MODELLING AND SIMULATION OF TRAIN SCHEDULE AND OPERATION

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ABSTRACT

A modelling and simulation study was carried out to examine the current performance of train scheduling and operation of Keretapi Tanah Melayu Berhad (KTMB). The objectives of this study were to measure the performance of KTMB operation according to the current schedule and available resources by build a model that can simulate the operation. Also to evaluate alternative to increase the performances of KTMB train schedule and operation. Simulation software named Arena was used in this study to build the models and simulate various situation. Three situations and conditions of the current system were modeled and simulated in Arena to understand the current performance of the system. The simulation results revealed that the current scheduling and operation was below the level of their actual capabilities. To increase the performance of their scheduling and operation, new and improved simulation models was developed. The models was improved by adding new ETS trains to the system and provide more choice of trip to the passengers. After the improvement, simulation result shows some increment to their performance. Their utilization can be increased up to 16.36% of improvement. With the new scheduling and operation system, more passenger can be served and more travel option by travel time can be offered. This can attract more customers and directly can give positif impact to the revenue of the company.

ABSTRAK

Satu kajian pemodelan dan simulasi telah dijalankan untuk mengkaji prestasi semasa penjadualan dan operasi Keretapi Tanah Melayu Berhad (KTMB). Objektif kajian ini adalah untuk mengukur prestasi operasi KTMB mengikut jadual semasa dan sumber yang ada dengan membina sebuah model yang boleh mensimulasikan operasi. Juga untuk menilai alternatif untuk meningkatkan prestasi jadual dan operasi KTMB. Perisian simulasi bernama Arena telah digunakan dalam kajian ini untuk membina model dan mensimulasi pelbagai keadaan. Tiga situasi dan keadaan sistem semasa telah dimodelkan dan disimulasi dalam Arena untuk mengetahui prestasi semasa sistem. Keputusan simulasi menunjukkan bahawa sistem penjadualan dan operasi semasa adalah di bawah tahap keupayaan sebenar mereka. Untuk meningkatkan prestasi sistem penjadualan dan operasi mereka, model simulasi baru dan lebih baik dibangunkan. Model telah dipertingkatkan dengan menambah kereta api ETS baru kepada sistem dan menyediakan lebih banyak pilihan perjalanan kepada penumpang. Selepas peningkatan, keputusan simulasi menunjukkan beberapa peningkatan terhadap prestasi mereka. Prestasi penggunaan mereka boleh meningkat sehingga 16.36%. Dengan sistem penjadualan dan pengendalian yang baru ini, lebih ramai penumpang boleh diambil dengan menyedikan pelbagai pilihan perjalanan. Hal ini dapat menarik lebih ramai pelanggan dan secara langsung boleh memberi kesan positif kepada hasil syarikat.

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LIST OF SYMBOLS AND ABBREVIATIONS

KTMB	-	Keretapi Tanah Melayu Berhad
ETS	-	Electric Train Service
EG	-	ETS Gold
ES	-	ETS Silver
DONS	-	Designer of Network Schedules
MyRA	-	Malaysia Railway Academy
Min	-	Minimum
Max	-	Maximum
PB	-	Padang Besar
BW	-	Butterworth
IP	-	Ipoh
KLS	-	KL Sentral

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CHAPTER 1

INTRODUCTION

1.1 General background

As we know, Malaysia is a developing country and toward achieving Vision 2020. As a developed nation, the public transport services must be able to work more efficiently. One of them is the rail system operated by Keretapi Tanah Melayu Berhad (KTMB) or Malayan Railways Limited should be able to meet the demand in the future. The railway system is used not only for passengers but also for the transportation of goods. Therefore, a good rail transport systems must be developed to keep up with demand and the rapid development in the year 2020. To upgrade the national rail system, current performance of rail system must be assessed beforehand. When the current level of performance is identified, it is easier to chart the development of the railway system in the country. Railway systems always are subject to disruption, this problem cause grater waiting time, and inefficient operation of the rail system.

So this project was to examine the performances of current KTMB scheduling and operation by using simulation software ARENA, then evaluates few scenarios/solutions to optimize the performance. In this project, performance is defined by several parameters such as utilization, waiting time, number waiting and scheduled utilization.

Utilization is defined as how often the resources are being used, versus the availability of the resources. In other words, how often are the stations and the inter-connecting lines being used? For example, if the station is available for 16 hour a day and it is only occupied for 6 hour a day, then the utilization of the station would be 37.5%. Meanwhile, waiting time is defined as the waiting time taken by a train to enter the station. Waiting time occurs when there is another train are using the platform that you want to use in the station. Number waiting is defined as the number of the trains have to wait for the service at platform. Scheduled utilization is value for utilization at resources (platforms). Its means the average number busy divided by the average number available.

An alternative situations, scenarios and improvements will be evaluate using simulation software ARENA to increase the performance of the current KTMB scheduling and operation. The increment in the performance will be seen through increment in utilization when the time taken by the resources is being used, versus the availability of the resources is increase. Besides, the queuing times for a train to enter the station and also schedule deviation must be reduced to improve the performance.

1.2 Problem statement

Keretapi Tanah Melayu Berhad (KTMB) provides transportation services from town to town with two types of train services, namely KTM Intercity Normal Train and Electric Train Service (ETS). Basically these two types of train service will be known as KTM Intercity. According to Hazalina Abdul Rahman (2012) in KTMB Annual Report 2012, the ETS had shown greater improvement overall since the service was introduced in August 2010. The 2012 revenue had shown an increase of 33.5% from RM23.9 million to RM31.9 million. The number of passengers also increased to 33.3% from 0.9 million in 2011 to 1.2 million in 2012. However, KTM Intercity contributed RM81.6 million to KTMB's revenue in 2012 compared to RM91.8 million in 2011 which showed a decrease of 11.1%. The number of passengers for the year 2012 recorded a ridership of 3.1 million compared to 3.7 million in 2011 which is a 16.2% reduction. In conclusion, KTM Intercity Normal Train contributed to the reduction in profit for KTM Intercity.

In order to improve this situation, some reforms must be implemented to both KTM Intercity Normal Train and ETS. The main focus must be on solid operating system. Therefore, KTMB must first determine the current level of performance. To assess the current level of performance, one method that can be performed is to evaluate manually. But it is difficult to evaluate any reforms to be undertaken.

Therefore, methods of modeling and simulation by using computer software can be implemented. This method can evaluate the current situation and also some changes to the system can be simulated.

1.3 Objective

The objectives of this project were:

i. To model and simulate KTMB train schedule and operation in order to study the performances.

ii. To evaluate an alternative of adding new ETS train to increase the performances of KTMB train schedule and operation.

1.4 Scope

i. The train route that had been studied is from Ipoh to KL Sentral.

ii. Only KTM Intercity Normal Train (Ekspres Rakyat 1, Ekspres Rakyat 2, Senandung Langkawi 20, Senandung Langkawi 21) and ETS (EG01, EG02, EG03, EG04, EG05, EG06, EG07, EG08, EG09, EG10, EG11, EG12, EG13, EG14, ES01, ES02, ES03, ES04, ES05, and ES06) had been studied.

1.5 Significance of study

Produce a model that can evaluate various situations and scenarios of rail system, and can help in planning national railway system development. It is useful to predict the situation of railway operating systems in the future. Thus, preventing the development which will bring congestion and discomfort that occurs in the rail. Also can be as a decision making tool for any improvement and changes to be implemented.

CHAPTER 2

LITERATURE REVIEW

In this chapter some description on related issues and a number of articles related problems concerning train scheduling and operation is reviewed. First, some description of concepts used in this project will be explain. Second, description of Keretapi Tanah Melayu Berhad (KTMB) will be explained. Then, some articles on simulation are reviewed because simulation is the subject of this project. Then, to understand the design and planning of schedules, the planning process of a railway network is explained. Also, some delays and disturbances which caused by planning problems and accidental is described. Then, some recovery strategies are presented. Finally, some description on simulation and ARENA software are included.

2.1 Description of concepts and terms used

Some description and definition of concepts and terms used in this project will be explained below. The description and definition is according to Hofman & Madsen (2005).

Robustness: Robust means that the performance of the system is less sensitive to deviations from the scheduled timetable.

Disturbance: A disturbance is typically defined as a delay above a certain size for example more than 2.5 minutes lateness.

Rolling stock: Trains are often described as rolling stock.

Train type: Train type depends on e.g. the type of fuel the train uses or the age of the trains.

Train series and lines: A train series is defined by two terminal stations and all the stations in between. A train line is covering a train series but the train running the line does not necessarily stop at all the stations between the terminal stations.

Shunting: Sometimes during the day, for example outside rush hour, not all the available rolling stock is used. To fully use the railway infrastructure by the running trains, the redundant trains are parked in a shunt yard. The process of parking a train is called shunting. In this project shunting covers both turning at terminal stations and actual parking of trains.

Headways: The time between two consecutive trains traversing a point in the network. Minimum headway is the minimum time between consecutive trains, which must be observed according to safety. Minimum headways are sometimes referred to as safe headways. Planned headways are the times between the departures for the different lines in the timetable.

Dwell time and running time: The dwell time is the time a train is waiting at a station or the duration of the stop at a station. The running time is the scheduled driving time from one station to another or between two points in the network.

2.2 Description of Keretapi Tanah Melayu Berhad (KTMB)

Keretapi Tanah Melayu Berhad is the largest railroad in the country. “Keretapi” is a Malay word that translates to fire wagon. The first railway track in Malaysia was built in 1885. This was a 12.8 km length of road from the tin mining town of Taiping to Port Weld known today as Kuala Sepetang (M.Lowtan, 2004; Mahadzir, 2007). This was followed by the establishment of the Keretapi Tanah Melayu (KTM) in

1946 before it was privatized in 1992 and known as the Keretapi Tanah Melayu Berhad (KTMB) (Mahadzir, 2007). Figure 2.1 shows the KTMB's logo.

Figure 2.1: KTMB's logo
(http://www.ktmb.com.my/)

Railway service over 100 years old has gone through many changes. Starting with coal locomotives, diesel engines and diesel power, to our commuter service using electricity was first introduced in 1995. KTMB control 1791 km length, 1000 mm gauge railway network, 1655 km in Peninsular Malaysia (Mahadzir, 2007). It consists of two main lines which are West coast line and East coast line and several branch lines. Now, KTM offers four types of services include KTM Intercity, KTM Cargo, KTM Commuter and KTM Distribution. Figure 2.2 shows rail track for KTMB services which include KTM Intercity and KTM Komuter.

Figure 2.2: Rail track, stations and stops for KTM Intercity and KTM Komuter (M.Lowtan, 2004; http://malaysiatrain.blogspot.com/2011/07/blog-post.html)

In this project, the focus of the study is to KTM Intercity. So, to some extent on matters concerning the KTM Intercity will be described. Intercity train service is a service that was introduced by KTM since more than a decade ago. As introduce additional services to the people by giving them choices in terms of diversity coach and travel destinations include Peninsular Malaysia. Change for change had been implemented to provide services in a comfortable and safe journey to your destination of choice in the shortest time possible. KTM managing multiple services under KTM Intercity brand. Most of these services operate from Station Kuala Lumpur Sentral. However, there is a train service only runs along the East Coast route between dense and Gemas and next heading to Singapore. There is a cross-border rail services operating between Butterworth and Bangkok, Thailand. Figure 2.2 shows list of stations and stops for North-South flows and East Coast flows.

2.3 Literature on simulation

2.3.1 Analysis of urban freight by rail using event based simulation

Motraghi and Marinov (2012) describe their analysis of urban freight by rail using event based simulation. The authors develop a model based on an event based simulation using the ARENA to strengthen the merits of moving urban transportation through the line and show that it is an alternative to the most popular method of transportation in today market. This model is used to analyze the current situation, evaluate alternatives and maximize the use of the proposed railway system. There are three main objectives of this paper, first to develop event based simulation model to study the performance of the Newcastle Metro. Second, to test possibility of the movement of urban freight by rail. Third to find out if it has any practical application.

This article describe some important parameters to be used to simulate the model such as attributes, process flow, queues, simulation parameters and results of the simulation. The authors also explain some steps to develop the model in Arena software. The authors analyzed the results of the current systems then the new schedule implemented to the model. They evaluate two scenarios where the original system was modified. First, where the system is running a fixed operating pattern and has additional trains running which represent a freight service. Secondly, a system in which two operating patterns run alongside each other, improvised for freight and fixed for passenger services.

As a conclusion, the authors conclude that it is possible to utilize rail for the distribution of freight in urban areas and it can bring some benefits to the existing system such as opportunities for new business, increased profit and optimized utilization of resources. Also it was found that the original system can accommodate 5% more trains on a number of existing ones.

2.3.2 Application of SIMAN Arena discrete event simulation tool in the operational planning of a rail system

E. Martinez (2002) describe his research on the design and use of SIMAN Arena in planning rail for Tren Urbano project. This study was conducted to review the operation of this system from the perspective of the user. So, it is important to have a model that allows them to test operational strategies and can be used by the operator.

The model includes an animation. The animation in the process model including traffic process which allows them to describe the performance of the system. Simulation models provide the ability to use realistic model railway network, including a group of four consecutive station (Sagrado Corazon, Nuevo Centro, Roosevelt and Domenech) simulate vehicle operation and calculating the special system performance parameters such as waiting time in the platform and performance time. In addition, the simulation will allow them to analyze the track layout, operational strategies, mode of coordination, timely performance and compare the operating schedule and headway operation system. A simulation model developed under this research project are expected to be used in the future as a building block of Tren Urbano network around them to explore some strategy in their operation.

At the end of the study, the author concluded the importance of the simulation in the transportation and engineering and benefit of SIMAN Arena simulation tool. Also, conclusion about the Tren Urbano simulation mode and some comparison on Headway-Based and Schedule Based.

2.3.3 The use of simulation in the planning of the Dutch railway services

Hooghiemstra and Teunisse (1998) explained their research on the effectiveness of the schedule in the Dutch railway network. Authors show their judgment about infrastructure planning and scheduling. They also notice the importance of reliability and punctuality. They used DONS (Designer of Network Schedules) to generate timetable. This paper is intended to determine whether the construction of schedule can be fine-tune to enhance operational efficiency. DONS-simulator was developed to achieve the goal. Simulation tool allows the author to investigate the effects of small disturbances on train accuracy in the whole network. Simulators may also be used to evaluate how investments in infrastructure affect the timeliness in the next study. This paper only explains the process of building and testing prototypes DONS-simulator and does not indicate the final results of the study.

2.3.4 Simone: Large scale train network simulations

Middelkoop and Bouwman (2001) describe the design and program features of the simulation program Simone (Simulation Model Network). Simone is a simulation environment developed aimed to determine the effectiveness of the schedule and the stability of the train network, and consequently improving the quality and stability of the timetable from a set of different criteria.

The authors briefly explains about the architecture and functionality of the simulation program. They describe a set of application and function of Simone such as Incontrol Center, Simulation Library, Infra and Timetable Database Interface, Automatic Model Generator, Simulation Models, Scenario Manager, Output Generator and Output Analyzer and Manager.

The author also describes the use of Simone in two case studies. The first case study on strategic planning. Simone program used in the Ministry of Transport to review the effects of investment in railway infrastructure in the past and also in the future. Simone used to evaluate the stability and effectiveness of different network configurations and to compare different configurations at the scale of the network. In second case study, Simone was used to assess the impact on the network environment of Hengelo station and when conflict had been deleted. Advantage of using the characteristics of an automatic model generation in Simone, construction models just take place in a few hours.

Also, the authors explicate their evaluation of the use of Simone. To date, Simone used in several different studies. These studies demonstrated that Simone research tools successfully. By using Simone and simulating an entire railway network, it furnish understanding into the performance of the combination of timetable-infrastructure.

2.4 Design and planning of schedules

According to Vroman, Dekker and Kroon (2003), the railway network planning process can be divided into several phases as shown in Figure 2.3.

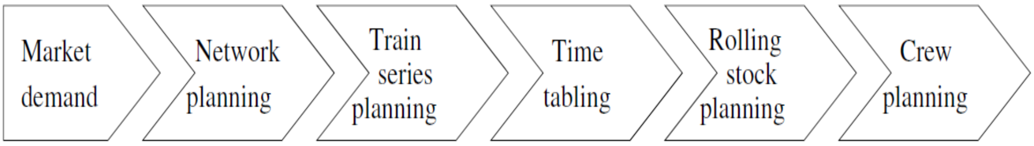


Figure 2.3: The sequence of interdependent railway planning phases
(Vroman, Dekker and Kroon, 2003)

Market demand is the first phase, then followed by network planning. Network planning is the first step in the planning process. Network planning has an impact on the effectiveness of the train operation. If there are more track on the network, it can be used as an alternative track for any delay and disruption, at once reduces the probability of secondary delays. Then, train series planning is the next phase where the process of determine the train connections, the process of choosing the starting, the stopping point, routes, the stations in between and terminal stations take places. The next phase is time tabling where departure and arrival times are determined. There may be several iterations between the two measures if the train series does not imply a feasible timetable. The train series planning and time tabling are combination process where it will decide the number of lines and the frequency of trains. These two parameters will affect the robustness and effectiveness of the operation where less the number of trains and lower frequency will create larger buffer time.

Once the timetable is complete, the next phase is rolling stock circulation. This step also includes planning for shunting and restructure the trip. The rolling stock planning also have an impact on the effectiveness. Different types of train will have different speed, different headways and different running patterns. These will affect the robustness if delay or disturbance occurs. To get a better shunting times and larger buffers time, the planning of rolling stock should consider a number of trains with the same frequency. For normal trip and for shunting train, drivers should be scheduled. The final phase is crew scheduling. Persistence in scheduling the crew is also very important. The robustness will reduced when there are scheduled crew are not available and cause the train to be late.

2.4.1 Design of timetables

Robust means that the performance of the system is less sensitive to deviations from the assumed timetable (Hofman & Madsen, 2005). Robust timetables can be create by incorporate time buffers or slack. The robustness will increase with the increasing of time margins. It can be done by reducing the number of train on a particular series. This will result in larger time margins and reduce the probability of secondary delays. But it will make longer travel time which will affect the satisfaction of customers. Scheduled headways between trains at stations should also be allocated shared as equally as possible to ensure that the largest buffer time between trains.

Usually tables are built to be cyclical. This means a passenger service every time the cycle is repeated, usually every hour. The planning of the timetable will be consider as a good table when the connections between the trains are good. Example, the train at large stations can fulfill reasonable waiting time for a customer to change between trains. A time schedule is designed to be implemented, in the sense that if there is no interference occurs then there will be no delay. Conversely, if it is not possible to run any trains at speeds that are taken, then the delay will occur.

2.5 Delays and disturbances

In a complicated network as rail network, there are many causes irritation can occur. Railway station complex busy with some platforms may have several hundreds of trains arriving and departing every day, serving thousands of passengers. Trains arrive and depart on the type of line that is contradictory and subject to the restrictions regarding online platform or occupied. Therefore, the delay is related to the normal scheduling of trains. There is a connection between how a railway system is designed and how delays will occur and propagate in the system.

Relationship can be determined by simulating different time schedule or by some form of sensitivity analysis. It also is likely to affect the risk of delays occurring, with the design of the table. To overcome the delays in scheduling of trains, slack time is usually included in the schedule of the train when it was built. This time the slack should help to stabilize the system and therefore reduce the transmission delay in the network. The degree of occurrence of delay also depends on the capacity utilization of the network, so if utilization is high, there is also a high probability of delays occurring.

Disturbances can be accidental or caused by planning problems (Hofman & Madsen, 2005). Examples of causes of accidental disturbances are:

i. Delays in passengers boarding or alighting
ii. Signaling problems
iii. Operation delays or mistakes
iv. Failure of equipment or rolling stock
v. Weather
vi. Accidents
vii. Obstacles on lines
viii. Crew lateness.

Examples of causes of disturbances caused by planning problems are:

i. Line maintenance
ii. Seasonal or rush hour changes in demand
iii. Lack of capacity (trains or tracks)
iv. Heterogeneity in the timetable or in the train types
v. Too high utilization of the system.

In the event of interruption, the stability of the system involved. Changes in stability depending on the size of the interruption, the total disruption and how strong the system is initially. If the system is sound small disturbances will not affect the stability and thus delay will not happen.

Mattsson (2004) explain an example of how number of trains, heterogeneity and stability is connected as shown in Figure 2.4.

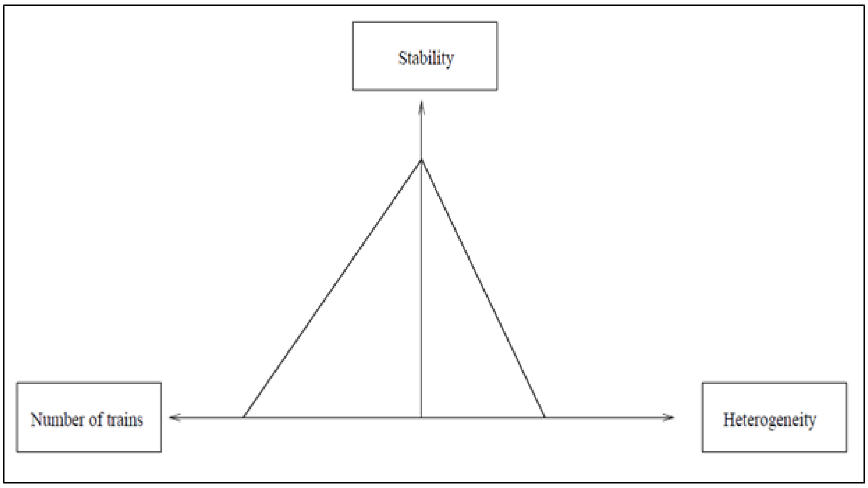


Figure 2.4: Stability balance
(Mattsson, 2004)

The figure shows that stability is reduced where the total train increases. When a train using the same track increases the risk of disorders of reproduction and thus affect the train a lot. Also when diversity factors increase, such as various types of trains are in use or very dissimilar stopping patterns are planned, the stability of the system decreases. If the stability of significant changes, delays will occur.

The delay can be divided into two categories, primary and secondary delays. Primary delays occur when a disturbance cause a delay on a single train (Hofman & Madsen, 2005). The primary delay cannot be deleted and not depend on the design of the table. Also primary delays in theory independent of capacity utilization, but the analysis of the main reasons for the delay and location can be used to generate a reliable schedule, in which primary delays cause the least secondary delays. This is possible because of the secondary delays is influenced by the design of the table.

When slack time in the timetable is too small a cause of delay on a train may create a conflict with another train. These delays are called secondary delays (Hofman & Madsen, 2005). For example if a train late leaving the platform, it may delay the arrival of the next train scheduled to use the same platform, which can slow down the train again. Conversely, if a train arrives late, a platform which is scheduled to be occupied, so the train was to be sent to another platform that could delay the scheduled train on the platform. It is important to ensure that the major delay to a low level, if not secondary delay can rapidly increase, because the dependence on the railway network.

2.6 Recovery strategies

In carrying out the daily operations of the railway, there are various types of disturbances that may occur to operations and systems. These disturbances can be dealt with in different ways such as by re-establishing the original plan, by rescheduling or by regaining regular headways (Hofman & Madsen, 2005).

2.6.1 Re-establishing the original plan

The time margin or slack that had been set out in the timetable will be used in this strategy. If any disturbances occurs, the traffic controllers will try to solve the problem within the allowed time margin. The effect of this strategy may result in problems such as disturbing the connections between different trains, train delays, platform changes, reduce running time and dwell time, but generally the planning schedule is still good. This strategy can be used to deal with minor disturbances, because otherwise it might take a long time to re-establish the original plan. Management of minor disturbances can usually be expected. Maybe there are rules for how long the train can wait at stations for connection or the rules to change the order of train if only one train is late.

Two examples as described by Hofman & Madsen (2005) of how to re-establish can be used are as follows. If there is a late train on arrival, reduce the dwell time can help train back in time. Example, a train has a scheduled dwell time of 6 minutes and a minimum required dwell time of 3 minutes. If it arrives 4 minutes late, it can be ready to depart after 3 minutes, therefore only 1 minute late instead of 4 minutes. Conversely, if the minimum dwell time is 1 minute, it is ready to take off after 1 minute, but of course it is not allowed to depart before the scheduled time, with the train can leave at any time after 2 minutes, and thus delays are eliminated.

Second example, when trains arrive later than scheduled, their assigned platform may be occupied by later trains. In this case the train could be held until the assigned platform becomes free. Otherwise it could also be send to another platform if one becomes free sooner. Likewise if a train departs late, the train is scheduled to come on the same platform can either wait until the platform is available, or go to another platform if one becomes free first. It should be noted, if these on-the-day changes in platforms not done carefully, it may cause further secondary delays to the following trains.

Nevertheless, an experiments have shown that allowing the change of platform reduces secondary delays (Carey & Carville, 2000). The strategy depends on the system which measured by how heavily congested the system. If the train runs on a tight schedule it may not be such a good idea, to allow for changes in the platform, as this will interfere with a large number of trains. Conversely, if the schedules contain larger headways it might reduce delays considerably. This strategy also depends on whether all platforms can be used for all types of trains. In addition there may be some restrictions due to the layout of the network, which might prevent the strategy from being possible. On passenger satisfaction, it also needs to be considered whether it is easy to go from one platform to another.

2.6.2 Re-scheduling

Re-scheduling strategy give the trains or lines an option to be re-routed or cancelled. Basically, the new plan is created and logistics plans disrupted. The main goal is to re-establish the original plan, but this may take several hours, or it may not be possible on the same day. This strategy is used in operations when major incidents such as accidents causing delays or failures of rolling stock. There might be rules on which train lines to cancel in case of disturbance or which lines to re-route. Although certain rules exist for the management of a major disruption, the results still depend on the exact circumstances and on the choices made by the operator who is responsible for traffic control.

2.6.3 Regaining regular headways

This strategy means to regain regular headways as quick as possible. After a disruption, the affected train can be combined. They are set off as fast as possible with the smallest possible headways instead of waiting for the scheduled departure time for every train. The idea is to get as many trains rolling as much as possible and maximize the utilization of the track. This recovery strategy was mostly used in urban rail network where trains are scheduled to run in the times of small intervals for example metro system. On very busy stations, because of the frequencies of train departures are very large, the exact time of departure is not a big problem. For example, if a train running between the two stations, with a duration of 3 minutes it rarely matters to passengers exactly what train is reached. In longer term when the disruption is stabilized, the trains are re-scheduled to the original plan.

2.7 Description of simulation

Simulation refers to a broad collection of methods and applications to mimic the behavior of real systems, usually on a computer with appropriate software (Kelton, P. Sadowski, & T. Sturrock, 2007). In addition, simulation is the process of designing and creating a computerized model of the real system for the purpose of conducting experiments to give an understanding of the behavior of the system (Hofman & Madsen, 2005). According to (E. Martinez, 2002), simulation is divided based on the manner in which the state variables change, which are discrete event and continuous. Discrete event refers to the fact that state variables change instantaneously at distinct points in time. In a continuous simulation, variables change continuously, usually through a function in which time is a variable. (Kelton et al., 2007) state that there is other way or dimension to classify simulation model. One of them is static and dynamic which time is the main parameter. Time does not play role in static models but does in dynamic models. Another one dimension is deterministic and stochastic. Deterministic are models that have no random input such as a strict appointment book operation with fixed service times. On the other hand, stochastic models operate with at least some inputs being random. Example, a bank with randomly arriving customers requiring varying service times.

Simulation techniques are used in many disciplines such as engineering, scientific and technology to design new systems, analyze existing systems, training for all types of activities, and also as a form of interactive entertainment. In engineering, simulation help the engineers in analyzing the task given and also in decision making process. Usually it is effectively used in activity such as (E. Martinez, 2002):

i. Planning and analyzing several process
ii. Choosing an operating strategies
iii. Planning logistic system
iv. Evaluating capacity and performance of existing and planned systems
v. Predict the system performance in the future

A simulation project can be divided into several phases (Hofman & Madsen, 2005):

i. Problem formulation. First the problem must be specified precisely. It is also very important to make sure that all parties understand and agree on the problem formulation.
ii. Data. Determine whether enough data is available and collect the necessary data.
iii. Assumptions. Determine if it is possible or necessary to build a model of the entire system or if limitations or assumptions can be made. The level of detail should be specified.
iv. Solution methodology. Determine how the given problem can be solved and whether it is possible to solve the problem by simulation given the obtained data.
v. System specifications. In this phase information about the system is collected. To build a simulation model, a good understanding of the system is required.
vi. Model formulation and construction. Considerations about how the model should be build and actually building the model.
vii. Verification and validation. Examining whether the model is behaving as expected (verification) and behaving in the same way as the real system (validation).
viii. Experimentation and analysis. Running the simulation and analyzing the data according to the desired output.
ix. Results and conclusion.

2.7.1 SIMAN Arena

Since simulation software SIMAN Arena will be used in this project to model and simulate the scheduling and operation of KTMB's train, some description of the software will be explained.

SIMAN is a powerful general propose simulation language for modeling discrete, continuous and combined systems. Arena is the animation component of the SIMAN simulation (Pegden, Dennis, 1990). Arena deals with entities, resources, variables, attributes and events. The definitions and some examples according to Hofman & Madsen (2005) as in Table 2.1 below.

Table 2.1: Details of parameters in SIMAN Arena
(Hofman & Madsen, 2005)

Parameters	Definition	Example(S)
Entities	Elements that traverse the model during simulation.	Trains
Resources	Represent processes and other static assets in the model.	Stations and tracks
Variables	All the adjustable or changing parts of the model. Variables are global and pertain the whole model as opposed to attributes, which are entity specific variables representing characteristics for the different entities in the model.	Running times and dwell times
Attribute	Only pertain the entity it is connected to.	The time the entity should be disposed and leave the system. This can be specific for each entity and can be stored in an attribute. If the value is used in other correlations, not only including the specific entity, the value should be stored in a variable.
Events	All the things that happen during the run of the simulation.	

Variables and attributes might be changed during an event. Examples of events are arrivals and departures, or when an entity enters or leaves the model.

The basic building block in building a simulation in Arena are modules. It can be split into two types which are flowchart modules and data modules.

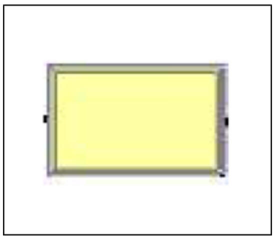


Figure 2.5: Flowchart module

Flowchart modules as in Figure 2.5 describe the dynamic processes, the movements and the changes in the model. The data for the flowchart modules can be specified in the associated dialog boxes. These modules are connected to indicate the movement of the entities in the model. Some basic flowcharts modules will be describe. The flowchart modules are divided into Process modules as in Table 2.2 and Transfer modules as in Table 2.3 (Hofman & Madsen, 2005).

Table 2.2: Process flowchart modules
(Hofman & Madsen, 2005)

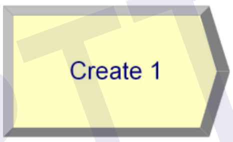
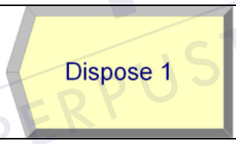
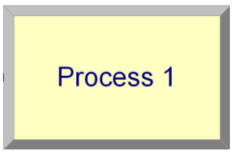
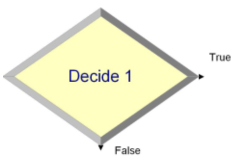
Flowchart Modules	Description
	The Create flowchart module is intended as the starting point for entities in a simulation model. The Create module is used to insert entities in the system. It is possible to specify what entity to create or insert, how many and the time interval between the created entities.
	The Dispose flowchart module is intended as the ending point for entities in a simulation model. The dispose module removes entities from the model.
	The Process flowchart module provides different possibilities. The entity entering the Process module is seized and can be delayed. A resource with a specific capacity can be added to the model and a queue is connected to this resource. When the job in the process is finished, the entity is released and the resource becomes idle. Instead of the Process module four separate modules can be used; a Seize module, a Delay module, a Resource module and a Release module.
	The Decide flowchart module is used if the entities should be able to transfer different ways in the model according to some given conditions. The decide module can split in as many different directions as wanted. The different directions can either be determined by chance (e.g. 20% one way and 80% another way) or by a condition (e.g. one way if an expression is true and another way if not).

Table 2.2: Process flowchart modules (continue)

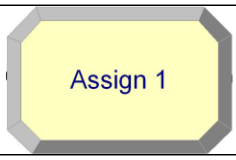
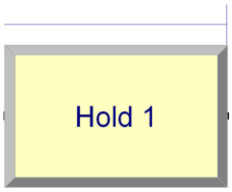
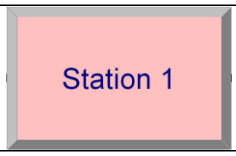
Flowchart Modules	Description
	The Assign flowchart module assigns new values to e.g. attribute or variables. Multiple assignments can be made within a single Assign module.
	The Hold flowchart module will hold back an entity in a queue, while it either waits for a signal or waits for a specified condition to become true. The queue is represented by the line above the module.

Table 2.3: Transfer flowchart modules
(Hofman & Madsen, 2005)

Flowchart Modules	Description
	The Station flowchart module defines a station, where entities can be routed to. The Station module is not specific for this project but a general Arena module.
	The Route flowchart module transfers an entity to a specified station, or the next station in the station visitation sequence defined for the entity. A delay time to transfer to the next station can be defined. If a Route module is not used, the travel time between two flowchart modules is zero.

The data modules as in Figure 2.6 define the characteristics of different elements like entities, queues and resources. They are also used to set variables or expressions that pertain the whole model. Some basic data modules will be describe in Table 2.4 (Hofman & Madsen, 2005).

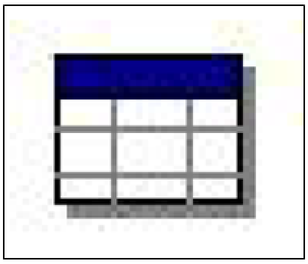
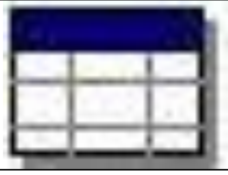


Figure 2.6: Data module

Table 2.4: Data modules
(Hofman & Madsen, 2005)

Data Modules	Description
	The Entity data module defines the various entity types and their initial picture values in a simulation. Entities can be defined in the Entity data module or a new entity will automatically be defined when used for the first time in a flowchart module. The entity pictures can be edited (see the menu Edit-Entity Picture). Various colored trains are made to match particular S-train lines in the models in this project.
	The Queue data module may be utilized to change the ranking rule for a specified queue. The default ranking rule for all queues is first-in-first-out.
	The Variable data module is used to define the dimension and initial value(s) of the variables. A variable can represent a single value, an array or a matrix of values. Variables can be referred to in other modules (e.g. the Decide module), can be reassigned a new value with the Assign module or can be used in any expression.
	The Advanced Set data module specifies queue sets, entity sets and other sets and their respective members. A set defines a group of similar elements that may be referenced via a common name and a set index.

The Arena window as shown in Figure 2.7 is divided into several pieces. At the top of the window the toolbars are placed. The toolbars can be added or removed as in other Microsoft Windows applications. In the left side of the window the project bar is placed. Here the flowchart and the data modules are found. The flowchart modules are inserted into the model by drag-and-drop. The model window is separated into the flowchart view and the spreadsheet view. In the flowchart view the building blocks in the model and the animation of the model are shown. This is the visualization of the model. The spreadsheet view shows all the data in the model. The same data, which can be seen in the dialog box by double clicking on the flowchart modules, can also be seen in the spreadsheet view, but the spreadsheet view shows all modules of the specific type at the same time. The data can be modified in the spreadsheet view or in the dialog box. At the bottom of the window is the status bar which displays an information of the simulation status such as (x, y) coordinates of the location of the mouse pointer, simulation clock value, replication number being executed and number of replications to be run.

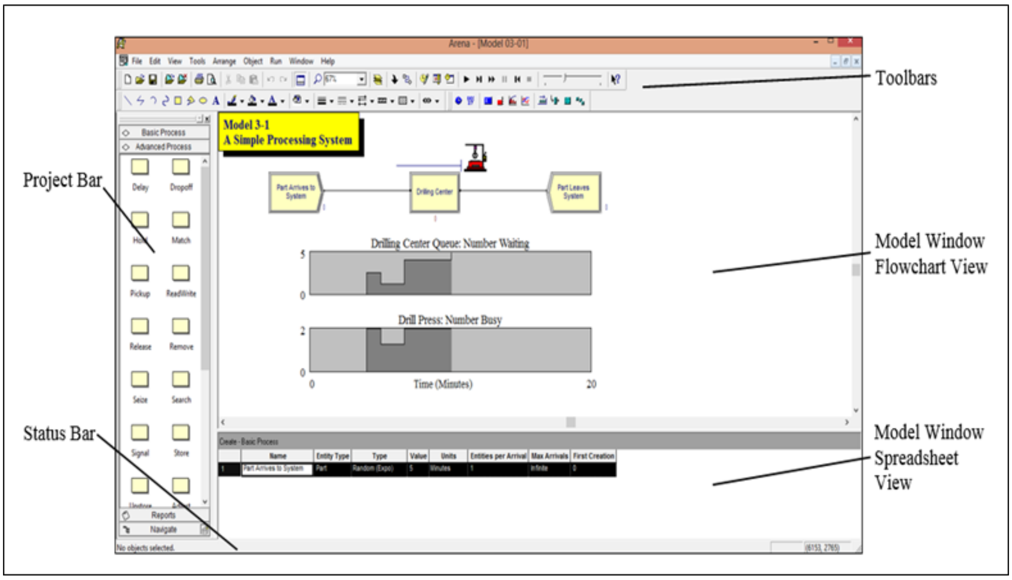


Figure 2.7: Arena window

As a conclusion, simulation software can be used to study the performance of railway system in Malaysia. It had been applied to various type of railway system over the world. One of the simulation software is Arena. It is widely used to model and simulate railway system to analyze disturbances, delay and the other factors in railway system. It also used to analyze new railway system to be build. This way can reduce the cost of testing for the system. By using simulation software, it is easier to conduct any changes to the model to study various type of situation and condition. It also can be used as a prediction tool to predict what will happen if there are any changes to the system.

CHAPTER 3

METHODOLOGY

This chapter is about the methodology used to conduct this project. First part is methodology for master project 1, second part is methodology for master project 2, and finally methodology for simulation. Some explanations on every stage on how this research was conducted will be included here.

3.1 Methodology for master project 1

This project is carried out based on methodologies that are divided into two parts. First part is methodology for master project 1 conducted in fourth semester, and second part is methodology for master project 2 conducted in fifth semester.

The project began when selecting a title suggested by some supervisor. Once agreement is reached, one meetings with supervisors conducted. The first meeting with the supervisor do to discuss more about the proposed project. Some changes were made to meet the needs of both parties. Further, the proposal contains details such as the objectives and scope of the study sent to the supervisor for evaluation. Thereafter, a second meeting was held to discuss more about the projects that will be carried out and make some corrections and additions to the first proposal. Meanwhile, the literature review was conducted after the first meeting with the supervisor and continuing to the end of the semester. Writing the first chapter begins in mid of October 2014 until early November 2014. Then, writing a literature review was conducted until the end of December 2014. Writing methodology starting end of November 2014 until the end of December 2014. During the writing process, each

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