby provinces), are as follows: (i) Nakhon Ratchasima Railway Station (and Jira Junction Railway Station); (ii) Nakhon Ratchasima Bus Terminal 1; and (iii) Nakhon Ratchasima Bus Terminal 2 (on National Highway No.2 or Mittraphap Road). These hubs are heavily congested with traffic, especially on entry and exit to and from the stations. Therefore, passengers trying to use these hubs are inconvenience.

2.1.3 Travel Demand

Figure 6 shows the current pattern of current travel in Nakhon Ratchasima City. Many trips use the downtown areas as a transfer point, due to the lack of cross-city routes in the existing public transit system.



Source: Analysed by the Consultant and modified from Department of Highways

Figure 6 Travel Desire Lines in Nakhon Ratchasima City in year 2016

2.1.4 Development of the Public Transport System in Nakhon Ratchasima City and Surrounding Areas

A hierarchy of routes is proposed as follows: (i) primary routes of high quality and frequency of service; (ii) secondary routes connecting less-densely populated areas with the city centre and primary routes; and (iii) feeder routes serving low density outer areas. The hierarchy of routes provides the policy underlying the vision for Nakhon Ratchasima City and the long-term plan for public transport. The concept for the development of the main public transport network of Nakhon Ratchasima City is shown in Table 1.

Table 1 The Proposed Main Public Transport Network

No.	Lines	Routes	Distance (kms)
1	Orange	Pradok junction - Chang Phueak Road - Old moat	9.81
2	Green	Saveone Market - Mukkamontri Road - Nari Sawat Reception Home/Protection	11.17
3	Purple	Saveone Market - Mittapap Road - Nari Sawat Reception Home/Protection	7.14 ²
Route extensions ¹	Orange (extension)	Tessabal 1 school - Huatalay - DoHome	5.37
	Green (extension)	Irrigation Station- Saveone Market and Nari Sawat Reception Home/Protection- Nakhon Ratchasima Transport Office 2	12.12
	Purple (extension))	Vongchavalitkul University - Cho Ho Junction - Suranarai Camp	4.48
Total			50.09

Note: ¹ All three extension routes are recommended for implementation after Orange, Green and Purple Lines open for the service.

² One direction construction distance

Source: The Consultant

Main public transport network (the three routes) shown on Figures 7 and 8 will form the main public transport network (LRT) and will connect residential communities with department stores, schools, hospitals, bus stations, railway stations and government offices. Future extensions are proposed for all three routes to connect outer areas of the city with the city centre. The three routes will make it easier and faster to travel from communities in the city to the inner city and the old central areas within the city moat.

The propose feeder public transport network system is illustrated in Figure 9. Changes to existing bus networks and new routes will establish connections with the main public transport system by adjusting the Category 1 and Category 4 bus routes.

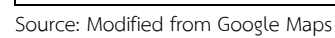
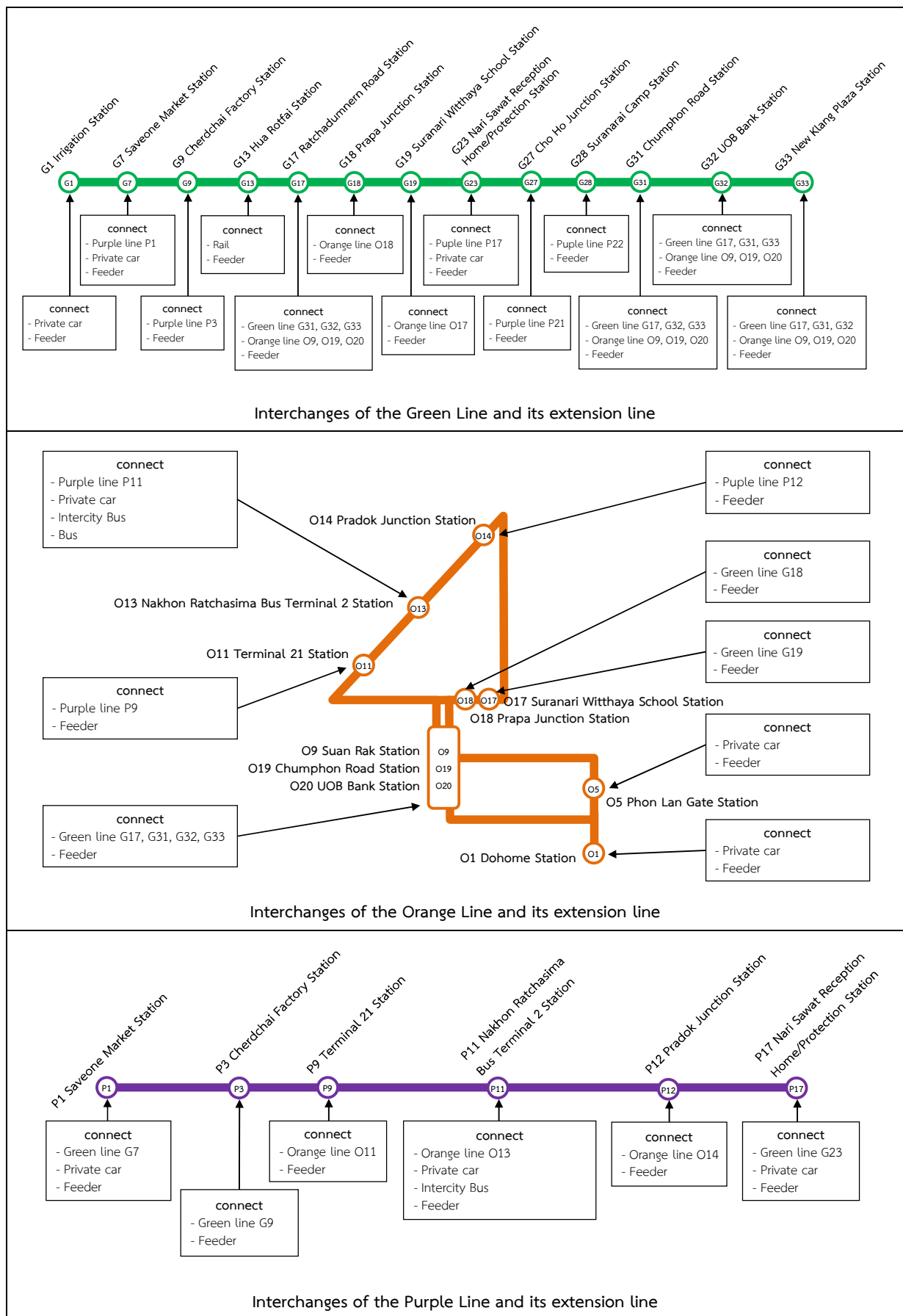
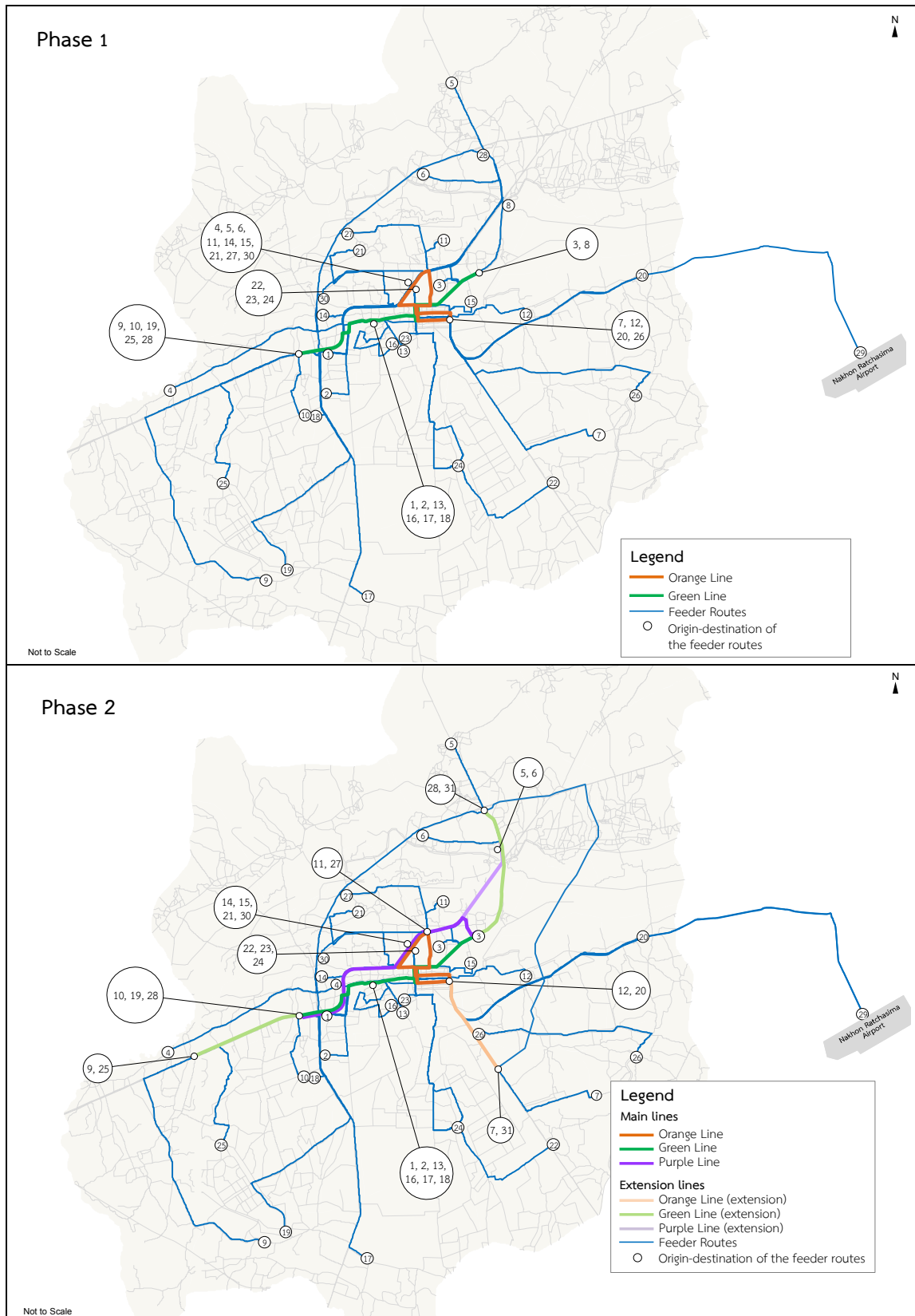


Figure 7 The Proposed Main Public Transport Network (LRT) including Extensions



Source: The Consultant

Figure 8 Interchanges for the Three Main Public Transport (LRT) Routes



Source: Modified from Department of Highways

Figure 9 Feeder Public Transport Network (Bus) System

2.1.5 The Main Public Transport Route proposed as the Pilot Project

The Main Public Transport Routes have been prioritized to identify the proposed pilot investment project. Five alternatives were considered as follows: (i) Green Line; (ii) Orange Line; (iii) Purple Line; (iv) Green Line and Orange Line together; and (v) Purple Line and Orange Line together. The purpose of the last two options was to combine the benefits of cross-city travel opportunities with increased accessibility in the inner city and old central areas inside the city moat.

Three groups of criteria were used to determine priorities: (i) impact on urban development and investment; (ii) environmental and community impacts and (iii) ease of project implementation. The results of the prioritization are summarized in Table 2, as follows:

- The highest priority route is found to be the Green Line combined with the Orange Line.
- The next priority option is the Purple Line which is proposed for commencement of operation after the Green Line and the Orange Line have been in operation for approximately 3 years. This will provide time for people living in the city to understand the benefits and effects of a much better public transport system.

Table 2 Prioritizing Public Transport Networks to select a Pilot Project Route

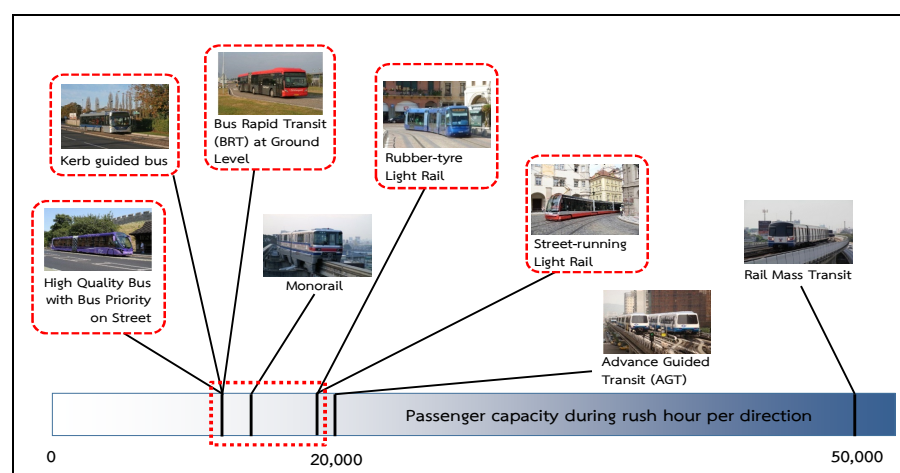
Criteria	Max Points (100 points)	Case (points)				
		Green	Orange	Purple	Green + Orange	Orange + Purple
1. Impact on urban development and investment	55					
1.1 The number of passengers that meet break even	15	13.05	12.07	13.93	14.44	15.00
1.2 Compliance with urban development trends	15					
1.2.1 Number of government offices passing through	1	0.94	0.59	0.18	1.00	0.74
1.2.2 Number of public hospitals (100 beds or more)	1.5	0.75	1.50	0.00	1.50	1.50
1.2.3 Number of schools passing through	1.5	1.27	0.92	0.23	1.50	1.04
1.2.4 Number of places of religious venues (1 or more rai)	1	0.70	0.75	0.15	1.00	0.75
1.2.5 Number of tourist attractions and recreational areas connected	2	1.67	1.67	0.00	2.00	1.67
1.2.6 Special buildings, high-rise buildings, factories, hotels, markets (Ten thousand square meters or more) at the passage	2	1.14	0.59	1.62	1.46	2.00
1.2.7 Total housing projects and residential buildings (Hundreds of units or more) at the passage	3	1.88	1.50	2.88	2.75	3.00
1.2.8 Number of potential areas for TOD development (10 rai or more)	3	1.50	1.50	1.50	3.00	1.50
1.3 Connecting with other travel modes	5	2.50	3.75	2.50	5.00	3.75
1.4 Support the travel of people in the city of Nakhon Ratchasima	5	2.50	0.00	1.25	5.00	3.75
1.5 Support for Business Development in Old Town	5	1.25	5.00	0.00	3.75	2.50
1.6 Budget for construction and expropriation	10	9.59	8.72	10.00	7.08	6.97
Sub Total 1		38.74	38.56	34.24	49.48	44.17
2. Environmental and Community Impacts	25					
2.1 Impact on sensitive areas	6	4.50	4.50	6.00	3.00	4.50
2.2 Impact on travel	6	3.00	1.50	3.00	1.50	1.50
2.3 Impact on the Ruins	7	1.75	1.75	7.00	1.75	1.75
2.4 Impact on flooded areas	6	6.00	6.00	4.50	4.50	4.50
Sub Total 2		15.25	13.75	20.50	10.75	12.25
3. Easy of the project implementation	20					
3.1 Number of intersections of roads and railways	10	2.50	2.50	2.50	2.50	2.50
3.2 Duration period from the project commencement to the opening of the operational Phase	10	8.79	10.00	8.22	8.79	8.22
Sub Total 3		11.29	12.50	10.72	11.29	10.72
Total		65.28	64.81	65.46	71.52	67.14

Source: The Consultant

2.1.6 Technology for Public Transport in Nakhon Ratchasima City

The analysis found that the number of passengers during peak hours in Nakhon Ratchasima City does not exceed 20,000 persons per hour in each direction. Public transport systems can be operated at-grade (at ground level) or they can be elevated or underground. Potential technologies are illustrated in Figure 10.

New public transport routes must follow the guidelines for conservation and development of the Old Town inside the city moat. The guidelines also apply to routes in areas adjacent to the Old Town. Two technologies were considered appropriate, i.e., Bus Rapid Transit (BRT) and Street-running Light Rail. An analysis was carried out to compare the appropriateness of both technologies and to select the preferred technology. The following criteria were applied: (i) the reliability of the technology; (ii) the physical fit of the system to the urban areas of Nakhon Ratchasima; (iii) the capacity to accommodate Ridership; (iv) Related Costs and Fare; and (v) environmental and community impacts. The results are shown in Table 3.



Source: Modified from Transportation Research Board

Figure 10 Public Transport Technologies

Table 3 Point Summary of the Main Public Transport Technology Choices for Nakhon Ratchasima Urban Areas

Major Criteria	Minor Criteria	Electric BRT			Street-running Light Rail	
		12m BRT (normal)	18m BRT (Trailer)	27m BRT (Trailer)	Steel Wheels on Steel Rail	Rubber-tyre
1. Reliability of technology (20 points)	Widely used technology (10 points)	10.00	0.00	0.00	10.00	10.00
	Many manufacturers (10 points)	10.00	10.00	0.00	10.00	0.00
2. Physical fit of the system to the urban areas of Nakhon Ratchasima (20 points)	Physical structure suitable for space condition (5 points)	5.00	2.50	0.00	2.50	2.50
	Turn radius (5 points)	5.00	5.00	5.00	5.00	5.00
	Power supply technology (5 points)	5.00	5.00	0.00	5.00	0.00
	Problems and obstacles during construction (5 points)	5.00	5.00	5.00	2.50	2.50
3. Capacity to accommodate Ridership (20 points)	Maximum system capacity (15 points)	3.21	5.14	9.43	13.71	15.00
	The ability to attract users. System Attractiveness (5 points)	2.50	2.50	2.50	5.00	5.00
4. Related Costs and Fare (20 points)	Project investment (5 points)	5.00	4.98	4.66	1.81	1.54
	Operation and Maintenance Cost per year (10 points)	7.83	10.00	8.05	8.29	8.23
	Lowest fare that can be charged to offset O&M costs or nearby (5 points)	3.92	5.00	4.03	4.14	4.14
5. Environmental and community impacts (20 points)	Noise pollution (10 points)	5.00	5.00	5.00	10.00	5.00
	The need for land expropriation (10 points)	10.00	10.00	5.00	5.00	5.00
Total		77.46	70.12	48.67	82.95	63.91

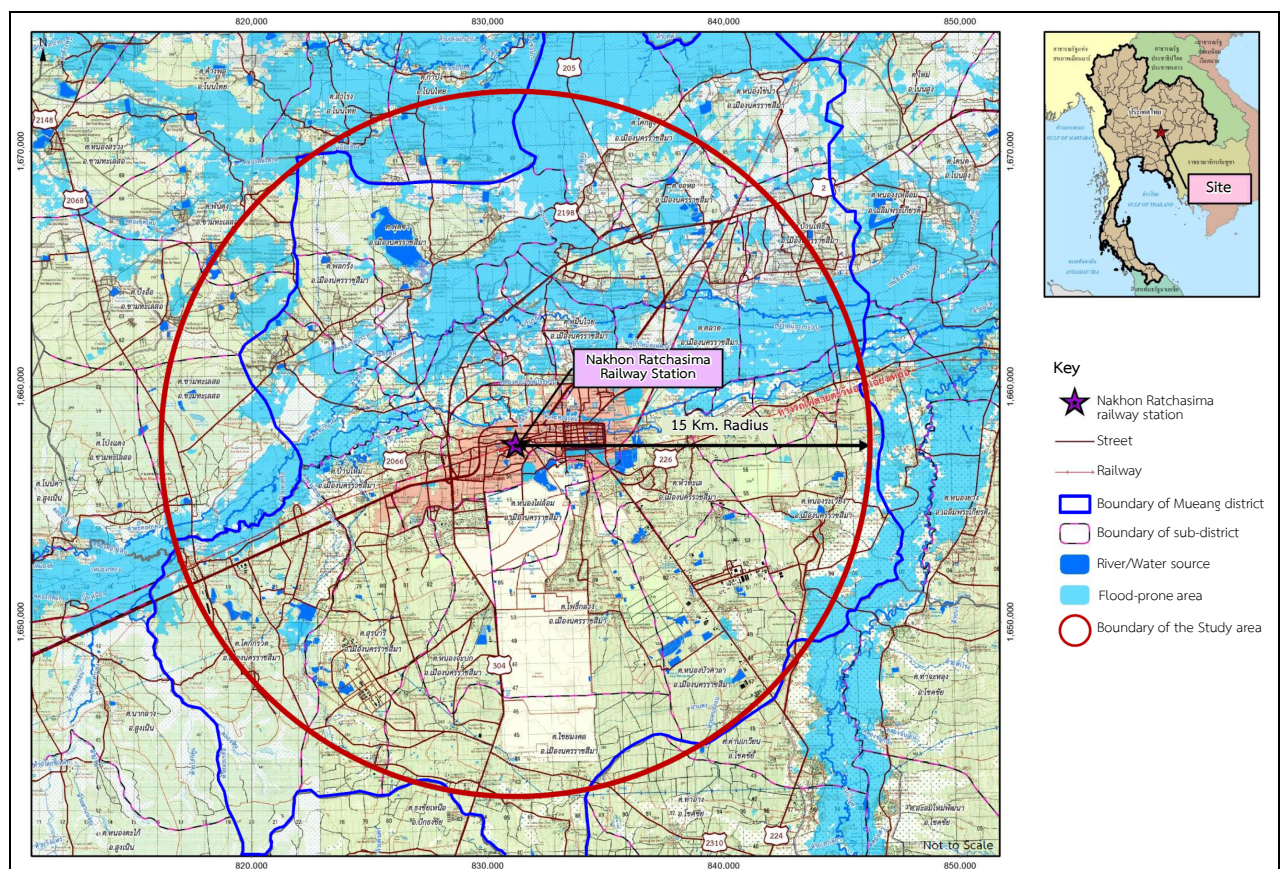
Source: The Consultant

The analysis concluded that a steel-wheels on steel rail (street-running light rail) system with a wire-free power supply system is the most suitable for Nakhon Ratchasima City for the following reasons: (i) it has sufficient capacity to accommodate passengers; (ii) it has the capability to attract passengers; (iii) it is safe; (iv) and it has a high-level charging system and a high floor as shown in Figure 11. This can help to prevent or minimize problems during flooding. The flood risk areas in Nakhon Ratchasima City is shown in Figure 12.



Source: www.wikiwand.com, www.thesun.co.uk

Figure 11 The Main Public Transport Technology proposed in Nakhon Ratchasima City

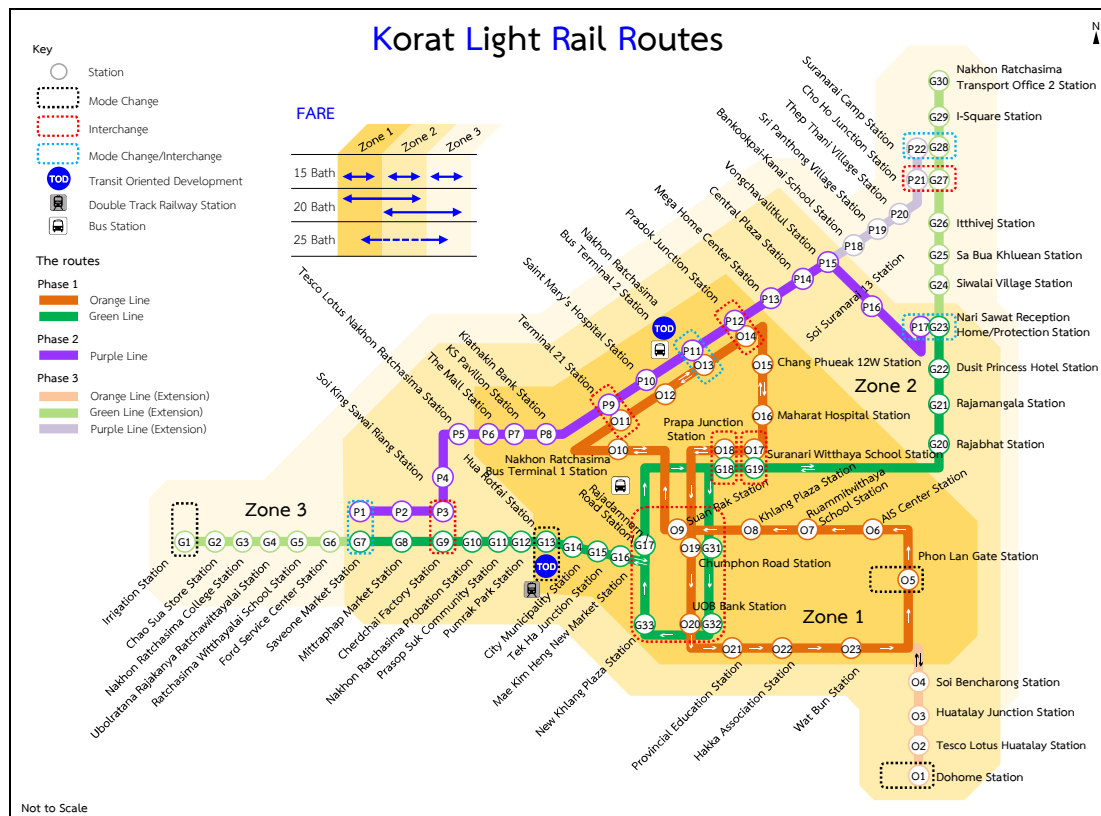


Source: Modified from the Office of Mitigation and Disaster Prevention, Nakhon Ratchasima Municipality, 2016.

Figure 12 Flood Areas in Nakhon Ratchasima City

2.1.7 Fares

The determination of fares for main public transport system in the urban area of Nakhon Ratchasima should be carried out on the basis of zones, as detailed in Figure 13.



Source: The Consultant

Figure 13 Zonal Fare System Concept

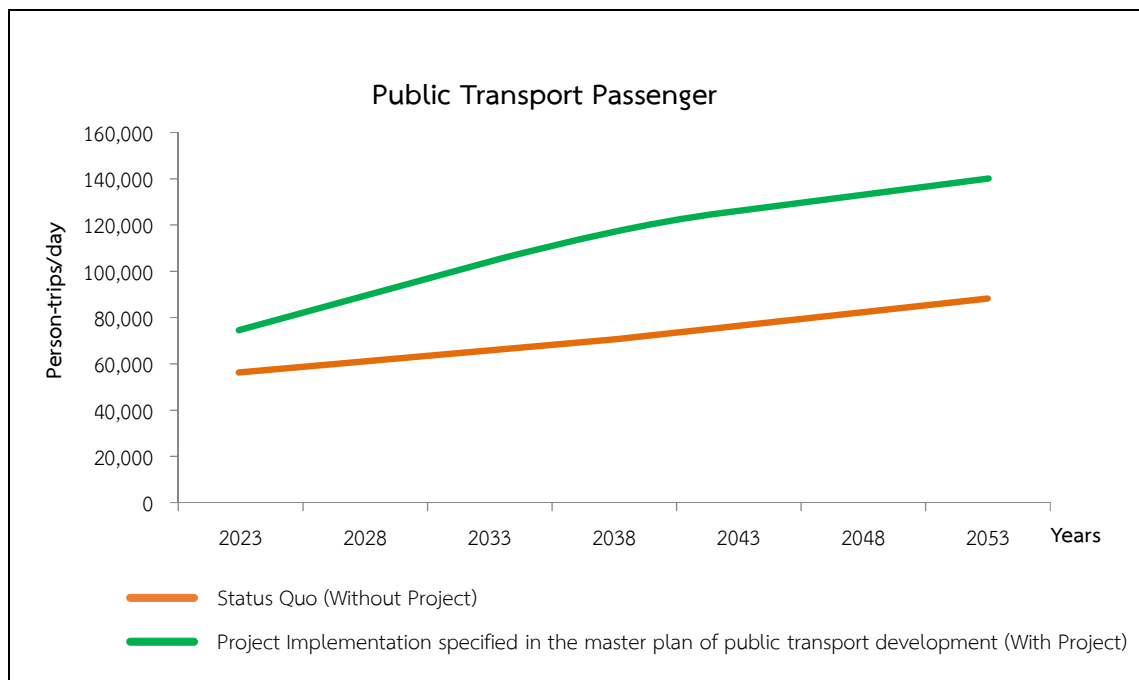
2.1.8 Ridership

Estimates of the number of public transport passengers (ridership) expected in future years are classified as (i) without a project in the Master Plan for Public Transport (Without Project), and (ii) with a project in the Master Plan for Public Transport (With Project). It is expected that the main street running light rail transit (LRT) public transport system will deliver the followings:

- The number of passengers using the LRT service will increase from 19,660 person - trips per day in the year 2023 to 110,250 person - trips per day in the year 2053 (an increase of number of passengers in public transport of about 50,000 person - trips per day (Figure 14)),
- It will result in a change in travel patterns. The number of passengers who use LRT service from private vehicles, will increase from 6.79% to 9.04% in 2023 and increase from 6.53% to 10.19% in 2053. That is, the LRT system in Nakhon Ratchasima City is able to attract more public transport passengers, approximately 35% (according to studies by the Committee for Perth, Australia¹ and the Department of Infrastructure, Northern Ireland, UK²),
- Travelers will increasingly use the LRT services: The proportion of LRT users to total public transport users will increase from 26% in 2023 to 79% in 2053 (Figure 15).

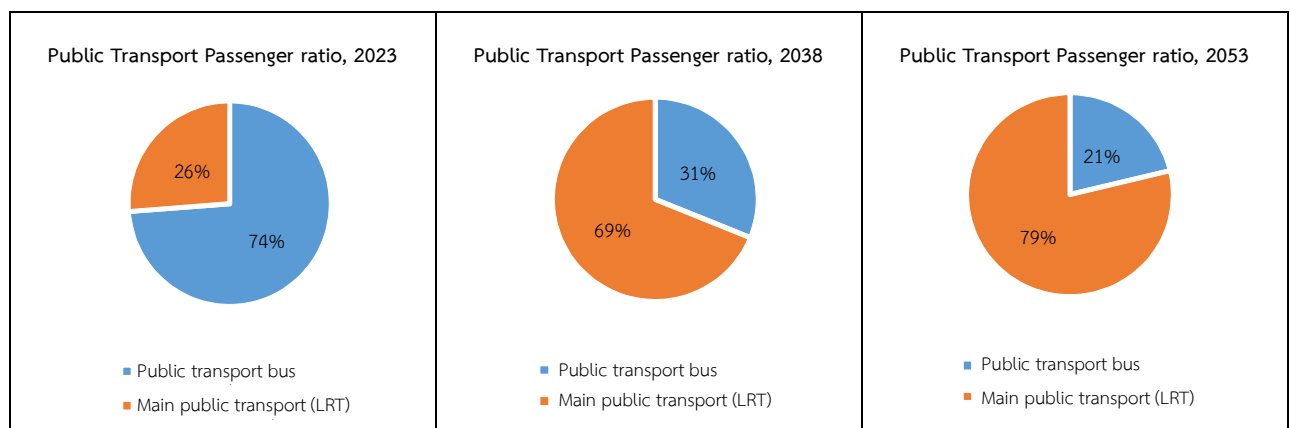
¹ "Bus Rapid Transit and Light Rail Transit, An Overview of Costs and Benefits" Research Report, Committee for Perth, Australia, November 2014.

² "Strategic Outline Case for Rapid Transit", Department of Infrastructure, Northern Ireland, UK, 2007



Source: The Consultant

Figure 14 Trends in Public Transport Use

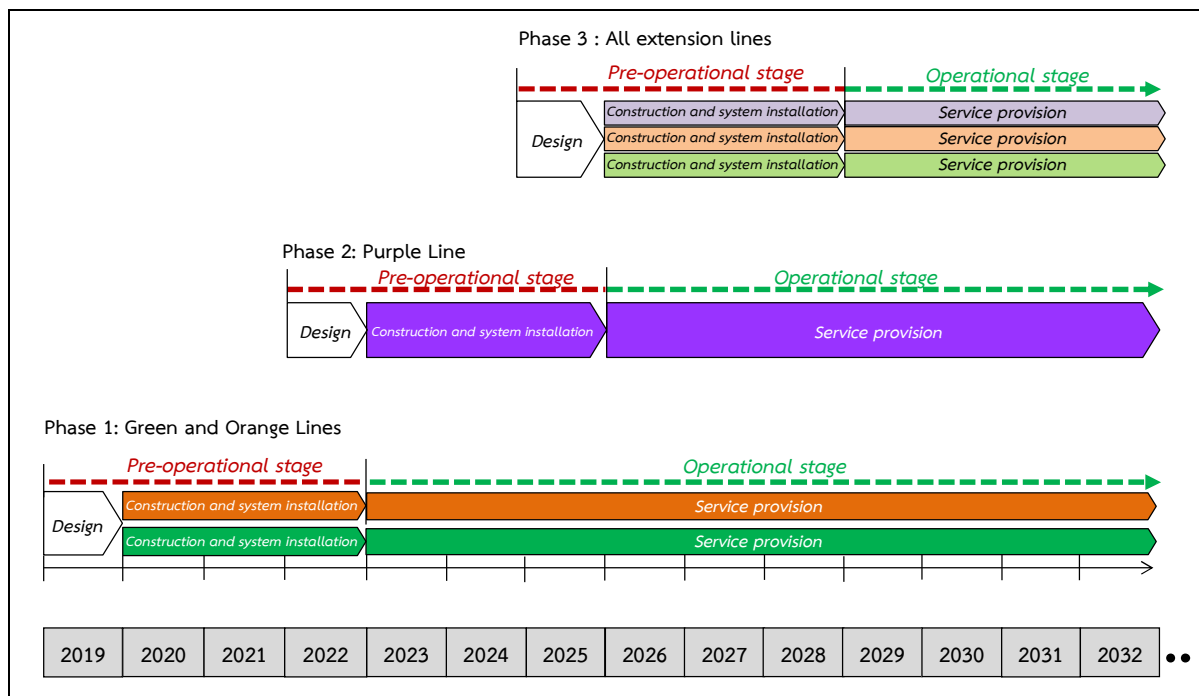


Source: The Consultant

Figure 15 Comparison of Passenger Numbers Using Public Transport Bus and the Main Public Transport System (LRT)

2.1.9 Process for the Main Public Transport System Development

The development of the main public transport network (LRT) proposed for operation in Nakhon Ratchasima City is divided into 3 Phases: (i) Phase 1: Green Line and Orange Line; (ii) Phase 2: Purple Line; and (iii) Phase 3 - complete out all extensions. The project commences in 2019 and divided into two phases: (i) the pre-operation stage design, construction and commissioning phase (LRT, Ticketing, ITS and related systems); and (ii) the operational stage (Figure 16).



Source: The Consultant

Figure 16 Project Overview of the Main Public Transport System Development
in Nakhon Ratchasima City

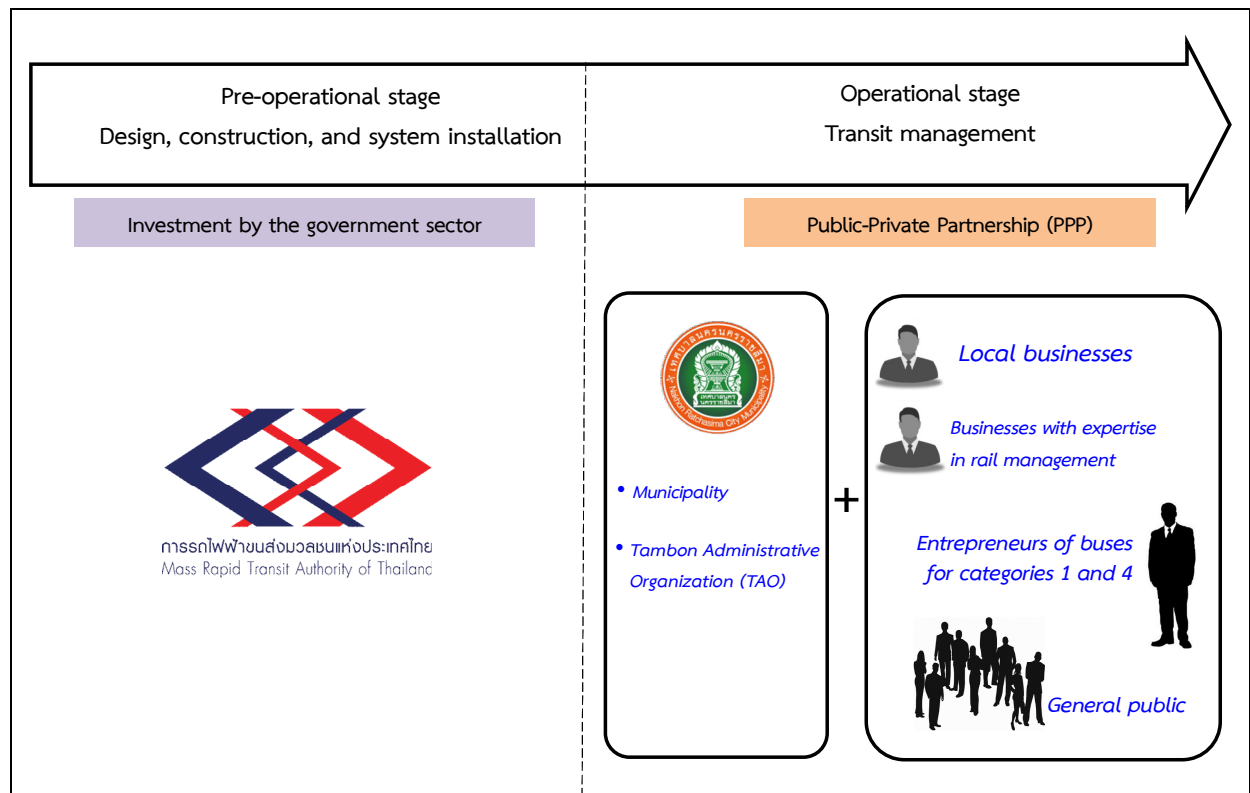
Implementation of the project to develop the main public transport system in Nakhon Ratchasima City will require many agencies to be involved, and need a high budget for construction and operation. Therefore, the proposal on how to implement the main public transport infrastructure development project in terms of investment and management are summarized below.

1) Project Implementation by Local Administrative Organization (LAO) in Nakhon Ratchasima Province

The project has significant budget needs for construction and operation. Therefore, it requires the coordination of several local administrative organizations, and there may be restrictions on investments and personnel with the required technical knowledge and expertise. A suggested approach to management of the project is shown in Figure 17.

- **Pre-operational stage:** the Mass Rapid Transit Authority of Thailand (MRTA) should have the leading role during the pre-operational stage on design, construction and commissioning of the system (LRT, Ticketing, ITS and related System). This is because the Mass Rapid Transit Authority of Thailand (MRTA) has experience in the design and construction of mass transit systems and in the management of construction and technical matters.
- **Operational stage:** during operation of the main public transport network the main purpose is to serve the majority of people in the Nakhon Ratchasima Municipality. The Municipality has the best understanding of the needs of the people in this area, therefore the operational period will be the time when the Local Administrative Organization (LAO) can play a role in the management of the system. Future commercial private sector co-investment is an option that could reduce the burden on the budget management and investment for Nakhon Ratchasima Municipality.

However, in the early stages of the project, Nakhon Ratchasima Municipality may not be ready to manage the first phase of the project. The Municipality needs to seek strategies for project implementation in order to reduce management costs. It could establish a limited company or take a shareholding in a limited company or, alternatively, it could form a syndicate in the Nakhon Ratchasima province under the law to manage the project.



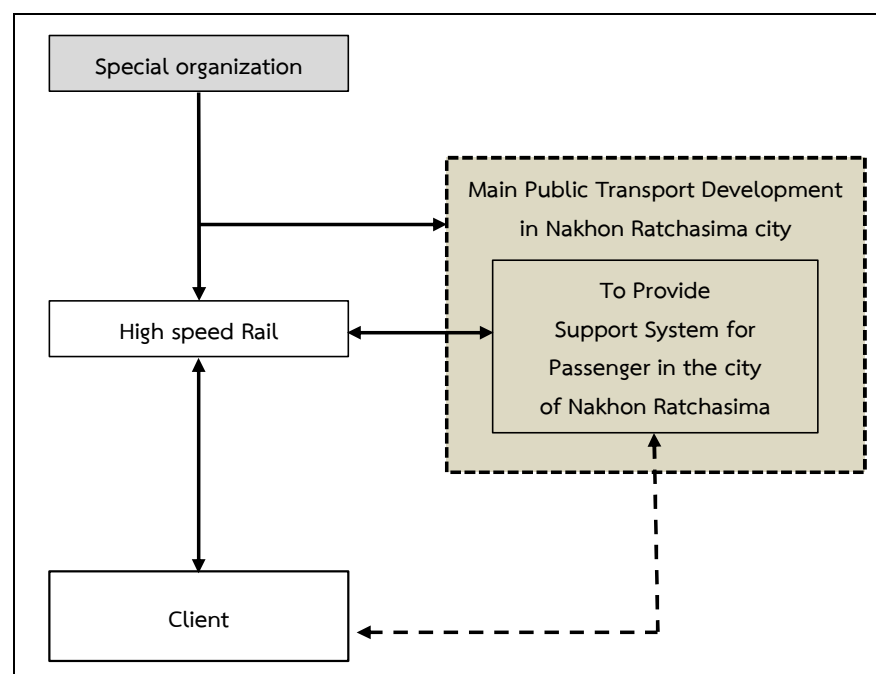
Source: The Consultant

Figure 17 Administrative Structure for Development of the Main Public Transport System in Nakhon Ratchasima City

2) Operation by a specially established organization

In the case where the Local Administrative Organization (LAO) of Nakhon Ratchasima province is unable to carry out transit management, a special organization may be established, similar to that the Thailand-China Rail Project linking Bangkok and Nakhon Ratchasima. This would serve as a key entity responsible for the operation of the LRT system development project, as shown in Figure 18. In order to ensure operational continuity and mitigate future risks, investment budgets should be allocated for both the pre-operational and the operational stages (design, construction, system installation, and operational management). Reasons for the establishment of a special organization are as follows:

- (1) eliminating local barriers to readiness and capacity constraints, especially investment funds and personnel with technical knowledge and expertise,
- (2) the main public transport system in Nakhon Ratchasima City is a system that directly supports the high-speed rail system,
- (3) implementation of the project for the development of the main public transport system in Nakhon Ratchasima City is aligned with planned commencement of the high-speed rail service in 2021 as the pilot project (Green plus Orange Lines) is scheduled to open in 2023 (Figure 16), and
- (4) in future, operation of high-speed rail and the main public transport system in Nakhon Ratchasima City will benefit from the use of common tickets, increasing passenger convenience and reducing costs. The system will benefit users of both high speed rail and of the main public transport system in the city of Nakhon Ratchasima. At that time, special organizations may be involved in common ticketing. This is in line with Thailand's common ticket system operation policy under the Common Ticketing System Management Act BE.....³.



Source: The Consultant

Figure 18 Management in the Form of Specialized Organization

³ Common Ticket Management Act ... is a draft Ticket Management System that co-ordinates the management structure of the Common Ticket System with the Common Ticket Ticketing Policy, which has the authority to set policy. Fare structure framework and rules associated Office of Transport and Traffic Policy and Planning is the agency serving as secretary of the board. Department of Rail, Government offices, Department under Ministry of Transport, are the regulatory body with the authority to supervise and set rules and procedures for managing the common ticket system. To establish a common ticket management system in the form of a company, with the criteria and guidelines for establishment and permission as prescribed in the Bill and set up a common ticket management system to support and promote the development of common ticketing or transport systems.

Draft Common Ticket Management Act was created to support common ticket management. This is a project that the government attaches importance to and urgently needs to be implemented to facilitate people traveling. By focusing on improving the capacity of the mass transit system with a more efficient system through the common ticket system. It benefits both the government, the operator as well as the user, thus saving time and travel expenses. Common tickets must rely on a legal mechanism to set the operational framework, and the scope of service cooperation. Delegation and a set of clear rules of conduct including the establishment of common ticket management system to support and promote the use of public transport in Thailand.

2.2 Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

In order to reduce traffic problems, the traffic in the Nakhon Ratchasima City and surrounding areas with travel demand needs can be classified in two stages: (i) prior to the launch of the main public transport system and (ii) after the launch of the main public transport system.

2.2.1 Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs: Prior to the Launch of the Main Public Transport System

- 1) Reduction in the Number of Vehicles by minimizing the Need to Enter Urban Areas:** by accelerating the outer ring and inner ring road projects to be completed before implementation of the main public transport project will result in through traffic no longer being routed through the city centre (Figures 19 and 20).
 - (i) Project 1: Construction of Nakhon Ratchasima Ring Road (outer Ring Road)
 - (ii) Project 2: Extension to and construction of Nakhon Ratchasima Ring Road (inner Ring Road)
 - (iii) Project 3: Intersection improvement
- 2) Prepare to Handle Traffic Problems on Main Roads used by Main Public Transport:** the development of the main public transport system (LRT) in Nakhon Ratchasima City will inevitably affect the road traffic system. It will therefore be necessary to develop the road system to accommodate changes by implementing the projects based on the LRT roadmap and integrated urban traffic management (Figures 21 and 22).
 - (i) Project 1: Construction of roads according to the draft Nakhon Ratchasima City Comprehensive Plan (3rd Amendment), 2013
 - (ii) Project 2: Construction of roads according to the City Municipality's development plans
 - (iii) Project 3: Four-lane road expansion (to respond to the traffic volume prior to the completion of the construction of the southern Outer Ring Road, Sections 3 and 4)
 - (iv) Project 4: Four lane road expansion for Road NM 1120, State Highway No. 2 Intersection - Ban Khopchai, Amphoe Mueang, Nakhon Ratchasima (to support Motorway No. 6 Bang Pa-in – Nakhon Ratchasima)
- 3) Traffic Management to Alleviate Traffic Problems in Nakhon Ratchasima and Surrounding Areas:** Road users do not respect traffic rules because traffic signal synchronization is not appropriate, which results in increased congestion. Therefore, implementation of the following projects is intended to alleviate such problems:
 - (i) Project 1: Road surface and traffic island improvement
 - (ii) Project 2: Installation of warning/traffic signs
 - (iii) Project 3: Road surface traffic sign improvement
 - (iv) Project 4: Traffic signals installation/improvement and traffic signals coordination improvement

The areas requiring improvement in traffic signal systems/traffic signs, and traffic law enforcement prior to the launch of the LRT system are illustrated in Figure 23.

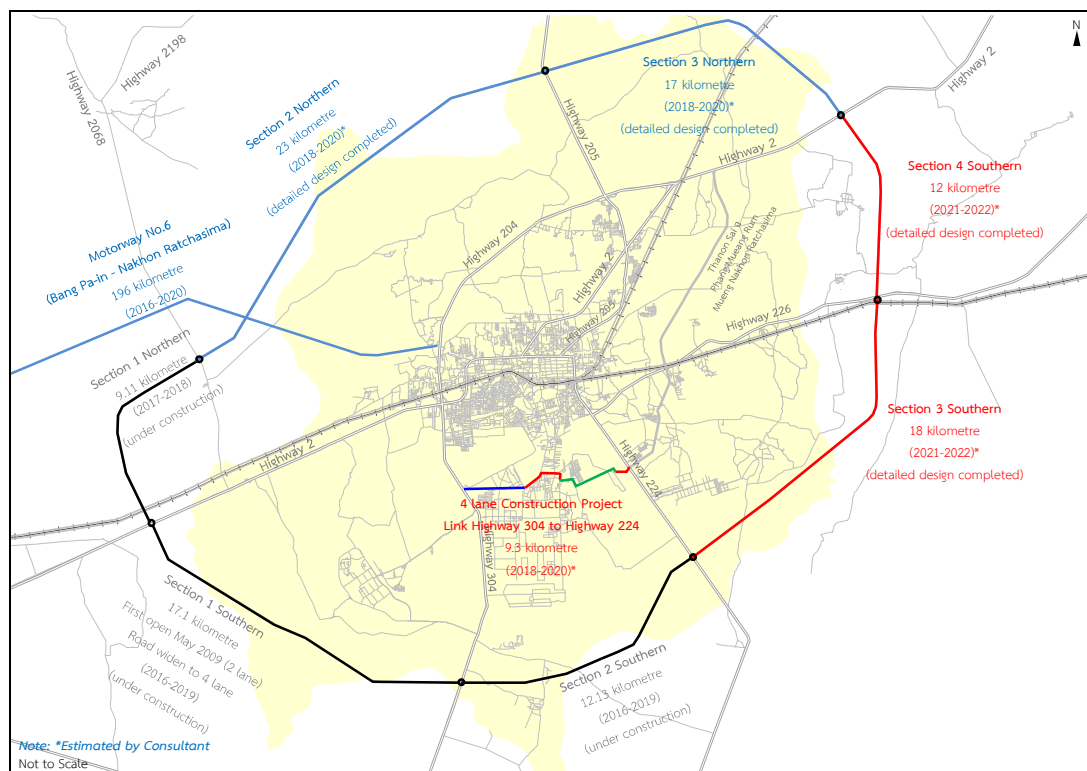
2.2.2 Traffic Management in Nakhon Ratchasima City and Surrounding Areas with the Travel Demand Needs: After the Launch of the Main Public Transport System

When the main public transport system (LRT) is implemented, substantial improvements are needed to be consistent with the agreed strategy. The main public transit route will require traffic legislation and effective enforcement to make overall traffic flow in Nakhon Ratchasima City efficient and flexible. The plan is to do the following:

- 1) road surface and traffic island improvement
- 2) installation of warning/traffic signs
- 3) road surface traffic sign improvement and
- 4) traffic signals installation/improvement and traffic signals coordination improvement.

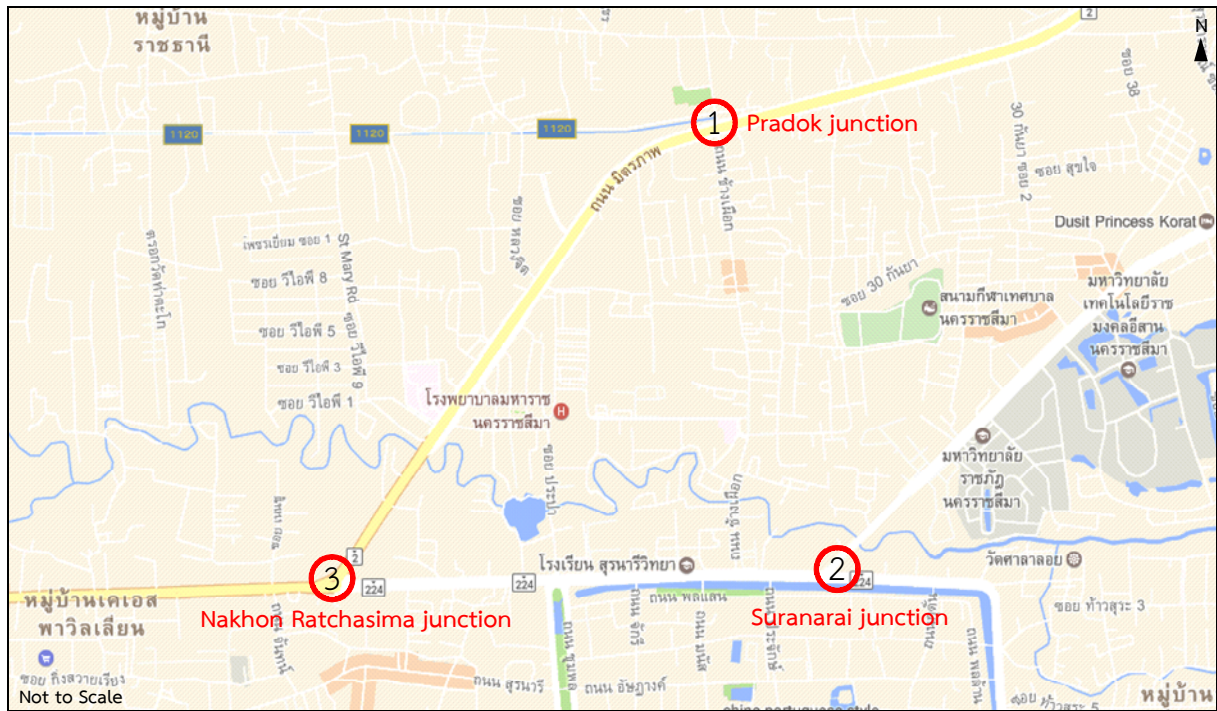
Areas where Traffic Signals/Traffic Signs and the effectiveness of law enforcement must be improved prior to the main public transport system is implemented, are summarized in Figure 24.

An evaluation was undertaken of the impact on the network of intersections of both physical and synchronous future updates. The conclusions relating to traffic management of intersections in the future (2023) are as follows: (i) prior to launch of the main public transport system: the physical characteristics and traffic management of the main intersections have been improved. During the peak hours, the results in average queue length reduced by 24.80%, average travel time reduced by 30.91% and average delay time reduced by 35.80%; and (ii) after the launch of the main public transport system: the physical characteristics and traffic management of the main intersections have been improved. During the peak hour, the results in average queue length reduced by 44.09%, average travel time reduced by 45.56% and average delay time reduced by 51.85% during peak hours.



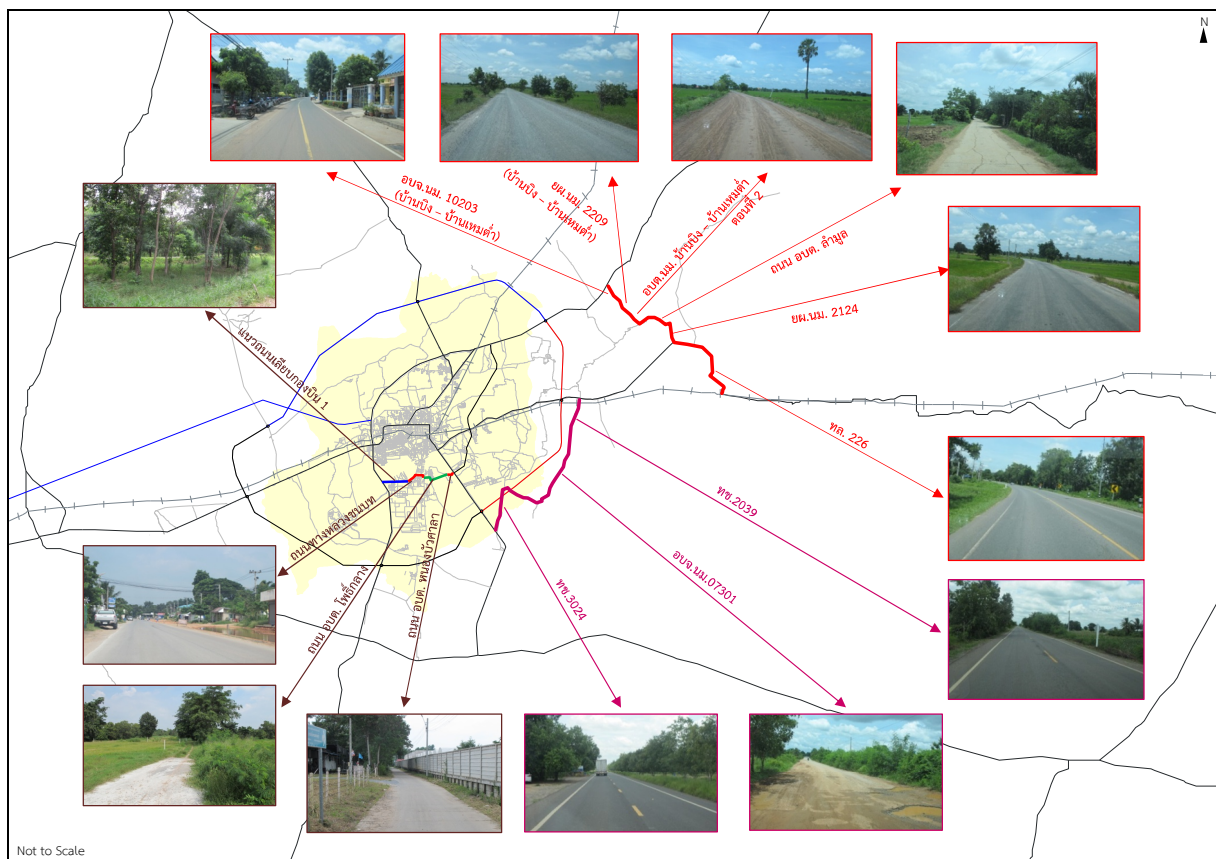
Source: Modified from Department of Highways

Figure 19 Outer and Inner Ring Road Construction Projects



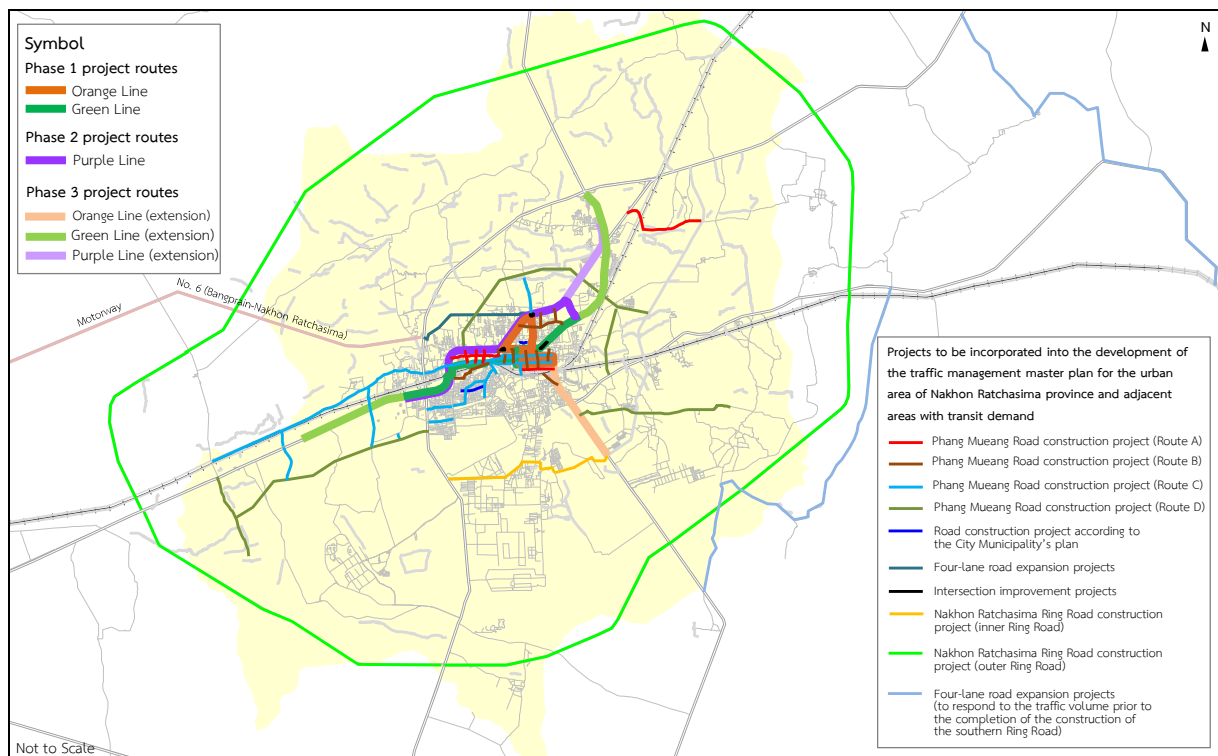
Source: Modified from Google Maps

Figure 20 Location of Junction Improvements



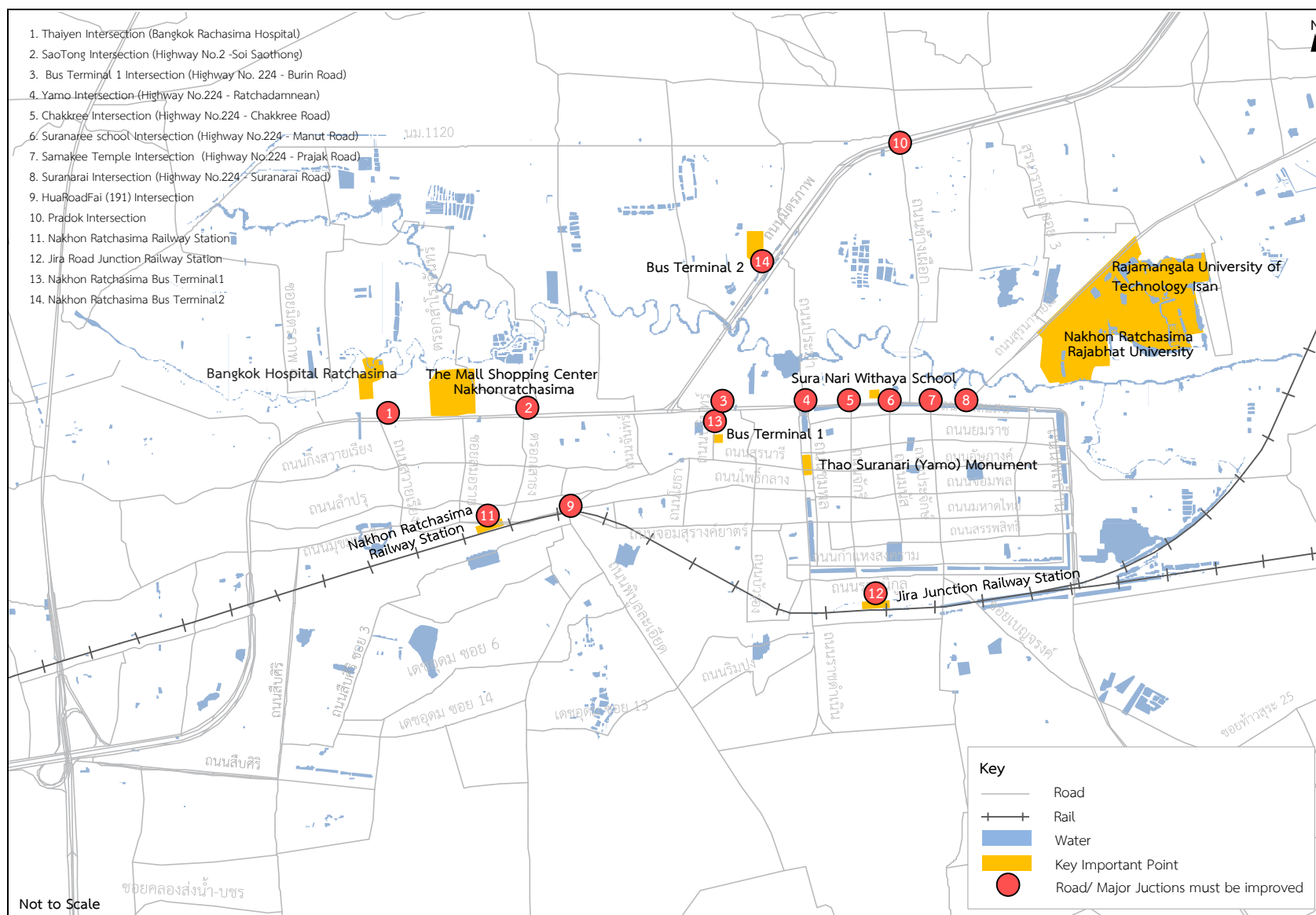
Source: Modified from Google Maps and Department of Highways

Figure 21 The Four-lane Road Expansion Project (to accommodate Traffic before the Outer Ring Road is completed – Sections 3 and 4 on the South)



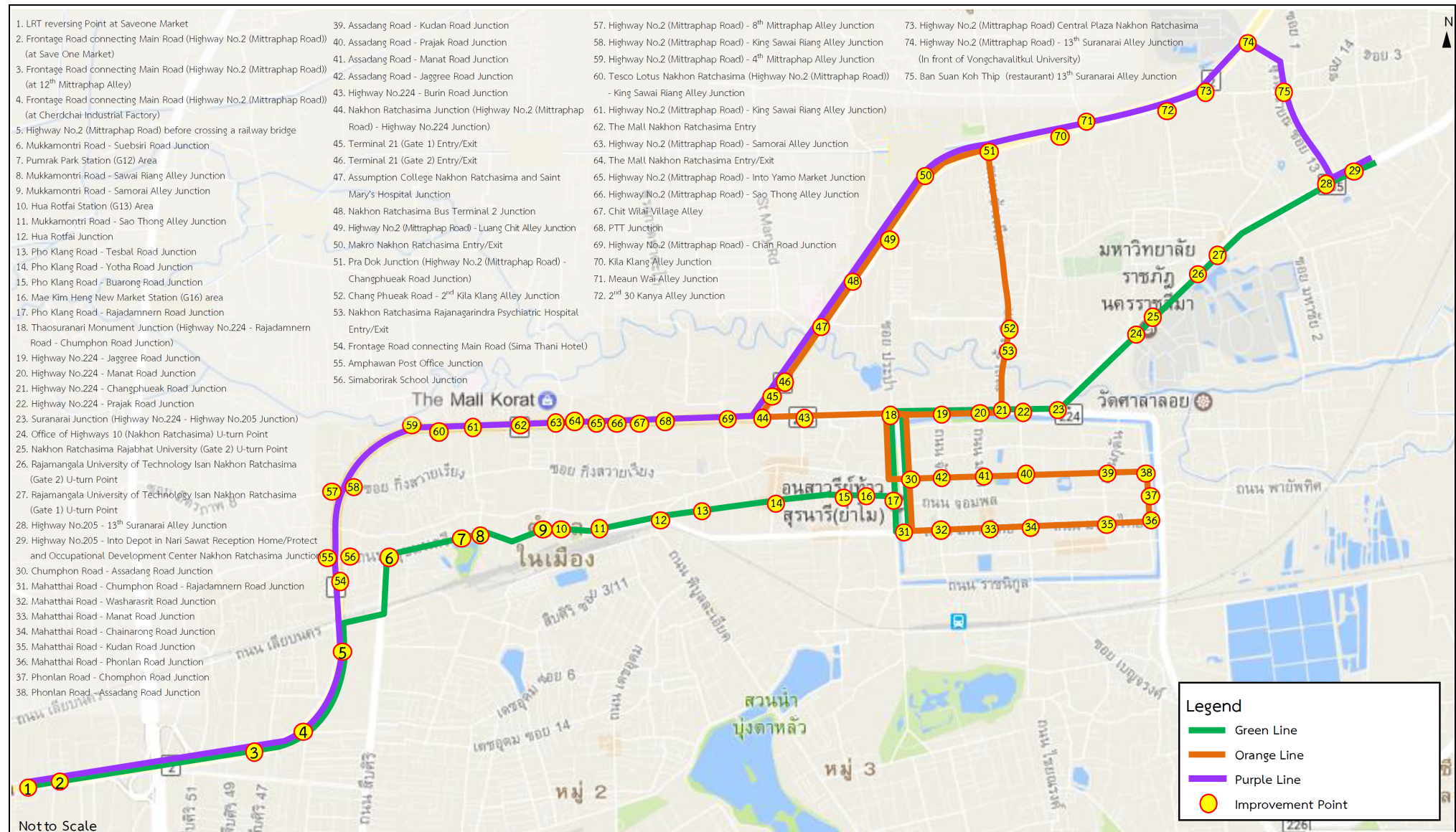
Source: Modified from Department of Highways

**Figure 22 The Proposed Road Projects to handle Traffic Congestion for
the Main Public Transport System**



Source: Modified from Department of Highways and Nakhon Ratchasima City Municipality

Figure 23 Areas where Traffic Signals / Traffic Signs and Law Enforcement must be Improved before the Service of the Main Public Transport System



Source: Modified from Google Maps

Figure 24 Areas where Traffic Signals / Traffic Signs and Law Enforcement must be Improved when the Main Public Transport System is Operational

2.3 Master Plan for Public Transport Development, Master Plan for Traffic Management and Urban Development Plan for Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

2.3.1 Master Plan for Public Transport Development in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

The Master Plan for Public Transport Development in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs is considered to be consistent and responsive to government policies and strategies relating to the development of country public transport and the provincial development plan including the relevant agency plans (Figure 25). The conclusion of the investment budget and the appraisal analysis are as follows:

1) Estimation of Investment for the Development of the Public Transport System according to the Master plan

Investment in the three lines of the LRT system extending over a total distance of 50.09 kilometers for Nakhon Ratchasima City and surrounding areas with travel demand needs is estimated at 32,600 million Baht, as detailed in Table 4.

Table 4 Estimation of Investment on Development of Public Transport in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

No.	Main Public Transport Routes	Distance (kms)	Investment (Million Baht)
1	Green Line	11.17	8,400
2	Orange Line	9.81	5,200
3	Purple Line	7.14 ²	4,800
4	Extensions ¹	21.97	14,200
Total		50.09	32,600

Notes: ¹ Extension routes are recommended for implementation after Orange, Green and Purple Lines open for the service.

² One direction construction distance

Source: The Consultant

2) Economic Appraisal Analysis of the Master Plan

The results of the economic appraisal analysis of the master plan can be divided into two cases (Table 5): (i) In the case of the Master Plan (Phase 1 and Phase 2) Green, Orange, and Purple Lines, and (ii) in case of the Master Plan (Green, Orange and Purple Lines) plus extension of each route (Ultimate Network). It can be said that it is economically viable because NPV is positive, EIRR is greater than 12% and B/C Ratio is greater than 1.

Table 5 The Results of the Economic Appraisal Analysis of the Master Plan

Indicators	Investment Network	
	Green + Orange + Purple Lines	(Green + Orange + Purple Lines) + Extension
NPV (million baht)	13,760	9,080
EIRR (%)	22.11	17.76
B/C Ratio	1.81	1.35

Source: The Consultant

3) Financial Appraisal Analysis of the Master Plan

The financial appraisal analysis of the master plan was conducted for two cases according to size of investment: (i) investment in the Green Line plus the Orange Line with the operation being scheduled to commence in 2023, as well as the Purple Line with the operation being scheduled to commence in 2026, and (ii) investment in the three lines as indicated in (i) plus their extension lines with the operation being scheduled to commence in 2029. It is concluded that operation of the LRT system in the Nakhon Ratchasima City is not financially feasible since the NPV is negative, the financial internal rate of return (FIRR) cannot be determined, and the B/C Ratio is lower than 1, as shown in Table 6.

Table 6 The Results of the Financial Analysis of the Project under the Master Plan

Indicators	Investment Network	
	Green Line + Orange + Purple	(Green Line + Orange + Purple) + Extensions
NPV (million baht)	- 18,750	- 30,820
FIRR (%)	Cannot be calculated	Cannot be calculated
B/C Ratio	0.18	0.14

Source: The Consultant

2.3.2 Master Plan for the Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

The Master Plan for traffic management in Nakhon Ratchasima City and the surrounding areas with travel demand needs was implemented in parallel with the Master Plan for the development of Public Transport in Nakhon Ratchasima City and areas with travel demand needs. The Master Plan for the traffic management was focused on problem solving and traffic management in Nakhon Ratchasima City and particularly in the areas surrounding the public transport hubs (railway stations, and bus terminals). The process and the essence of the Master Plan is shown in Figure 26. The project plan is aligned with the Master Plan. The measures included in the Master Plan for the development of Public Transport in Nakhon Ratchasima City with travel demand needs are summarized as comprising 15 projects with a total investment budget of 18,300 million baht.

Vision	“Development of the main public transport system for travelling in the Nakhon Ratchasima city”				
Mission	To develop a convenient, safe and efficient public transport interchange				
Goal	1. Centrally connected for travelling		2. Safety travel and traffic, Energy saving and environmentally friendly		3. Public transport services can improve the quality of travel
Strategic Policy	Strategic Policy 1: Development of main public transport system in Nakhon Ratchasima City and the development of interchange within Nakhon Ratchasima City with main public transport system		Strategic Policy 2: Increasing the convenience and safety of public transport routes within Nakhon Ratchasima city		Strategic Policy 3: Development and improvement of service with appropriate facilities
strategy	Strategy 1.1 : Development of the main public transport network in Nakhon Ratchasima city	Strategy 1.2 : Development of access points and access for transit traffic of the main public transport system	Strategy 2.1:Improvement of bus routes to be consistent and linked to the main public transport system	Strategy 2.2: Increasing Safety Measures for Public Transport Journey	Strategy 3.1: Development of travel information system by information technology
Plan	Major public transport investments in Nakhon Ratchasima city	Development of access points and access for transit traffic of the main public transport system	To improve feeder bus routes.	Safety in transit using public transport.	The use of information technology in public transport
Project	- Project 1: Main Public Transport Investment Project: Green Line - Project 2: Main Public Transport Investment Project: Orange Line - Project 3: Main Public Transport Investment Project: Purple Line - Project 4: Main Public Transport Investment Project : Extension (Green Line, Orange Line and Purple Line)	- Project 1 Flyover/Overpass - Project 2 Park and Ride	- Measures 1:To reroute the bus route category 1 - Measures 2:To reroute the bus route category 4	- Measures 1: To increase safety measures of the bus. - Measures 2: To make understanding how to use public transport for travelling	- Project 1: Passenger Information System (PIS) - Project 2: Feasibility Study of Common Ticketing System
Budget Investment	31,000 Million Baht	1,300 Million Baht	50 Million Baht	50 Million Baht	200 Million Baht
The responsible agency	Mass Rapid Transit Authority of Thailand		Provincial Land Transport Office of Nakhon Ratchasima	Provincial Land Transport Office of Nakhon Ratchasima	Mass Rapid Transit Authority of Thailand/ Provincial Land Transport Office of Nakhon Ratchasima

Source: The Consultant

Figure 25 Master Plan for Public Transport Development in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

Vision	“The most efficient traffic system”			
Mission	To manage traffic in urban area and its vicinity for free flow and safety			
Goal	1. To manage traffic for maximum efficiency			2. To develop public participation on solving traffic congestion
Strategic Policy	Strategic Policy 1 Solving traffic congestion on through area main roads (Through Traffic)	Strategic Policy 2 Solving traffic congestion for the entry and exit traffic in the area (Local Traffic)		Strategic Policy 3 Changing the behavior of public space applications.
Strategy	Strategy 1.1: Solving traffic congestion on main roads	Strategy 2.1: Preparing to handle on traffic congestion on roads connecting main public transport system	Strategy 2.2: To improve Traffic Signals / Traffic Signs and law enforcement	Strategy 3.1: Adjustment of public space behavior / public awareness and participation
Plan	Solving traffic congestion on main roads	Preparation for main public transport system	To reduce traffic congestion in affected areas	Improvement on public behavior in public transport service
Project	- Project 1: Construction of Nakhon Ratchasima Ring Road (outer Ring Road) - Project 2: Extension to and construction of Nakhon Ratchasima Ring Road (inner Ring Road) - Project 3: Intersection improvement	- Project 1: Construction of roads according to the draft Nakhon Ratchasima City Comprehensive Plan (3rd Amendment), 2013 - Project 2: Construction of roads according to the City Municipality's development plans - Project 3: Four-lane road expansion (to respond to the traffic volume prior to the completion of the construction of the southern Outer Ring Road, Sections 3 and 4) - Project 4: Four lane road expansion for Road NM 1120, State Highway No. 2 Intersection - Ban Khophai, Amphoe Mueang, Nakhon Ratchasima (to support Motorway No. 6 Bang Pa-in - Nakhon Ratchasima)	- Project 1: Road surface / traffic island improvement - Project 2: Installation of warning / traffic signs - Project 3: Road surface traffic sign improvement - Project 4: Traffic signals improvement / installation and traffic signals coordination improvement	- Project 1: Korat Car Free day - Project 2: Walking Street, Tourism on 6 temples in old city area, Nakhon Ratchasima - Project 3: Bike for Green Korat Campaign - Project 4: Providing a campaign week for respecting traffic rules and discipline in using shared road
Budget Investment	13,960 Million Baht	3,940 Million Baht	370 Million Baht	30 Million Baht
The responsible agency	DOH, DRR, Pho Klang TAO, Nong Buasala TAO	DPTNR, PAONR, TAO, NRCM, DOH, DRR	NRCM, DOH	NRCM

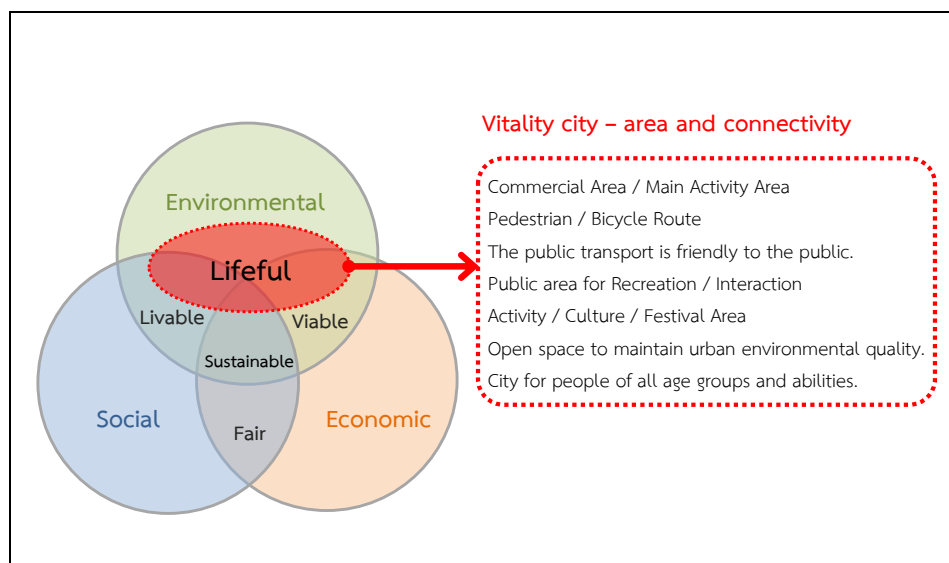
Note: * DOH = Department of Highways, DRR = Department of Rural Roads, TAO = Tambon Administrative Organization, DPTNR = Department of Public Works and Town and Country Planning of Nakhon Ratchasima, NRCM = Nakhon Ratchasima City Municipality, PAONR = Provincial Administrative Organization of Nakhon Ratchasima

Source: The Consultant

Figure 26 Master Plan for the Traffic Management in Nakhon Ratchasima City and Surrounding Areas with Travel Demand Needs

2.3.3 Development Plan Consistent with the Integration of Public Transport Links

The development of the urban areas of Nakhon Ratchasima needs to focus on the environmental issue, as well as the economic issue, in order to develop the “vitality” of the city (Figure 27). In the areas of the Old Town inside the city moat, and in the Pho Klang Central Trade Areas, a dense areas of activity should be created and interconnected to promote fair and creative trade. Effective and comprehensive circulation of people and activities, goods and services as well as the vision for the development of Nakhon Ratchasima City must be consistent with the integration of public transport, namely “lively Korat is the Gateway to Isan, a Creative Center and, the Old Town is walking friendly”.



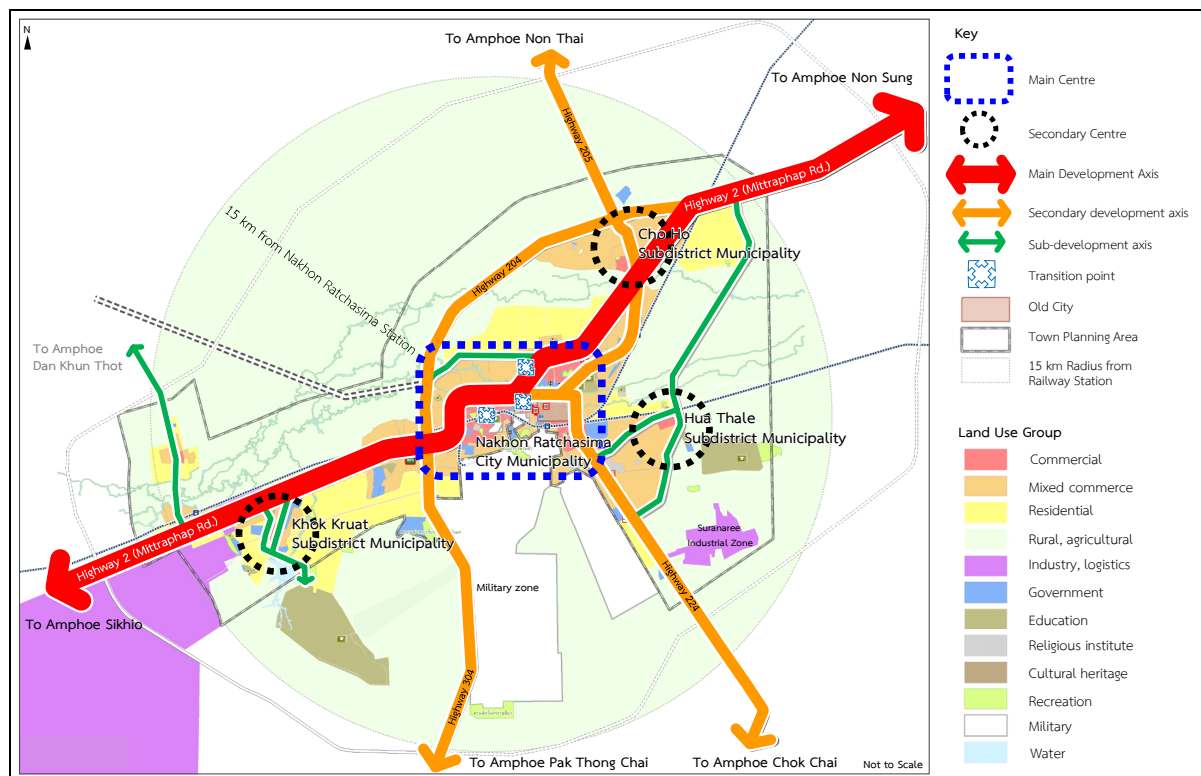
Source: The Consultant

Figure 27 The Urban Development Concept in Nakhon Ratchasima City

Nakhon Ratchasima Railway Station is an important interchange hub for the existing situation, and in the future, it will become an important attractor for development. As a result, the development of the city is concentrated around this location, areas inside the city moat, and around the old moat. The city can attract people travelling from the surrounding areas, especially in the north and east, who want to connect with Bangkok. It was decided to expand the areas east and west to accommodate the growth of the city. The concept of spatial development and the preparation of a spatial development plan consistent with the integration of public transport is summarized in Figure 28.

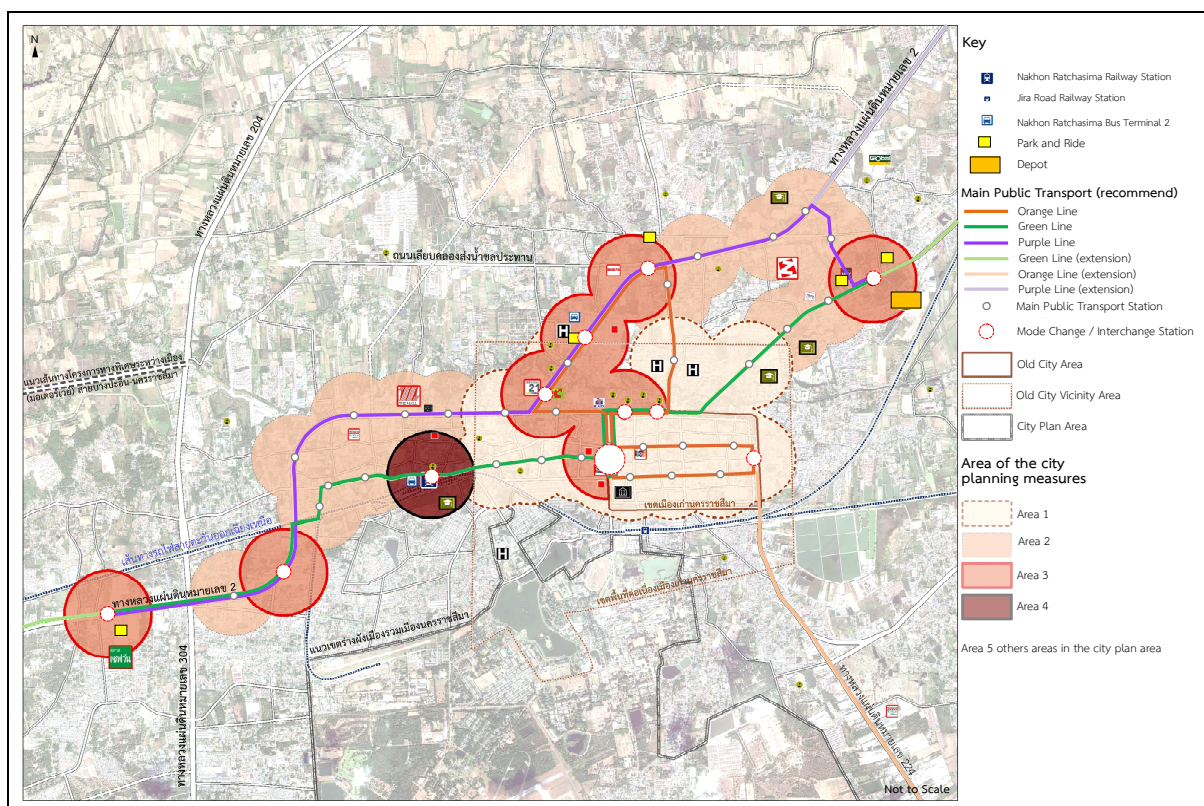
Urban planning measures should be both encouraged and regulated under the law of urban planning and building control such that they are applied to the local areas taking account of the diversity and overlap with the old town of Nakhon Ratchasima. By definition, the areas for urban development measures in these areas should be consistent with the integration of public transport, as shown in Figure 29. Details of the potential measures can be classified into 6 main categories as shown in Table 7.

The duration of the urban development plan corresponds to the integration of the public transport system in three phases. The development of the connection to the appropriate areas, as shown in Figure 30, is considered to be consistent with travel interchange points and the appropriate access points in phase 1, phase 2 and phase 3 (Figure 31).



Source: Modified from Draft Nakhon Ratchasima City Comprehensive Plan and Nakhon Ratchasima Province Comprehensive Plan

Figure 28 Area Development Plan Consistent with the Integration of Public Transport Links



Source: Analysed by the Consultant and modified from the Google Maps

Figure 29 Area Classification for Urban Planning Measures for Area Development on the Integration of Public Transport Links

Table 7 Summary of City Planning Measures and other Measures to develop a Space in Line with the Integration of Public Transport Links

No.	Areas	Density and Mass Building		Land Use	Promotion of Public Transport			Network Development for Public Transport Connection	Creation Fairness	Other Measures
		Max FAR*	Min OSR**		Offering to Have	Walking / Bicycle Routing By Plot	Space Management for Footpath and Parking			
1.	Within 500 meters of the public transport system in the old town and adjacent areas	6.5 per 1	10 %	1) Hotels in accordance with hotel law. 2) Theater under the law on building control.	If the areas is parked bicycle or It is a public way through land plots linking the public. FAR * can be increased by 20%, but the total building areas must not exceed two times that of bicycle parking areas, or twice as much space as the public way without taking into account FAR * and OSR **		The fence or wall is built along the public road. The areas above the level of soil that exceeds 1.50 meters must be constructed with visible material.	Layout of the road project according to the plan, to develop secondary and suburban road networks within a 500 meter radius around public transport stations. To increase space and comfort for pedestrians and Bicycle spin by the quality of the footpath improvement project	Transfer of development rights to land plots of valuable buildings should be preserved	1) Establish database of land use and land valuation. 2) Development of utilities, and sanitation systems especially garbage and waste water management of the community.
2.	Within 500 meters of the public transport system outside the old town and the adjacent areas	6.5 per 1	10 %	3) Residential housing includes dormitories, condominiums or large buildings.		If there is more parking than the law. FAR * can be increased 20%, but the total building areas must not exceed 30 square meters per 1 car park without taking into account in FAR * and OSR **.				
3.	Within 500 meters of the public transport station, which is a major intersection or major change of route outside the Old Town	7 per 1	10 %	4) Conference Centre or Exhibition						
4.	Within 500 meters of the railway station around Nakhon Ratchasima	8 per 1	5 %							
5.	Other areas in the study areas	4 per 1	20 %	Review and develop a plan to control the development of the city						

Note: * FAR (Floor Areas Ratio) is the ratio of the total floor areas of all floors in all buildings to size of the land that the buildings are located.

** OSR (Open Space Ratio) means the ratio of the total areas of the uncovered space to the total floor areas of all buildings on the same land plot.

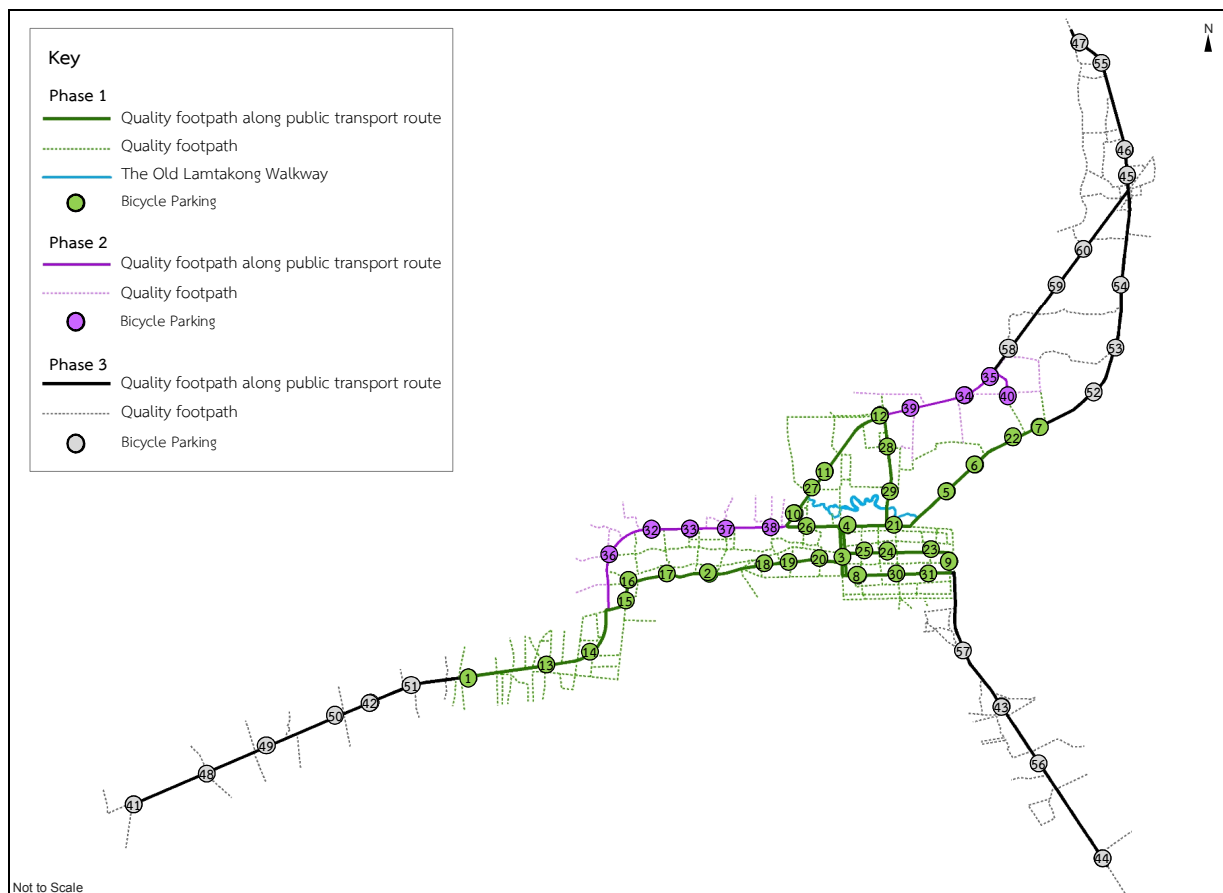
Source: The Consultant

Phasing	Phase 1: Development of public transport network and area, in the original center and the adjacent area of main public transport (LRT), green and orange lines			Phase 2: Development of public transport network and area, in the new secondary area, the main public transport links (LRT), purple line			Phase 3: Development of a public transport network, in the new secondary area, linking the main public transport (LRT) extension (green, orange and purple)		
	- Study on urban planning measures for space development in line with the integration of main public transport link (LRT) - Study the concept of development of the area of Nakhon Ratchasima Bus Terminal 2 and suggesting the development of the area of the railway station in Nakhon Ratchasima. - Study the concept of community development in Nakhon Ratchasima Municipality. - Detailed design of the main public transport infrastructure (LRT) - Construction / improvement of quality pavement infrastructure, in the main Nakhon Ratchasima. - Construction / renovation of the area surrounding the monument Thaosuranari, and the surrounding area - Construction / improvement of quality pavement infrastructure, around the Nakhon Ratchasima Bus Terminal 2 - Construction / improvement of quality pavement infrastructure, around the railway station, Nakhon Ratchasima. - Construction / improvement of quality pavement infrastructure, link to Nakhon Ratchasima Railway Station- Old Town - Construction / improvement of quality pavement infrastructure, around the Control and Maintenance Center (Depot) - Construction / renovation of the area of Pradok (Wat Khok Phai)			- Review of urban development measures for space development in line with the integration of major public transport links (LRT). - Detailed design of the main public transport infrastructure (LRT) - Construction / improvement of quality pavement infrastructure, Nakhon Ratchasima, CM - Construction / improvement of quality pavement infrastructure, Nakhon Ratchasima, Ban Koh SM			- Review of urban development measures for space development in line with the integration of major public transport links (LRT) - Detailed design of the main public transport infrastructure (LRT) - Construction / improvement of quality pavement infrastructure, Nakhon Ratchasima CM - Construction / improvement of quality pavement infrastructure, Nakhon Ratchasima CM and the Suranaree SM - Construction / improvement of quality pavement infrastructure, connected to Suranaree University of Technology - Construction / improvement of quality pavement infrastructure, Ban Mai SM, Ban Koh SM and Cho Ho SM - Construction / improvement of quality pavement infrastructure, Nongbuasala and Huatlay SM - Construction / improvement of quality pavement infrastructure, connected to Suranaree Industrial Zone - Construction / Improvement of Nongbuasala Area (Center of Technology Transfer 5th and 6th Cooperative)		
Project	1. Quality footpath development to connect with public transport			2. Development of facilities to promote the use of bicycles, mode change points, route connectors, Park and Ride, and station or parking as appropriate					
Area	Phase 1	Phase 2	Phase 3	Phase 1	Phase 2	Phase 3			
	- Sidewalk areas along public roads. - Pedestrian areas along secondary and suburban roads within a 500 meter radius around a station or public transport stop. - The old Lam Ta Khong Canal connects the school district (4 schools in Nakhon Ratchasima, ie, Muang Nakhon Ratchasima School, Nakhon Ratchasima Vocational College, Anubannakhonratchasima School and Suranarivithaya School)	- Sidewalk areas along public roads. - Pedestrian areas along the secondary and suburban roads within 500 meters of the public transport station or station	- Sidewalk areas along public roads. - Pedestrian areas along the secondary and suburban roads within 500 meters of the public transport station or station	- Saveone Market Station - Hua Rotfai Station (Nakhon Ratchasima Railway Station) - The area around the Thaosuranari monument - Prapa Junction Station (4 schools area in Nakhon Ratchasima, ie Muang Nakhon Ratchasima School, Nakhon Ratchasima Vocational College, Anubannakhonratchasima School and Suranarivithaya School) - Rajabhat Station (Nakhon Ratchasima Rajabhat University) - Rajamangala Station (in front of Rajamangala University of Technology Isan Nakhon Ratchasima) - Nari Sawat Reception Home/Protection Station - Provincial Education Station (in front of Education Nakhon Ratchasima Provincial Education Office) - Phon Lan Gate Station - Terminal 21 Station (Nakhon Ratchasima Junction) - Nakhon Ratchasima Bus Terminal 2 Station - Pradok Junction Station - Stations G8, G9, G10, G11, G12, G14, G15, G16, G19, G22, O6, O7, O8, O10, O12, O15, O16, O22, O23 - Queen Sirikit Sericulture Center (Nakhon Ratchasima)	- Tesco Lotus Nakhon Ratchasima Station - The Mall Station, Nakhon Ratchasima - Central Plaza Station, Nakhon Ratchasima - Vongchavalitkul Station (Vongchavalitkul University) - Stations P4, P7, P8, P13, P16	- Irrigation Station (Irrigation Water Test Station 3 and The National Broadcasting Services of Thailand, Nakhon Ratchasima) - Ford Service Center Station (Queen Sirikit Sericulture Center, Nakhon Ratchasima) - Huatlay Junction Station - Dohome Station (Center of Technology Transfer 5th and 6th Cooperative) - Cho Ho Junction Station (Cho Ho SM) - Suranarai Camp Station (Provincial Police Training Center Region 3) - Nakhon Ratchasima Transport Office 2 Station - Stations G2, G3, G4, G6, G24, G25, G26, G29, O2, O4, P18, P19, P20			
Budget (Baht)	99,950,000	18,128,000	59,430,000	6,330,000	1,150,000	2,710,000			
The responsible agency *	Nakhon Ratchasima CM	Nakhon Ratchasima CM/ Meaun Wai SM/ Ban Koh SM	Nakhon Ratchasima CM/ Muangmai Kokkrud SM/ Suranaree SM/Ban Mai SM/ Ban Koh SM/ Cho Ho SM/ Nongbuasala SM/ Huatlay SM	Nakhon Ratchasima CM	Nakhon Ratchasima CM/ Ban Koh SM/ Meaun Wai SM	Muangmai Kokkrud SM/ Nakhon Ratchasima CM/ Huatlay SM/ Nongbuasala SM/ Cho Ho SM/ Suranaree SM/ Ban Koh SM			

Note: * CM = City Municipality, SM = Subdistrict Municipality

Source: The Consultant

Figure 30 Area Development Plan Consistent with the Integration of Public Transport System



Source: The Consultant

Figure 31 Park and Ride, Interchange/Mode Change and appropriate Access Points for Phase 1, Phase 2 and Phase 3

2.4 Pilot Project for the Development of the Main Public Transport System in Nakhon Ratchasima City

The work in this section consists of the preliminary study, the economic and financial appraisal analysis, and consideration of the of investment model. The development concept of the surrounding area of the public transport (LRT) station is as follows:

2.4.1 Conceptual Design

Specifications of the conceptual design are provided in Table 8, and Figures 32 and 33.

Table 8 Conceptual Design of Pilot Project for the Development of Main Public Transport in Nakhon Ratchasima City

No	Items	Detail
1	Geometric Design	- Maximum Speed 70 km / hr. - Minimum radius 20 meters - maximum slope 6% - Minimum vertical length 350 meters
2	Track cross-section and drawing	- LRT Green Line and Orange Line Routes - Starting point (and reversing direction of traffic) of the green line, in front of the Saveone Market. The ending point is in the Nari Sawat Reception Home/Protection. - The orange line has a starting point at the Mahatthai - Phon Lan Junction. (Soi Burapha Road, Phon Lan Road Side) and the ending point of Mahatthai - Phon Lan Junction. (Beside School District 1 (Burapha Vithayakorn)) - The track runs on a standard gauge of 1.435 meters using a grooved rail, with a vibration damper. The rear level is the same level as the road surface. Excluding for the Mittraprab Road, (Opposite Cherdchai Factory) - Suebsiri Road Soi 6 - Suebsiri Road, which is under (underpass) the railway
3	The connection between the main public transport	All areas of Nakhon Ratchasima City can access to public transport, by changing the route and mode. Therefore, there should be a connection between the lines using the interchange for the mode change.
4	Park and Ride	The 6 locations of the Park and Ride: (i) the Saveone Market; (ii) the Nakhon Ratchasima Bus Terminal No.2; (iii) the Nakhon Ratchasima Agricultural Co-operative Club, (iv) Talad Night Ban Koh (v) Wat Weru Wanaram (Khok Phai) and (vi) Queen Sirikit Sericulture Center (Nakhon Ratchasima) (Approximately 1.6 km from LRT Saveone Market (G7) with 20 Seats Shuttle Buses running at the same frequency as LRT)
5	Drainage and flood protection systems	The existing drainage system along main roads and sois should be used in the community, as improved to a diameter of 1.20 to 1.50 meters.
6	Drawings of LRT crossing on railway or road	- Summary as 3 main cases: - Traffic signal or warning signs are used in cases where the LRT runs through junction, or - Closing the junction, in case of the LRT run through the junction, (running on the middle of the road on island), between frontage roads and main roads. - Underpass Route (under railway track) (the Mitraphap Road - Suebsiri Road (soi 6) - Suebsiri) is used for the LRT, in case of running through the junction. The layout profile is based on the following: (i) depth based on the height of the LRT and the standard height of the gap distance (8.00 to 10.00 meters). (ii) the bottom surface is applied with a Tension Pile. (iii) the geometry of the intersections have the appropriate profile level, avoiding unnecessary depth setting.

Table 8 Conceptual Design Pilot Project for the Development of Main Public Transport in Nakhon Ratchasima City (continued)

No	Items	Detail
7	Station, Control and Maintenance Center (Depot)	- The platform layout is 1.00 meters high, with a width of about 1.50 meters and a length of about 28.00 meters. There are 6 basic types of stations: (i) small station located along the road (ii) small station located on the middle of the road (iii) medium station located along the road; (iv) medium station located on the middle of the road; (v) underground station and (vi) station for a special design. - Control and Maintenance Center (Depot) - Storage Sidings 30 x 150 meters, with a capacity of at least 30 vehicles, a distance of at least 900 meters, a distance between tracks of at least 4.5 meters. If there is a roof, the ceiling is at least 6 meters. - 30 x 80 meter workshop with at least 3 simultaneous storage capacities, at least 80 meters in length, at least 6 meters between the vehicle, and at least 5 meters in the storage areas. The height of the roof ceiling is at least 7 meters. There is space for the installation and use of lifting cranes, storage space and transport equipment. The office building has a minimum size of 20 x 40 meters. It also requires office space for general administration. The control room is not less than 15 x 40 meters and the temperature control room for computers as controlled equipment as required. - Electricity Sub-station is not less than 10 x 15 meters. - Areas for minimum turning radius is not less than 20 meters.
8	Electrical System	Use a wireless battery system that is fully charged. The control and maintenance center (Depot) has a power source to increase the charge level of the battery, in some stations or every stations as to be able to continue service throughout the day. Without recharging the battery at the Depot, which is called a Decentralized Power Supply System.
9	Communications	Intelligent Transport System (ITS) is used to facilitate data transmission to bus operators and passengers receiving information for traveling, performance report, security and system management.
10	Intelligent Transport System	- ITS Application on the public transport system: (i) Operation Control Center (ii) Closed Circuit Television (CCTV) (iii) Automatic Vehicle Location (AVL) (iv) Automatic Fare Collection System (AFC) (v) Transit Priority Systems (TPS) (vi) Passenger Information System (PIS)

Source: The Consultant

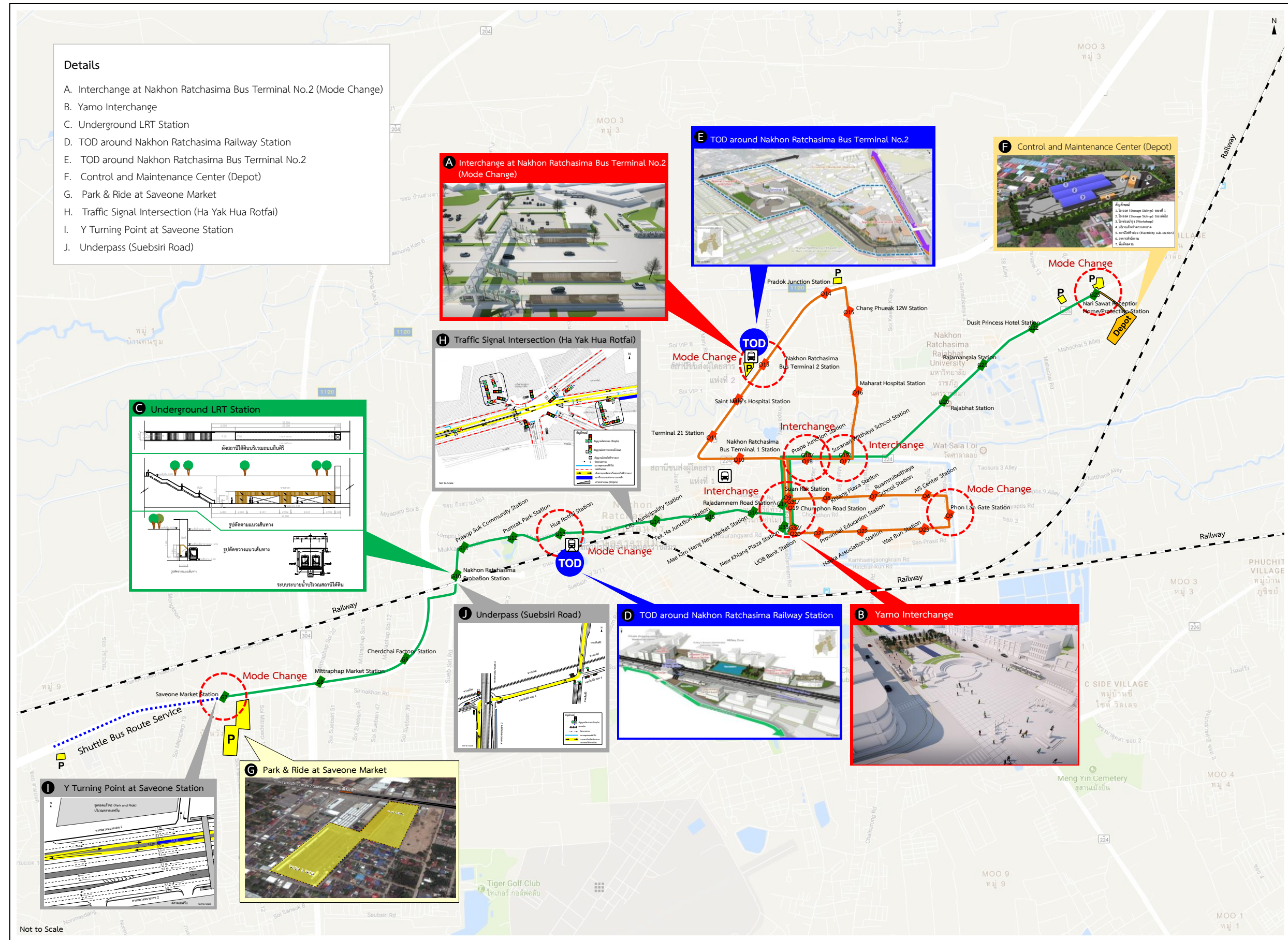
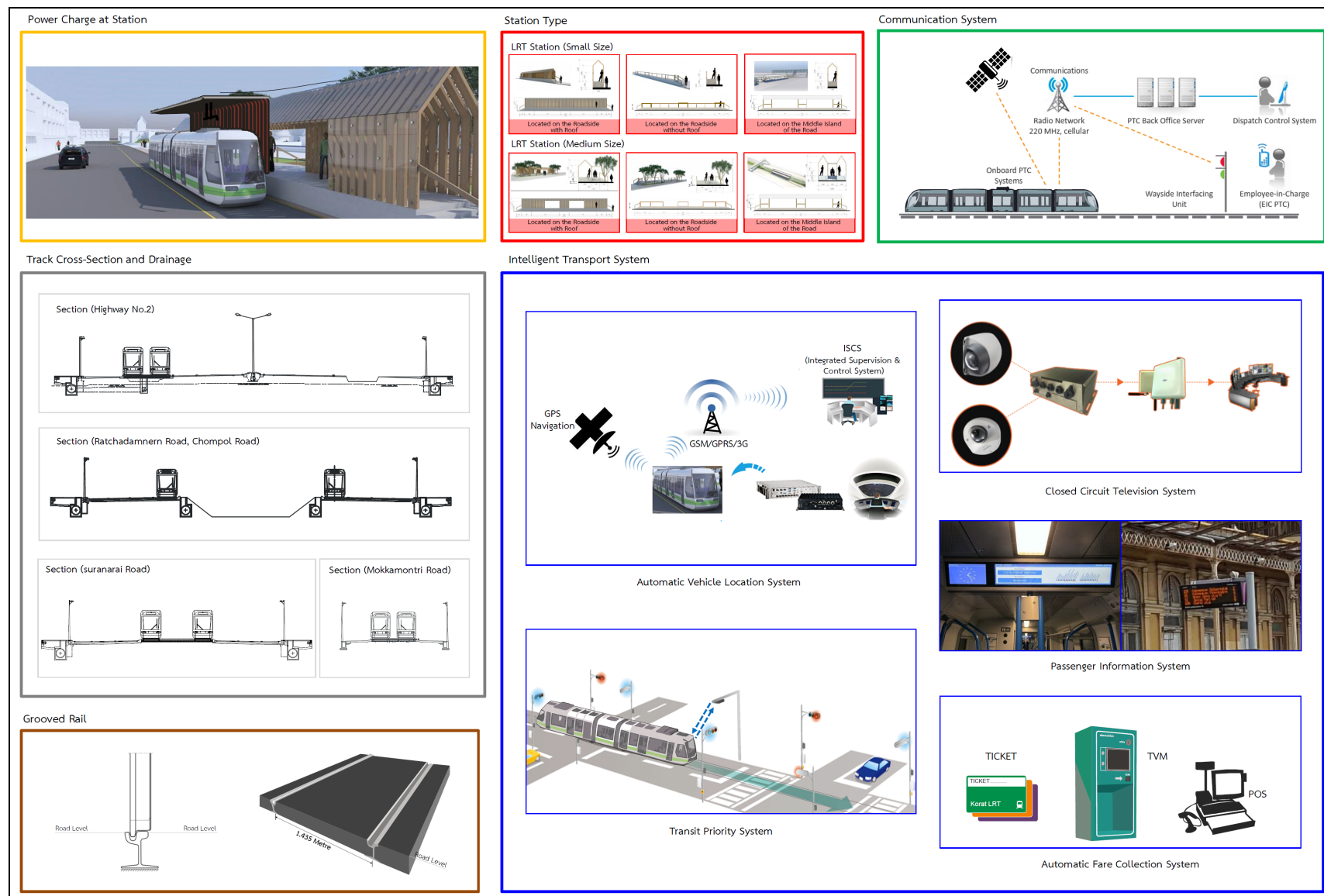


Figure 32 Overview on the Main Public Transport System proposed as a Pilot Project

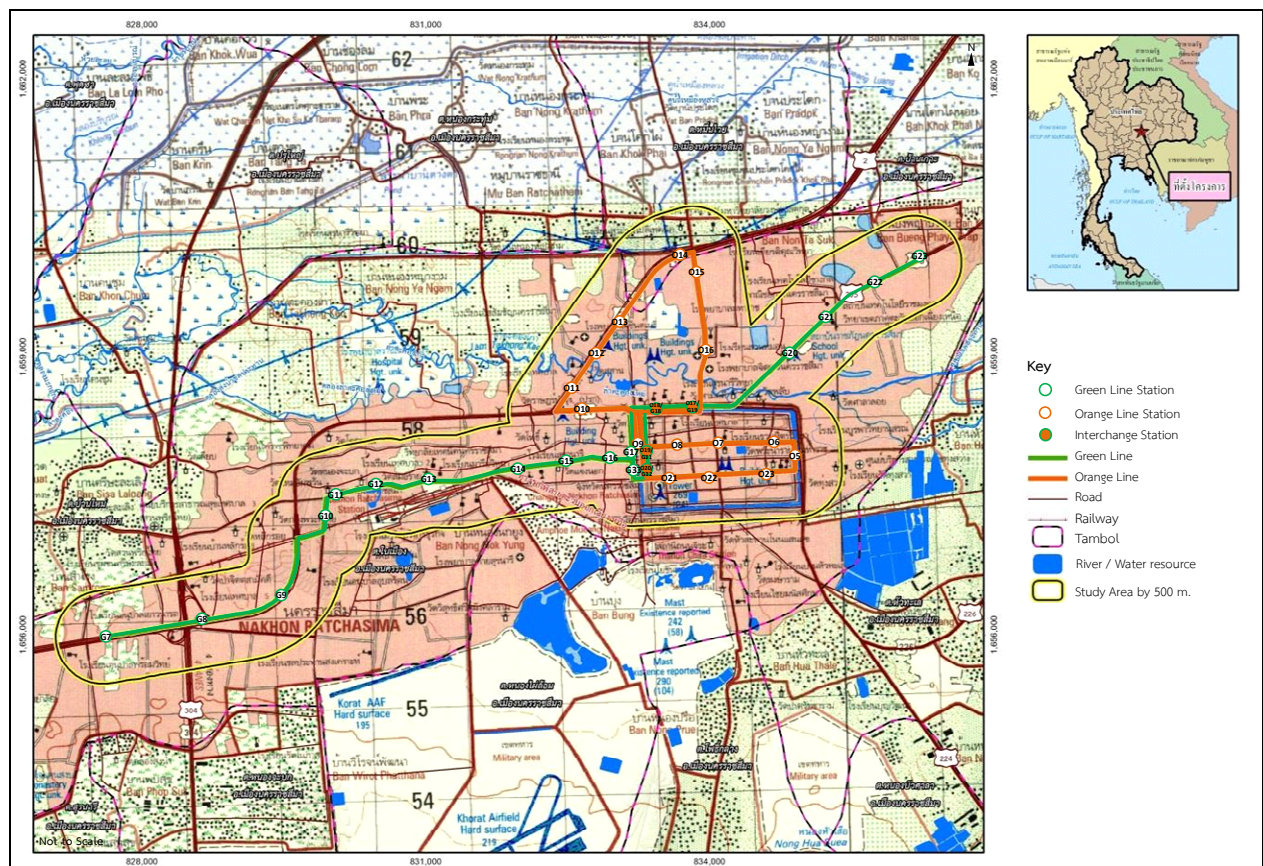


Source: The Consultant and modified from Techmahindra, Provider of Flexible Network Solutions, RK Telesystem, www.global-sei.com, www.southernelectric.org.uk, www.railsystem.net, www.aco.co.uk/

Figure 33 Overview on the Main Public Transport System proposed as a Pilot Project (General)

2.4.2 Environmental Impact Study and Public Relations and Public Participation Process

The Initial Environmental Examination (IEE) on the Pilot Project (Figure 34) covers the areas along the route within a radius of 500 metres from the centre of the main public transport route. Including surrounding areas affected by the project development. The results of the initial environmental examination (IEE) study are summarized in Table 9. The overall environmental impact is low. However, some environmental impacts are moderate to high (such as air quality, noise level, vibration), but it is only a short-term impact during the construction stage. There are measures to prevent and reduce the impact on the environment and the community around the study area.



Source: Modified from Topographic Maps, Royal Thai Survey Department

Figure 34 Study Areas for Environmental Examination

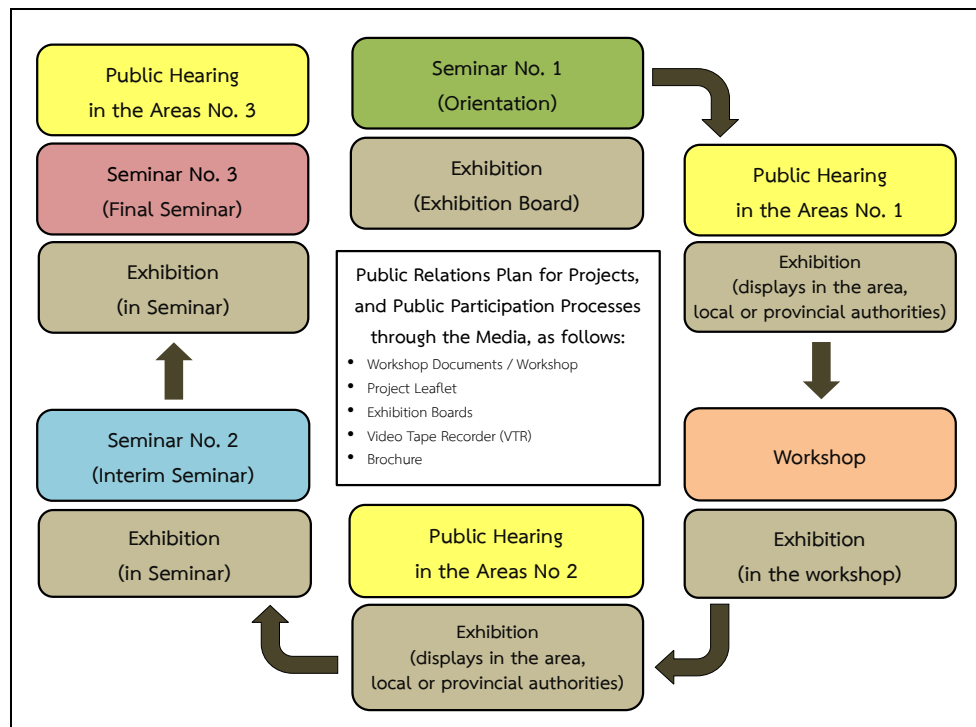
Table 9 Initial Environmental Examination (IEE) Conclusion

Impact Level	Environmental Issues
Moderate to High Impact *	Air Quality, Noise Level, Vibration, Surface Water Quality, Transport, Drainage and Flood Protection, Historical Areas and Archaeology
Low impact	Soil Resources, Aquatic Ecology, Terrestrial Ecology, Infrastructure and Public Utilities, Land Use, Transition, Compensation and Resettlement, Public Health, Occupational Health and Safety, Touristic Areas and Aesthetics Value
No effect	Topography, Geology and Earthquake, Hydrogeology and Surface Water Quality, Industry

Note: * Moderate to high impact is the only short term effect during the construction period.

Source: The Consultant

The study also recognizes the concerns of those who may be affected by project development. Public relations and public participation continue through activities as shown in Figure 35. There has been participation in providing comments and suggestions on the Traffic Management Master Plan and Master Plan for Public Transport Development in Nakhon Ratchasima City during the study and project planning stages. The decision to implement the project is transparent, justifiable and beneficial to the public.



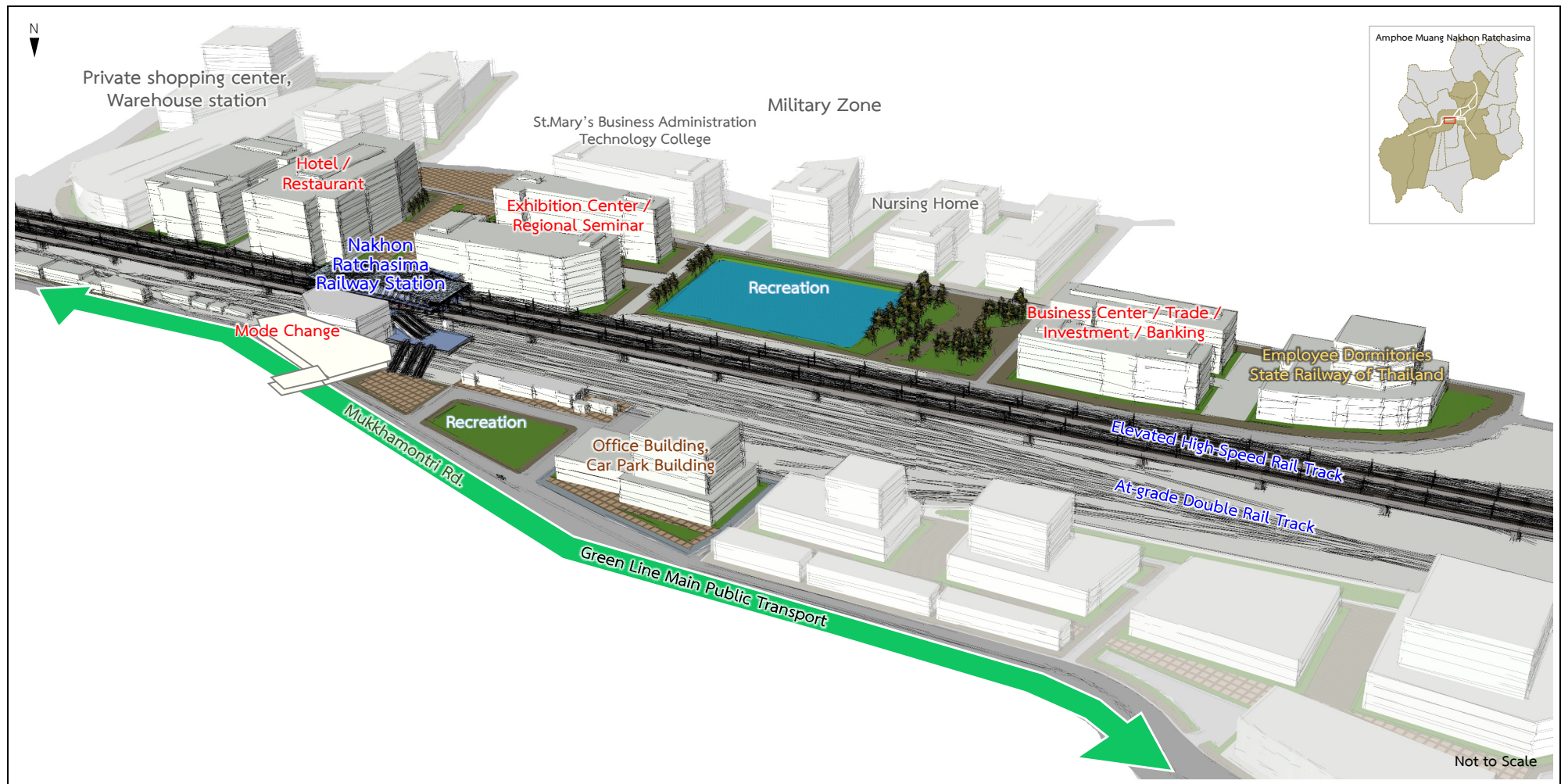
Source: The Consultant

Figure 35 Public Relations and Public Participation Processes

The public relations and the public participation processes, as mentioned above, it can be concluded that the public and related persons have agreed on the implementation of the Roadmap for the Traffic Management Master Plan and Master Plan for Public Transport Development in Nakhon Ratchasima City. The public also supports the project focus on sustainable development in Nakhon Ratchasima City. The aim is to ensure the main public transport system always provides the travel from origin to destination as comfortable and safe manner.

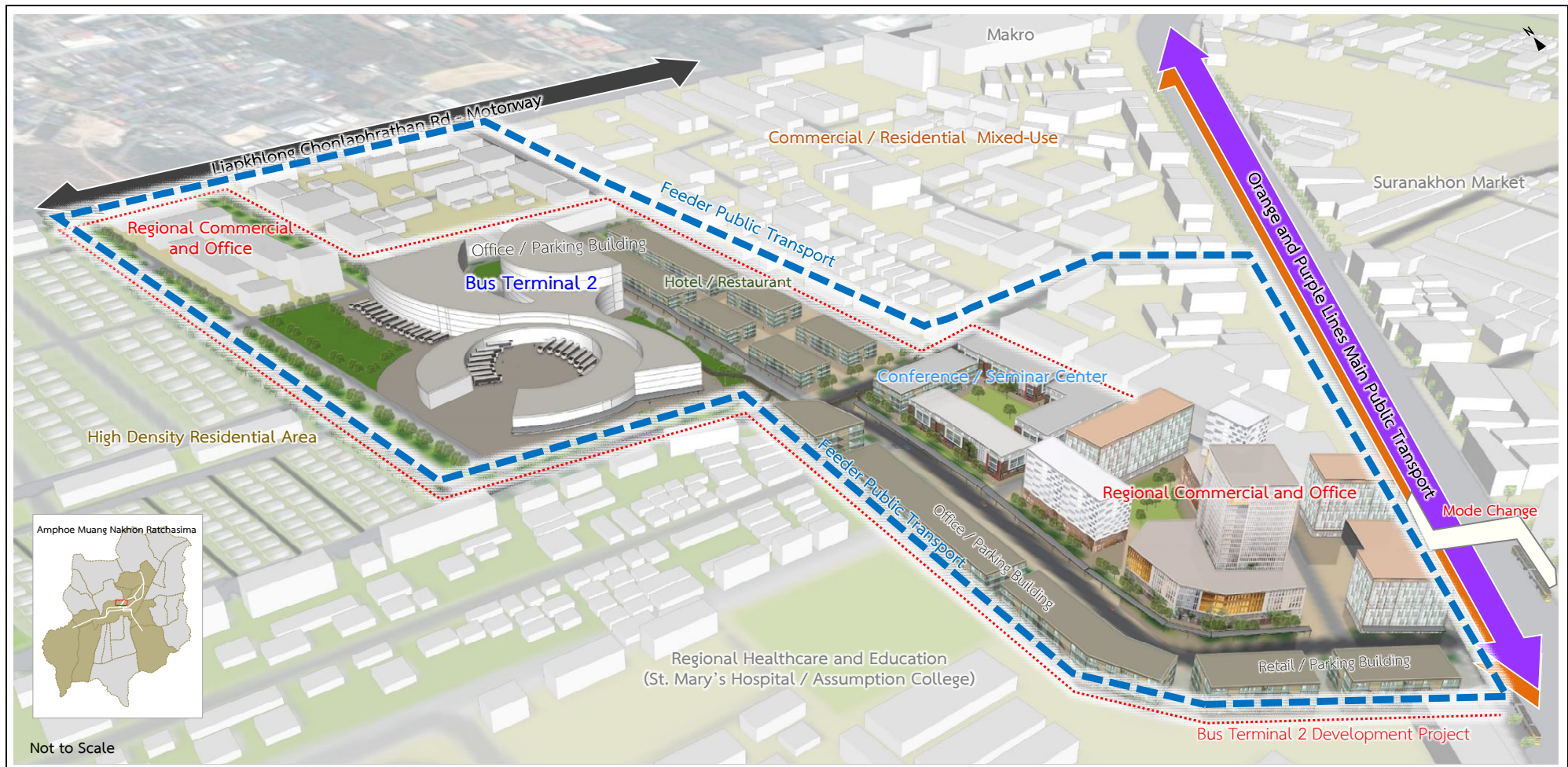
2.4.3 Areas Development around Stations or Public Transport Terminals

Transit Oriented Development (TOD) is proposed for two potential areas: (i) Nakhon Ratchasima railway station and areas within 500 meters of the station (TOD 1), and (ii) Nakhon Ratchasima Bus Terminal No. 2 and areas within 500 meters of the terminal (TOD2), as shown in Figures 36 and 37, respectively. Nakhon Ratchasima railway station, or 'Korat railway station', is located on an areas of approximately 297 rais under the ownership of the State Railway of Thailand, 170 rais are allocated for buildings and railway operation, 85 rais are for employee quarters, 29 rais are for future development purposes, and 13 rais are for long-term rent to private organizations. Nakhon Ratchasima Bus Terminal No. 2, or 'Bus Terminal 2', is a private property. In addition to TOD, these two areas will also be developed in terms of their connection with other areas, especially accessibility to the LRT system and feeder mass transit systems.



Source: The Consultant

Figure 36 Schematic Layout of the Transit Oriented Development (TOD)
at Nakhon Ratchasima Railway Station or "Korat Railway Station"



Source: The Consultant

Figure 37 Schematic Layout of the Transit Oriented Development (TOD)
at Nakhon Ratchasima Bus Terminal No.2 or "Bus Terminal 2"

2.4.4 Economic and Financial Appraisal

1) Economic Appraisal

The economic appraisal analysis of the project indicates that the LRT system is economically feasible since the NPV (a 30-year period) is positive, the EIRR is over 12%, and the BCR is greater than 1, as shown in Table 10.

Table 10 Economic Appraisal Analysis for the Project

Indicators	Analysis Results
NPV (million baht)	14,100
EIRR (%)	24.05
B/C Ratio	2.02

Source: The Consultant

2) Financial Appraisal

Financial analysis is considered on 5 options (Table 11) according to the groups of expenditures or investments. The results of the financial analysis (Table 12) show that in all cases, the project is not suitable for business. Cash flow is insufficient, the present value of cash flow is negative and the ratio of benefit to cost is less than 1.

However, the main LRT public transport system in the city of Nakhon Ratchasima should be considered as a welfare project that the state should provide to the people. Due to high investment needs of the project and with high fares being unaffordable for the public, the cash flow is insufficient. In addition, the project is also economically feasible. The economic return is quite high. This means that the project will be able to add value to the economy of Nakhon Ratchasima City and the country. However, if the marketing can be clearly defined this would help to reduce operating costs. There is an opportunity to have a financially rewarding investment (Tables 13 to 15). (B/C Ratio approximately 1)

Table 11 Case Study for Financial Analysis

Options	Initial Investment				Operation and Maintenance		Improvement after opening	Increasing investment after opening
	Civil Works	M&E Works	Ticketing system	Rolling stock	Operation	Infrastrucure		Rolling stock
1	✓	✓	✓	✓	✓	✓	✓	✓
2					✓	✓	✓	✓
3					✓		✓	✓
4					✓		✓	
5					✓			

Source: The Consultant

Table 12 Free Cash Flow Analysis

Indicators	Option 1	Option 2	Option 3	Option 4	Option 5
NPV (Million Baht)	-14,990	-2,400	-990	-900	-340
FIRR (%)	Cannot be calculated	Cannot be calculated	Cannot be calculated	-11.83	2.43
B/C Ratio	0.33	0.52	0.73	0.74	0.89
Financial ability	Not be suitable for business	Not be suitable for business	Not be suitable for business	Not be suitable for business	Not be suitable for business

Remark: Details of options 1 to 5 are shown in Table 11

Source: The Consultant

Table 13 Sensitivity Test for Financial Analysis (Changes of Income)

NPV (Million Baht)	Case 5
Base case	-340
10% higher than estimation	-80
10% lower than estimation	-600

Source: The Consultant

Table 14 Sensitivity Test for Financial Analysis (Changes of Investment)

NPV (Million Baht)	Case 5
Base case	-340
10% higher than estimation	-640
10% lower than estimation	-50

Source: The Consultant

Table 15 Sensitivity for Financial Analysis (Changes of Income and Investment)

NPV (Million Baht)	Case 5
Base case	-340
Revenue increased by 10 % and Investment decreased by 10 %	230

Source: The Consultant

2.4.5 Investment Analysis

In the case of the development of the main public transport system in the urban area of Nakhon Ratchasima by the special organization (Section 2.1.9 (2)), the government sector can be an investor for both before and after the opening of the service (design, construction, installation and operation). However, in the case where the government sector cannot invest by itself, the private sector may invest in the project. It is necessary to analyze the feasibility of the investment for this case.

The analysis of Investment is an in-depth analysis of the Free Cash Flow analysis as above, taking into account the effects of raising funds and government support to make the project feasible. The government needs to be satisfied that the project is financially sound (this will result in a different result than the alternative test in the Free Cash Flow analysis). Therefore, to reduce the financial burden on the public sector and to increase the efficiency of bus operation, the private sector should invest in the government sector. The Public-Private Partnership (PPP) is a PPP Modified Gross Cost model, which is the most cost-effective form for government. It can encourage the private sector to operate effectively, as shown in Table 16.

Table 16 Results from Project and Investment Analysis

	Investment	
	PPP Gross Cost	PPP Modified Gross Cost
NPV (Million Baht)	-530	-490
FIRR (% Per annum) ^(a)	12.50	13.00

Note: ^(a) At the end of the year

Source: The Consultant

Concerning the financing of the main public transport system (LRT), this will require a significant amount of investment, but it is important to note that this service is required for benefit of the public and will significantly improve convenience and journey times. With regard to urban planning and ridership growth increasing the income is however not enough to operate the LRT system. The government sector will be, therefore, still obliged to provide different types of subsidies, such as subsidies on investment and maintenance expenses. The estimated investment requirements and responsibilities are shown in Table 17.

Table 17 Responsibility for Investment and Project Expense

Investment Terms	Responsible parties		
	Government	Local Authority Organization	Public Private Partnership (PPP)
Investment Model	PPP Modified Gross Cost		
Duration of the investment contract	30 years (January 2023 to December 2052)		
Financial Responsibility (Million Baht)			
• Infrastructure works (rails, stations, control and maintenance center, traffic management)	✓		
• Number of cars at the beginning and more cars	✓		
• Infrastructure maintenance		✓	
• Private expense and fare revenue share		✓	
• Operation and maintenance costs. (related to the operation)			✓
• Expense after opening the service			✓
Fare revenue receiver		✓	
Initial Investment			
• Infrastructure works (tracks, stations, control and maintenance center, traffic management)	10,400 million baht		
• Train procurement	3,200 million baht		
Cash Flows of Government (Local Administrative Organization) throughout the contract period. (Present Value: Million Baht)		-490 (Present Value)	

Source: The Consultant

Furthermore, the government sector may need to grant the Local Authority Organization (LAO) financial subsidies for the amount of 190 million Baht per year to offset the loss incurred by the LRT system for a period of 10 years after the launch of the system (from 2023 to 2032). It may also have to assist the LAO in taking out a loan for the amount of 431 million Baht in 2023 and 71 million Baht in 2033 to cover the remaining project loss with the LAO being responsible for interest payment and the loan repayment, and the Ministry of Finance acting as the surety. Details are shown in Table 18.

Upon the launch of the LRT System in 2023, the LAO should begin collecting the special land development tax from owners of land within a 200-meter radius of LRT stations, who are deemed direct beneficiaries of the project, in order to reduce the long-term financial burden of the government sector. Such tax should be levied at a fixed rate per square wah that will least affect the private sector and no sooner than 15 years after the launch of the LRT System.

**Table 18 Details of Cash Flow of Local Authority Organization during the Years 2023 to 2037
in case of Loan**

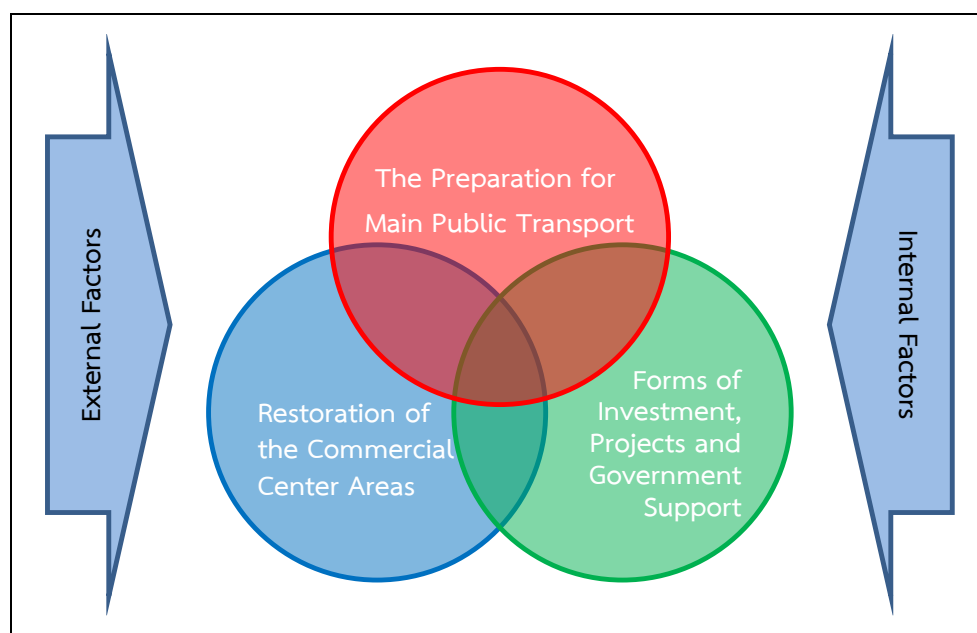
Items	Years							
	2023	2024	2025	2026	2027	2028	2029	2030
Government subsidy	190.00	190.00	190.00	190.00	190.00	190.00	190.00	190.00
Cash flow after subsidy	-136.13	-108.04	-71.52	-33.42	6.31	47.71	95.41	109.75
Withdraw the loan	141.00	121.00	91.00	58.00	20.00	-	-	-
Loan repayment	-	-	-	-	-	-21.00	-72.00	-91.00
Outstanding Loan	141.00	262.00	353.00	411.00	431.00	410.00	338.00	247.00
Items	Years							
	2031	2032	2033	2034	2035	2036	2037	
Government subsidy	190.00	190.00	-	-	-	-	-	
Cash flow after subsidy	124.69	140.27	-42.82	-20.27	3.19	27.61	53.00	
Withdraw the loan	-	-	45.00	24.00	2.00	-	-	
Loan repayment	-112.00	-135.00	-	-	-	-24.00	-47.00	
Outstanding Loan	135.00	-	45.00	69.00	71.00	47.00	-	

Note: Estimated numbers have not been deducted from the special land development tax.

Source: The Consultant

2.5 Recommendations to Drive the Development of Public Transport and Traffic Management System in Nakhon Ratchasima City and Surrounding Areas to Achieve the Goals and Success

The key factors relating to the development of public transport and traffic management systems in Nakhon Ratchasima City and the surrounding areas to achieve the goals and success is shown in Figure 38. It is necessary to implement the development in three main stages: (i) Preparation for Main Public Transport (ii) Restoration of the Commercial Center Areas (iii) Forms of Investment, Projects, and Government Support. The details are summarized in Table 19.



Source: The Consultant

Figure 38 Key Factors in the Development of Public Transport and Traffic Management in the Nakhon Ratchasima City and Surrounding Areas to Achieve the Goals and Success

Table 19 Recommendations on the Development of Public Transport and Traffic Management in Nakhon Ratchasima City and Surrounding Areas to Achieve the Goals and Success

No.	Suggestion	Details
1	Preparation for main public transport (LRT)	Prior to implementing the project, the main public transport system for the Green Line and the Orange Line, it is required to prepare for supporting the main public transport, namely, (i) To carry out projects to alleviate urban traffic and improve connectivity to public transport. The construction of the ring road around the city of Nakhon Ratchasima. (Outer Ring Road and Inner Ring Road) and other projects (Figures 19 to 24). (ii) To promote the Flood Protection and Drainage Development Project of the Flood Protection and Flood Prevention Project in the Nakhon Ratchasima Areas (Option 2), Department of Public Works and Town and Country Planning, 2015 (iii) To develop the connection system between the feeder system and the main public transport system, (1) To modify the Category 1 bus routes, those overlap with main public transport routes. Additional services are provided as feeder transport. One of the destination is at the main public transport station. This reduces the length of service routes. Therefore, the frequency of service is higher (Figure 9). (2) To add new routes in suburban areas that the population density area likely to grow or increase. Although, currently there is no public bus service available (Figure 9). (3) To develop the interchanges for the main public transport system for various modes, as efficient and easy access (Figure 8)
2	Restoration of the Commercial Center Areas	• Urban planning measures are used as a tool to improve access and connection system between the feeder and main public transport systems (Figure 29). • To prepare TOD 1 and TOD 2 to be able to effectively link to other areas. Especially access to the areas and the interconnection of both main and feeder public transport networks (Figures 36 and 37).
3	Forms of Investment, Projects and Government Support	• Although the government will support the project investment. PPP Modified Gross Cost is an option, but net present value of cash flow is negative, so the government must provide additional support after the project is launched, to improve the efficiency of budget management. To compensate for the loss of the public transport project in Nakhon Ratchasima City within the first 10 years, therefore, Local Authorities Organization can continue to operate sustainably (Tables 17 and 18).

Source: The Consultant