EFFECT ANALYSIS OF RELIABILITY, AVAILABILITY, MAINTAINABILITY AND SAFETY (RAMS) OF TRAIN OPERATION

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ABSTRACT

This project was conducted for maintenance and operation process and its effects on Reliability, Availability, Maintainability and Safety of Diesel Locomotive System. The focus is on Diesel Locomotive that has a model and analysis study was carried out to examine the current performance based on RAMS for Keretapi Tanah Melayu Berhad (KTMB). This Project presented a study for the risk assessment of Diesel Locomotive System using the operation data collected from the railway industry. The proposed assessment method of railway risks was demonstrated and the investigation on the RAMS performance of the Diesel Locomotive and their major failure causes was done. Reliability of the system in this thesis was analysed in qualitative and quantitative methods. The effective parameters on the reliability of the Diesel Locomotive System, FMEA, FTA and its application were done qualitatively. In achieving the aims of the project, the events and incident which could be generated by the system failure were defined to determine the consequences of the realized incidents. In this step two categories were taken into account including operation and system component. Then, the next phase was concentrated on considering and analysing the relevant processes and the root causes which result in the identified failure. After all probable root causes were clarified, then the root causes identified and necessary preventive actions were taken. The aim of this step was either decreasing the occurrence of root causes or increasing the detectability of failure. In the last part quantitative method has been used to measure the amounts of Reliability, Availability and Maintainability of the system, based on MTBF and MTTR of different components of the system and the solutions to improve system reliability based on components FTA model was introduced.

ABSTRAK

Projek ini dijalankan bertujuan untuk menentukan penyelenggaraan dan proses operasi sistem Diesel Lokomotif dengan Menggunakakan kaedah Kebolehpercayaan, Ketersediaan , penyelenggaraan dan Keselamatan (RAMS) . Model Lokomotif Diesel Keretapi Tanah Melayu Berhad (KTMB) telah dipilih untuk dianalisis. Projek ini berpandukan kajian penilaian risiko Lokomotif Diesel dengan menggunakan data operasi Lokomotif yang dikumpul daripada industri kereta api bagi mengaplikasikan kaedah penilaian risiko kepada operasi keretapi dan mengenalpasti prestasi RAMS bagi Lokomotif Diesel dan sebab-sebab kegagalan utama sistem tersebut. Kebolehpercayaan sistem dalam projek ini telah dianalisis dalam kaedah kualitatif dan kuantitatif. Dalam kaedah kualitatif adalah berpandukan parameter RAMS pada kebolehpercayaan sistem Lokomotif Diesel secara kaedah FMEA dan FTA. Untuk mencapai proses terebut, sebab-sebab dan kejadian utama kegagalan sistem Lokomotif Diesel telah ditentukan berdasarkan kejadian daripada insiden. Dalam proses ini dua kategori diambil aspek utama telah diambil kira iaitu operasi lokomotif dan komponen sistem lokomotif. Fasa seterusnya tertumpu kepada pertimbangan dan menganalisis proses-proses yang berkaitan kepada punca yang menyebabkan kegagalan yang telah dikenal pasti. Setelah itu semua punca kegagalan ia terjadi kepada sistem utama telah dikenal pasti maka tindakan-tindakan pencegahan yang diperlukan dapat ditentukan. Tujuan langkah ini adalah sama ada mengurangkan berlakunya punca kegagalan atau meningkatkan pengesanan kegagalan. Dalam bahagian terakhir projek ini adalah kaedah kuantitatif telah digunakan untuk mengukur jumlah Kebolehpercayaan, Ketersediaan dan penyelenggaraan sistem, berdasarkan MTBF dan MTTR komponen yang berbeza pada setiap sistem dan penyelesaian untuk meningkatkan kebolehpercayaan kepada sistem berdasarkan komponen model FTA.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	-	Intermediate event
AC	-	Alternate current
Aux	-	Auxiliary
CCA	-	Cause - Consequence Analysis
DC	-	Direct Current
DMU	-	Diesel Multiple Unit
DP	-	Dynamic Positioning
Down	-	Down time
EMU	-	Electrical Multiple Unit
FMEA	-	Failure Mode and Effects Analysis
FMECA	-	Failure Mode, Effects and Criticality Analysis
FTA	-	Fault Tree Analysis
H	-	Hour
HAZOP	-	Hazardous Operability Analysis
KL	-	Kuala Lumpur
Km	-	Kilometer
Kph	-	Kilometer per hour
KTM	-	Keretapi Tanah Melayu
KTMB	-	Keretapi Tanah Melayu Berhad
M_s	-	Maintainability of System
MAMT	-	Mean Active Maintenance Time
MCSs	-	Minimal Cut Set
MDBF	-	Mean Distance Between Failure
MDBM	-	Mean Distance Between Maintenance
MDT	-	Mean Down Time
MDTF	-	Mean Distance To Failure

MKBF	-	Mean Kilometer Between Failure
Mm	-	millimeter
MMH	-	Mean Maintenance Hour
MTBF	-	Mean Time Between Failure
MTBM	-	Mean Time Between Maintenance
MTTF		Mean Time To Failure
MTTR		Mean Time To Repair
MYRA		Malaysian Railway Institute
R		Reliability
RAM		Reliability, Availability, Maintainability
RAMS		Reliability, Availability, Maintainability and Safety
RCM		Reliability Centered Maintenance
T		Top event
t		Time
Up		Uptime
X		Basic event
λ		Failure rate
μ		Repair rate

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Keretapi Tanah Melayu Berhad (KTMB) is a private limited company, incorporated and domiciled in Malaysia. The company is wholly owned by the Minister of Finance Incorporated, a corporate body established in Malaysia. The principle activities of KTMB are to operate the railway transportation and the provision of related railway services in Peninsular Malaysia and Singapore. The company operates these activities pursuant to a license issued by the Minister of Transport.

KTMB has always been the nation's established player in the logistic industry, moving passengers, goods and services throughout the railway network in Peninsular Malaysia and Singapore. Its rail network strategically links and helps to develop the industrial growth centres in the inland to the seaports such as Penang Port, Port Klang, Port of Tanjung Pelepas and Tanjung Pagar. It also connects cross border movements of freight between Singapore, Malaysia and Thailand (Angelalia Roza 2013).

Encik Mohd. Salleh Abdullah, The Managing Director of KTMB remarked, KTMB continues to focus on providing safe, efficient and reliable integrated rail services with greatly improved services for both passengers and goods. KTMB is committed to becoming a respected and significant total land transport solution services provider. Therefore, a good rail transport system has to be developed in Malaysia to keep up with the demands and the rapid development as a developing country. 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.

In the latest Malaysia Plan, the Government has indicated its intention to develop rail transport to play a larger role in both inter-city and urban transport. The main intercity rail line of KTMB, from Johor Bahru in the south to Padang Besar on the Thai border in the north, is now being double-tracked and electrified. Double track system is built to increase the capacity of train by added the new commuters train technology trends set which is Electrical Multiple Unit (EMU) to replace the trend Diesel Multiple Unit (DMU) as a main passenger transport while the DMU used to transport goods including cargo, cement, sugar and other. Dual Track system is built on the original route by adding another track to the existing track. Double-track railway between Ipoh and Klang Valley is designed to allow trains to passes through at speeds of up to 160 km / h and this will introduce a rapid train service with 16 trips per day or until a maximum of 32 trips per day. In addition, it can reduce travel time and increase the frequency of trains schedule between towns and cities. With this can help countries improve rail infrastructure in line with the government's objective to achieve a vision towards 2020 (Sarah et al. 2012).

Malaysian railways are facing a challenge to improve their reliability and speed in order to offer competitive services to the public and enhance their importance as a road alternative. Considering these situations, it is required to establish an evaluation method which applicable in designing railways system that has an excellent RAMS performance. RAMS is an acronym for the four assessment indicators which are reliability, availability, maintainability and safety. This RAMS was the required for train operation in order to maintain the good balance by considering those indicators and system efficiency. It also increases the service performance when it applied in train operation.

1.2 Problem Statement

RAMS of a railway system affects the system during operation (operating conditions) and the system during maintenance activities (maintenance conditions). To comprehend the dependable system, factors which can affect the RAMS of the system need to be identified, as they can also affect the life cycle of the system.

Reliability and safety of railway operating system are among the crucial aspects in any organization since they have direct implication on the performance and productivity of an organization.

In this project, we consider the problem arises in the train operation system that will disturb the train operation. For KTMB that runs multiple train units in rail network, predicting and keeping a required level of train operation availability is a challenging task. The stochastic nature of train breakdowns and the corrective maintenance to fix them are problems to keep track of availability of the train operation. If more trains are withdrawn from an operation due to failure, the train operator cannot provide the required transportation capacity to cover the scheduled services. To enhance the availability of the operation, the management needs to keep reliability of trains.

Each day KTMB keeps 16 trains operation between Ipoh to KL central for demand the customer satisfaction. Standby trains are spare trains available in case of one of the operational trains fail. However keeping a high number of spare trains is very costly and it is not economical. The challenge of this situation is how the RAMS to be analysis for the long run train availability in order to keep the serviceability to the passenger satisfy (Sarah et al. 2012).

1.3 Objective

The objectives of this project are:

i. To evaluate the reliability of locomotive system reliability performance.
ii. To determine the effect of availability and maintainability of train operation using RAMS analysis.

1.4 Scope of Study

The scopes of this project are:

i. The Locomotive Class 24 includes passengers and freight train operation.

ii. Only Diesel Locomotive System to be study based on the failure of the system.

1.5 Significant Of Study

The purpose of this research is to analysis the existing of train operation by included RAMS into available railway systems to achieve the succeed performance, such as reliability, availability and maintainability. The methodology and the model that has been developed will determine the RAMS performance which helping the railway system to establish their functions and activities.

The significant of this study is to evaluate the reliability of critical system that forms part of the Diesel Locomotive within Malaysia Railways industry. Other than that, it is to identify and analyse the potential cause of the failures. Therefore, the project should be able to evaluate the reliability performance of the critical system of the diesel locomotive at KTMB and to determine the highest failure rate that contributes to loss of operation and the reliability performance targets.

In the previous project, Tomo state that to reduce equipment failure and increase their availability and maintainability, it is important that RAMS engineering and maintenance management understand the concept of RAMS. The goal of this study is to find the best concept of RAMS engineering as to provide guidelines on how these concept can be implemented to improve the RAMS of diesel locomotive. This project constitutes for KTMB organization dealing with the RAMS for maintenance strategy in order to improve the reliability, availability and maintainability of train operation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The Malaysian railways are indeed a dynamic, diverse corporatized entity that has the potential to play an important role in the development of a sustainable transportation system in the country. In year 2020 the rail transport systems must be developed to keep up with demand and the rapid development. Malaysian railways are facing the challenge to improve their reliability and speed in order to offer competitive services and enhance their importance as a road alternative (Donavan 2004).

KTMB operates a mixed network of railway system that is used for tranport both passengers and goods. Due to the ubiquity of single line tracks throughout the network, there is some competition between freight and passenger rail for line time. The shortage of resources for locomotives and crews, the low average train speeds (60 kph), narrow 1 meter track gauge and old rolling stock have become the constraints in rail transport (Abdul *et al*., 2008). These constraints have resulted in longer travel times on certain routes. However, the railway sector is striving to increase its capacity to meet the growing demand for the transport of goods and passengers with a high level of punctuality in its services. Now, the railway Efforts to make a double track network are underway (in 2003) in the hopes of alleviating some of these problems.

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.

In this project are generally to study the KTM Intercity and good, therefore to some extent on matters concerning the KTM Intercity and good 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 choice in terms of diversity coach and travel destinations includes Peninsular Malaysia. Change for change has been implemented to provide services in a comfortable and safe journey to your destination of choice in the shortest time possible. Most of these services operate from Station Kuala Lumpur Sentral. However, there is a train service runs along the East Coast route and Gemas and next heading to Singapore. There is a cross-border rail services operating between Butterworth and Bangkok, Thailand.

2.2 RAMS Parameters

RAMS is a characteristic of a system's long term operation and is achieved by the application of established engineering concepts, methods, tools and techniques. RAMS of the system can be defined as qualitative and quantitative indexes which are related to the system, subsystem or the grade of component parts of the system can be relied upon to function as specified and to be both available and safe. RAMS is used as an available tool to understand how the whole system functions such as train operation on a track. There also used to predict the imperfections and showing the influence the quality and performance of the system. It also used the method to improve the quality of the operation for an optimum long term behavior and choosing the best maintenance strategies. Railway on vehicle transport system is a mission and safety critical system. Therefore, to achieve the safety operational of a railway system, all possible potential hazards that affect the system component must be identified, assessed and controlled through RAMS to achieve of safety and reliability (Tzanakakis et al., 2013).

According to Ali Ebrahimi in the previous research was implement the reliability analysis based on qualitative and quantitative methods. Their used of RAMS in analysis of analysis of Reliability, Availability, Maintainability and Safety (RAMS) Parameters in design and operation of Dynamic Positioning (DP) systems in floating offshore structures. In qualitative method to find the effective parameters on the reliability of the DP system, Reliability Centered Maintenance (RCM) and its application as a main tool have been used. In the part of quantitative method has been used to measure the amounts of Reliability, Availability and Maintainability of the system, based on MTBF and MTTR of different components of the system (Ali Ebrahimi 2010). The description and definition is according to Melkamu Teshome as following.

Reliability is defined as probability that an item can perform a required function under given conditions for a given time interval.

Availability is defined as ability of a product to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval assuming that the required external recourses are provided

Maintainability is defined as probability that a given active maintenance action, for an item under given conditions of use can be carried out within a stated time interval when the maintenance is performed under stated conditions and using stated procedures and resource.

Safety is defined as the state of technical system freedom from unacceptable risk of harm.

2.2.1 Reliability Parameters

Reliability is measured by the probability that a system or component will work without failure during a specified time interval, with consideration of given operating conditions and environment (Tzanakakis, 2013). The failure categories of system or component of work can explain in table 2.1. To determine the performance that required of the track system, the failure modes of the train should be identified and categorised as the failure categories illustrated in the table 2.1.

Table 2.1: RAM failure categories (EN 50126, 1999)

Failure Category	Definition
Significant (Immobilizing Failure)	A failure That - Prevent train movement or causes a delay to service greater than specified time and/or generates a cost greater than a specified level
Major (Service Failure)	A failure that - Must be rectifier for the system to achieve its specified performance and - Does not cause a delay or cost greater than the minimum threshold specified for a significant failure
Minor	A failure that - Does not prevent a system achieving its specified performance and - Does not meet criteria for significant or major failure

Higher reliability targets placed on a significant failure while the small failures target is place in the small failures category. Therefore, the infrastructure manager must know which failure mode of the train needs to be given more attention in order to achieve the reliability of both systems and incur less cost because of failure. Among the factors which have an important influence on the equipment reliability are period of use and environment of use. The Typical reliability parameters that have been used for track show in table 2.2.

Table 2.2: Typical reliability parameters that have been used for track (Tzanakakis, 2013).

No.	Reliability Parameter	Description
1	Mean Time To Failure (MTTF)	for non-repairable system
2	Mean Distance To Failure (MDTF)	for non-repairable system
3	Mean Time Between Failure (MTBF)	for repairable system
4	Mean Distance Between Failure (MDBF)	for repairable system

The rate of failure is often described as the Mean Time Between Failure (MTBF) which determines the time for the average period between failure. For part of non-repaired with constant failure rate, reliability is given by:

$$R = \left(\frac{\text{Number of failure}}{\text{Total operating time}} \right) \quad (2.1)$$

If failures occur randomly then they can be described by an exponential distribution

$$R(t) = e^{-\lambda t} = e^{\frac{-t}{MTBF}} \quad (2.2)$$

Where; λ = Failure rate ($\lambda = \frac{1}{MTBF}$)

Probability of Failure; The general expression for probability of failure F(t) is given by

$$F(t) = 1 - R(t) \quad (2.3)$$

Reliability is obtained from failure rate, as described above. Failure rate is the time rate of change of the probability of failure. Failure rate is a function of time and often obtain some indication as to which of the influencing factors is controlling and at what time it is controlling. For this to happen, failures must be recorded. In most databases today, failure data sets are scarce or they have a short background. The whole process is illustrated in Figure 2.1.

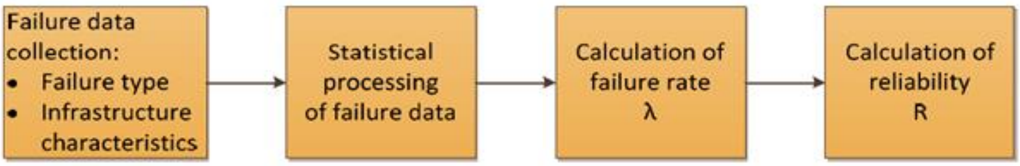

Fig. 2.1: Reliability and failure rate forecasting procedures (Tzanakakis, 2013).

2.2.2 Availability Parameters

Reliability and maintenance to strongly related to the availability of systems and equipment. Reliable system requires less maintenance and good maintainability in shorten repair time. A system has different operational phases: The description and definition is according to Tzanakakis.

- Uptime (Up) : the time that a system works
- Downtime (Down) : the system does not work

Availability is a function of uptime and downtime as shown the following Figure 2.2 and equation (2.4)

$$\text{Availability} = \frac{\text{Uptime}}{\text{Total time}} = \frac{\text{Uptime}}{\text{Uptime} + \text{Downtime}} \quad (2.4)$$

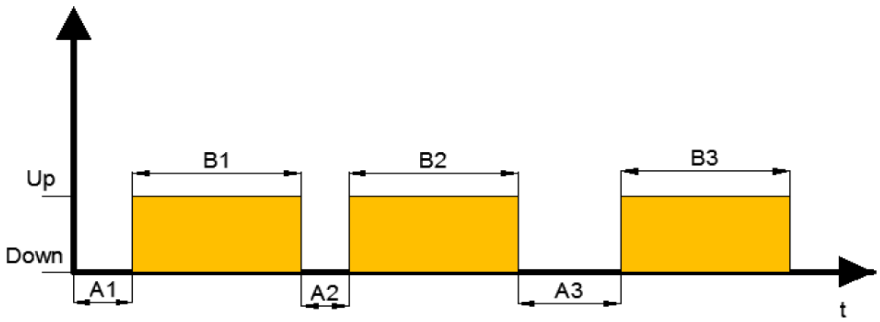

Fig. 2.2: System Operational States (Tzanakakis, 2013).

System availability can be determined in three ways such as:

i. Inherent availability
ii. Achieved availability
iii. Operational availability

Inherent availability there is appropriate circumstances to analysis the availability. Inherent availability is the probability that a system or equipment when used under specified conditions which will operate properly at any time as required (Tzanakakis, 2013). Inherent availability is based on an ideal support environment, which assumes that tools, spare parts and personnel are readily available. Inherent availability for example only takes corrective maintenance into account:

$$\text{Inherent availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \qquad (2.5)$$

Where; MTBF - Mean Time Between failure

MTTR - Mean Time To Repair

Achieved availability is based on the fact that the system that requires maintenance and consider preventive and corrective Maintenance. Achieved availability is also based on an ideal support environment but with consideration of preventive maintenance or schedule (Tzanakakis, 2013).

$$\text{Achieved availability} = \frac{\text{MTBM}}{\text{MTBM} + \text{MDT}} \qquad (2.6)$$

Where; MTBM - Mean Time Between Maintenance

MAMT - Mean Active Maintenance Time

Operations availability is the probability of system or equipment including preventive and corrective maintenance, logistics delay time and delay time of administration. It shows the availability of the actual operating environment (Tzanakakis, 2013).

$$\text{Operational availability} = \frac{\text{MTBM}}{\text{MTBM} + \text{MDT}} \qquad (2.7)$$

Where; MTBM - Mean Time Between Maintenance

MDT - Mean Down Time

Increase in preventive maintenance or renewal actions can have an adverse effect on the availability of the system as it reduces MTBM or MDBM. But at the same time it increases the MTBF/ MDBF of the system. So optimisation of the number of preventive maintenance actions is necessary in order to achieve availability of the system.

Mean Down Time (MDT) comprises of Mean Detection Time (troubleshooting time), Mean Decision time (time to take decision in case of a failure), MTTR, Mean Functional Test time (testing for startup time) and Mean Logistic Time. The availability of a track is for example 98,5%. This means that the track should be operational 360 days of 365 days per year (=365 X 98,5%).

2.2.3 Maintainability Parameters

Maintainability design is related to the function and must be current Engineering design phase, definition, and the early development of life cycle. Maintainability Engineering done for the following reasons:

i. To achieve ease of maintenance through design, reducing maintenance time and cost
ii. To estimate maintenance and system downtime
iii. To estimate labour, hours, time, and other resources for proper maintenance

Maintainability is usually measured by mean time to repair (MTTR). The elements contained in the MTTR given by the time access and repair/replacement time. Maintainability is also represented by the mean time between maintenance (MTBM) or mean distance between maintenance (MDBM). Maintainability is calculated with the mean time to repair (MTTR), which represents the downtime because of maintenance done (Tzanakakis, 2013).

$$M_S = 1 - e^{-\mu t} = 1 - e^{\frac{-t}{MTTR}} \tag{2.8}$$

Where; μ is repair (restoration) rate (μ = 1 / MTTR)

2.2.4 Safety Parameters

Safety analysis is relating to the categories and levels of hazardous events that can happen to a track or train system. Hazard identification must consider early phase in the safety analysis. The hazardous events should be categorized as frequent, probable, occasional, remote, improbable and incredible. Likewise severity level can be divided into four categories namely catastrophic, critical, marginal and insignificant.

Safety can be defined as a subset of reliability with consideration of the severity of the failure mode. Typical safety parameters that have been used to track or train scenario as the following:

i. Mean Time Between Hazardous Failure (MTBHF)
ii. Mean Time Between Safety System Failure (MTBSF)
iii. Hazard rate H(t)

Time units in the above cases are considered in Million Gross Tonnes (MGT).

2.2.5 Summaries of term RAMS Values for System Operational States

Table 2.3: The key values for system operational state (Tzanakakis, 2013).

Reliability	MTBF	Mean Time Between Failure (for corrective maintenance)
	MTBM	Mean Time Between Maintenance for preventive Maintenance MTBF and MTTF: Often used to describe equipment or system reliability. Of use when calculating maintenance costs. Meaningful even if the failure rate is not constant.
	Train delaying failures	
Availability	Train delay hours	
maintainability	MTTR	Mean Time to Repair Often expressed in percentile terms such as “the 95% repair time shall be 1 hour”. This means that only 5% of the repair actions shall exceed 1 hour.

Table 2.3: (continued)

	MDT	Mean Down Time In organizational management, mean down time (MDT) is the average time that a system is nonoperational. This includes all time associated with • repair, corrective and preventive maintenance, • self-imposed downtime, and • any logistics or administrative delays. The inclusion of delay times distinguishes mean down time from mean time to repair (MTTR), which includes only downtime specifically attributable to repairs.
	NAMT	Mean Active Maintenance Time
	MMH	Mean Maintenance Hour (MMH)
Safety	Hazard Rate	
	Number of derailment due to asset	
	Number of accidents	

2.3 Methods and Tools for RAMS Analysis

Various tools and methods are used for RAMS analysis. Some of these tools and methods are here presented, for example (Tzanakakis, 2013),

i. FMEA (Failure Mode and Effects Analysis),
ii. FMECA (Failure Mode, Effects and Criticality Analysis),
iii. FTA (Fault Tree Analysis),
iv. Failure Block Diagram Analysis,
v. CCA (Cause - Consequence Analysis),
vi. HAZOP (Hazardous Operability Analysis).

2.3.1 FMEA

Failure Mode and Effects Analysis (FMEA) is a systematic tool for identifying:

i. Effects or consequences of a potential product or process failure.
ii. Methods to eliminate or reduce the chance of a failure occurring.

A successful FMEA activity helps a team to identify potential failure modes based on past experience with similar products or processes, enabling the team to design those failures out of the system with the minimum of effort and resource expenditure, thereby reducing development time and costs.

2.3.2 FMECA

Failure Mode, Effects and Criticality Analysis (FMECA) is an extension of FMEA by including a *criticality analysis*, which is used to chart the probability of failure modes against the severity of their consequences. The result highlights failure modes with relatively high probability and severity of consequences, allowing remedial effort to be directed where it will produce the greatest value.

2.3.3 FTA

Fault Tree Analysis (FTA) is a diagnostic tool used to predict the most likely failure in a system breakdown. This analysis method is mainly used in the field of safety engineering and reliability engineering to determine the probability of a safety accident or a particular system level (functional) failure.

2.3.4 CCA

Cause - Consequence Analysis (CCA) technique combines cause analysis and consequence analysis. The purpose of CCA is to identify chains of events that can result in undesirable consequences. With the probabilities of the various events in the

CCA diagram, the probabilities of the various consequences can be calculated, thus establishing the risk level of the system.

2.3.5 Failure Block Diagram Analysis

Failure Block Diagram Analysis is the analysis of a system based on the component reliabilities. It is a method of modeling how components and sub-system failures combine to cause system failure. Reliability block diagrams may be analysed to predict the availability of a system and determined the critical components from a reliability viewpoint. Figure 2.3 shows examples of reliability block diagrams models for reliability design and assessment.

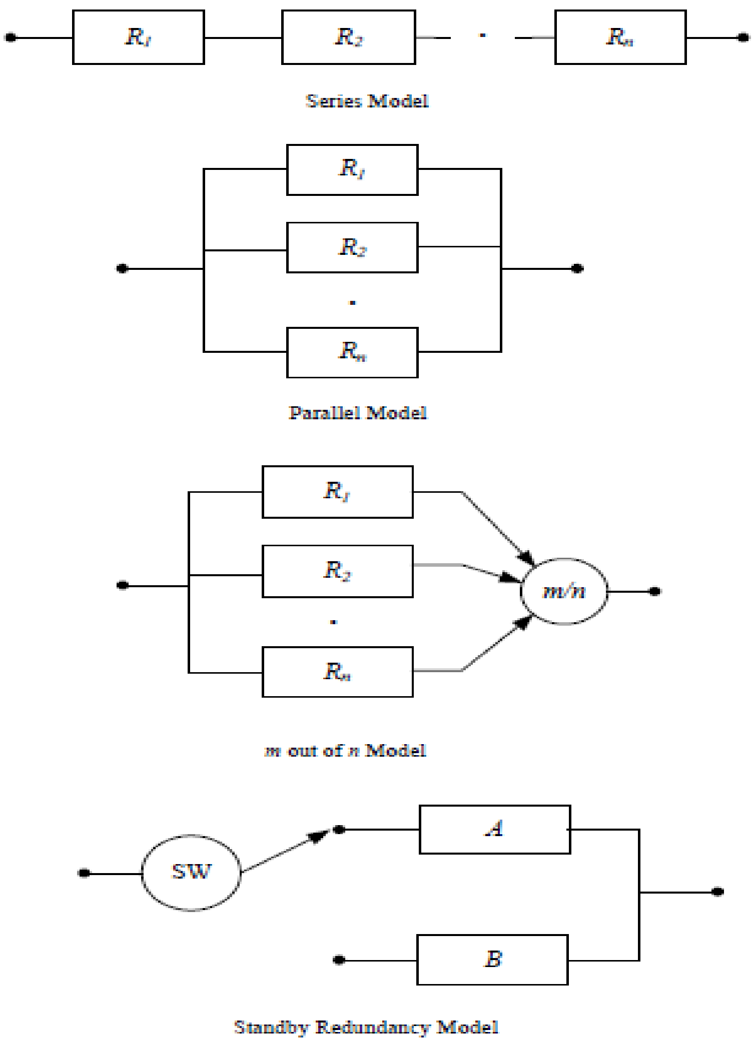

Figure 2.3: Reliability Block Diagram Models (Mun Gyu Park 2013)

2.3.6 HAZOP

A Hazard and Operability study (HAZOP) is a structured and systematic examination of a planned or existing process or operation in order to identify and evaluate problems that may represent risks to personnel or equipment, or prevent efficient operation. A HAZOP is a qualitative technique based on guidewords and is carried out by a multi-disciplinary team (HAZOP team) during a set of meetings, to assess the hazard potential that arise from deviation in design specifications and the consequential effects on the facilities as a whole. This technique is usually performed using a set of guidewords: NO / NOT, MORE / LESS OF, AS WELL AS, PART OF REVERSE, AND OTHER THAN.

From these guidewords, scenarios that may result in a hazard or an operational problem are identified. Consider the possible flow problems in a process line, the guide word MORE OF will correspond to high flow rate, while that for LESS THAN, low flow rate. The consequences of the hazard and measures to reduce the frequency with which the hazard will occur are then discussed. This technique had gained wide acceptance in process industries as an effective tool for plant safety and operability improvements. Table 2.4 shows an example of the application of HAZOP for analysing the operational problems of train doors at platforms

Table 2.4: An example of the application of HAZOP (From Mun 2013)

Guideword	Deviation	Cause	Effect
No	Doors fail to open	Defective mechanism	No passenger egress
More	Doors open to early (train moving or not adjacent to platform)	Operator error	Possible harm to passengers
Less	Only one door open	Defective mechanism	Restricted passenger egress, may lead to crush injuries
As well as	Doors open on both sides of train	Failure in control circuitry	Possible harm to passengers if they exit the wrong door
Part of	Same as less	-	-
Reverse	N/A	N/A	
Other than	Doors open wrong side	Failure in control circuitry	Possible harm to passengers if they exit the wrong door

2.4 Reliability Centre Maintenance

Reliability-based maintenance (RCM) is analytical technique maintenance to identify and determine the failure management policies for the achievement of operational objectives such as safety, availability and cost. Failure management policies generally include maintenance strategy, operational changes, modification of design or other to control due to the mode of failure. RCM implementation steps are detailed along with the tools and techniques needed or improvements made to the effectiveness of the system (Melissa et al. 2014).

RCM provides a structured logical decision process to determine the appropriate basic preventive maintenance, design improvements, or a suitable alternative for security, operational impact, and potential degradation mechanisms malfunction, the analysis is supported by FMECA, FTA and other. The application of RCM at the operation and maintenance stages can be applied for the improvement of the existing maintenance policy. Figure 2.4 shows a procedure that can be done with RCM FMECA in the design process systems engineering. RCM is usually implemented to monitor the results of the risk assessment with preventive maintenance strategies (Mun 2013).

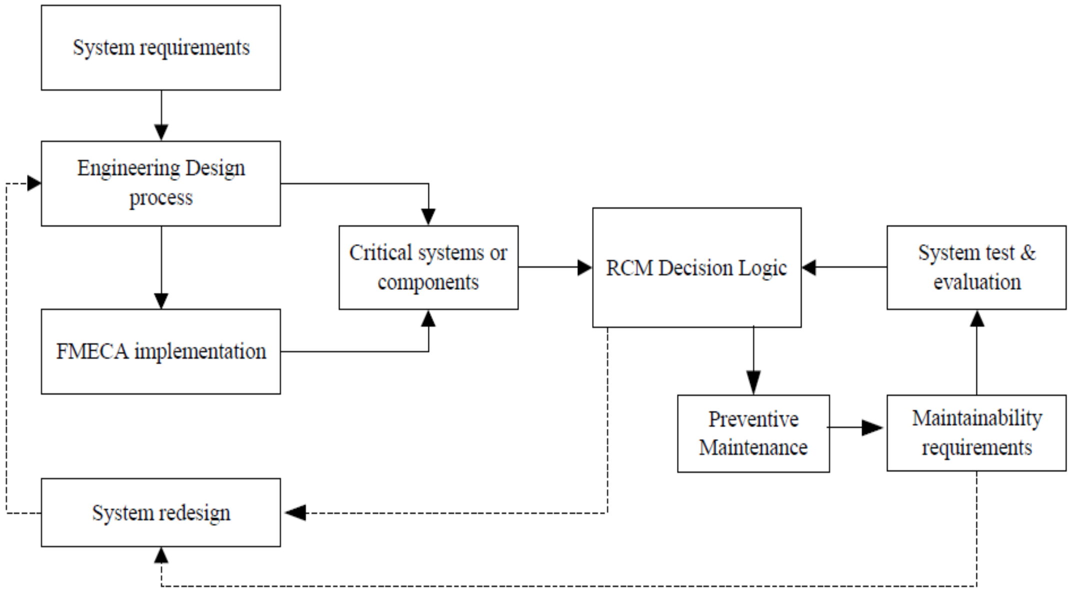

Figure 2.4: RCM Model (Mun 2013)

2.5 RAMS in Operation and Maintenance

The objective of this phase is to operate, maintain and support the combination of components and subsystems such that compliance with the requirements RAMS system is maintained.

Figure 2.5 shows the process for RAMS track system in operation and maintenance phase in the life cycle of the system. It is a process of continuous improvement in all phases of operation and maintenance.

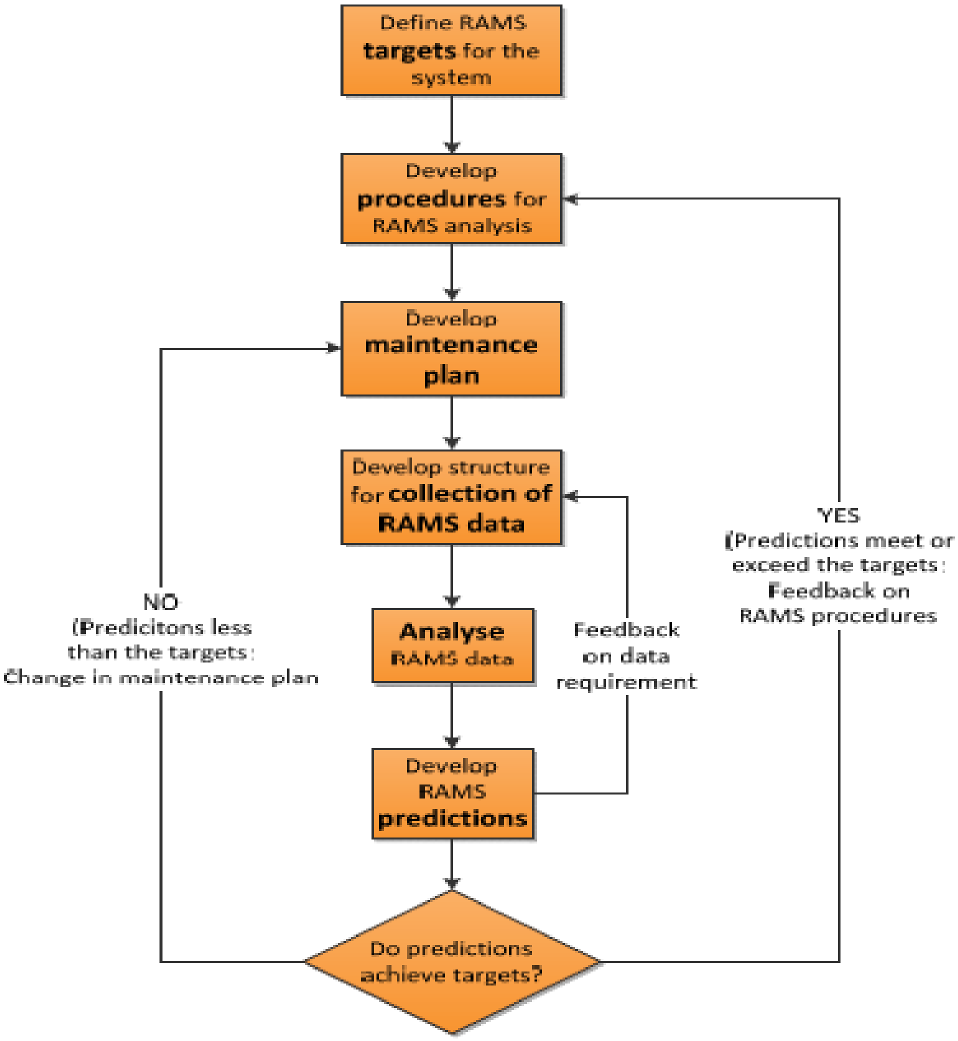

Fig. 2.5: RAMS process in the operation and maintenance phase (Tzanakakis 2013)

RAMS analysis should be done as early as possible in the design stage to ensure performance calculation is performed for the entire system, including all existing subsystem and not only for one subsystem that can be affected by other subsystems.

2.6 Literature review about Reliability and Maintainability of railway track.

Train need maintenance to performed to keep the train operating (preventive maintenance), and they are repaired when they fail (corrective maintenance). The ease with which maintenance work (including repair) can be carried out determines train maintainability. Maintenance work can be divided in two categories, preventive and corrective (Klaus et al.1993).

Preventive maintenance seeks to retain the system in an operational or available state by preventing failures from occurring. This can be by servicing, such as cleaning and lubrication or by inspection to find and verify incipient failures. Preventive maintenance affects reliability directly. It should be performed in a planned manner. Preventive maintenance can be measured by the time taken to perform the specified maintenance tasks and their specified frequency.

Corrective maintenance includes all actions to return a system from a failed to an operating or available state. The amount of corrective action is, therefore, determined by reliability. Although a plan for corrective maintenance can be established, the timing and complete details of corrective maintenance action cannot be planned; it happens unexpectedly and should be avoided by design.

System maintenance related to the actual maintenance work to develop maintenance procedures. Based on the failure modes, various tools and methods are used to calculate reliability and maintainability of the system are used FMEA (Failure Mode and Effects Analysis), FMECA (Failure Mode, Effects and Criticality Analysis), FTA (Fault Tree Analysis), Failure Block Diagram Analysis, CCA (Cause Consequence Analysis) and etc. (Kumar et al. 2001). Failure modes directly affect reliability based on probability of occurrence of failure modes, maintainability is related the number of failures occurring in a period of time of the system.

Ambika stated, the available of the track barely consider the train Schedule. The availability of the track is necessary to consider demand availability in operational availability. Availability request is the probability that a system will be in a condition that works on demand. In the case of the track, the availability request defines the long unit provided track when a train passes over it. To achieve the demand availability of the track section following measures must be considered;

i. Reduce the corrective maintenance on the track.
ii. All the preventive maintenance on the track must be carried out in the train free periods.

Maintenance plans on the track need to utilise when the train not operation in order to maximum maintenance actions. In order to calculate the availability of a track section within period the reliability and maintainability of the track along time instead of train time table need to be considered.

2.7 Literature review about railway signaling system

The purpose of the signaling system is to ensure that trains keep a safe distance between each other. Based on previous research, the railway signaling system has a method to control the train operation to ensure safety of railway Transport. This signal system it depends on train authorities and it must be appropriate to the tracks used, train density and train schedule. Based on that for careful signaling system design must be concerned to ensure the availability and safety of train operations. In addition, to manage the rail it should take into account several factors, namely the amount of transportation and the layout of the track at the station (Shigeto et al. 2008)

Signaling systems based on information technology will be introduced more active in the future. Therefore, a systematic method for evaluating the signal system will become more important in the development phase. For safety, various technologies have been developed and used, and signaling systems have an excellent safety record. They are also responsible for assigning and provide use of the track, control the direction of the train, all the traffic order within the limits of infrastructure and establish timetables and regulations to ensure that the train is operating safely and efficiently.

In the previous research of signaling system, through the definition expresses a performance of each equipment, the relationship between equipment failures and their impact on railway traffic service is not clear. Therefore, the author state a method to evaluate system availability based on the following concepts of estimating the impact on train operation caused by an equipment failure (a component of signaling system) (Shigeto et al. 2008).

The basic procedure is illustrated in Fig.2.6. Take into account the signaling system at a single station. When the equipment (eg, signals, track circuits, machines and interlocking devices) fail, there are various types of impacts. In some cases, the train cannot operate, while in other cases the train can run through the station via an alternative route.

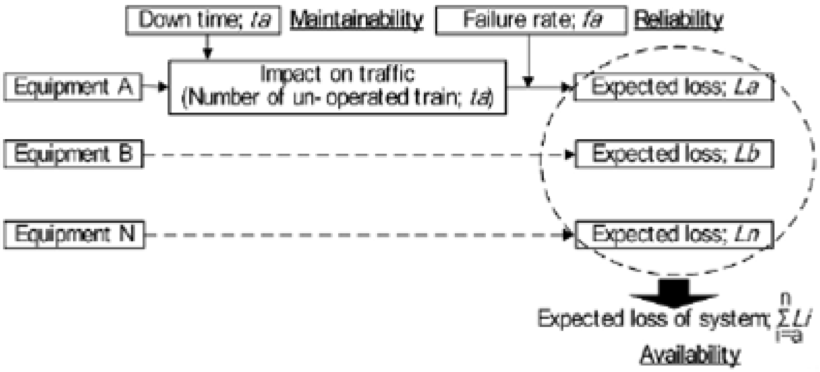

Fig. 2.6: basic evaluation procedure (Shigeto et al. 2008).

The number of the train does not operate during failure and each equipment failure estimated based on the conditions specified. The failure is one of the conditions, and corresponds to the indication of maintainability. The loss of fare revenue caused by failure is estimated from the difference between the total actual planned and operated railway. The outline must be estimating loss each case shown in Fig. 2.7.

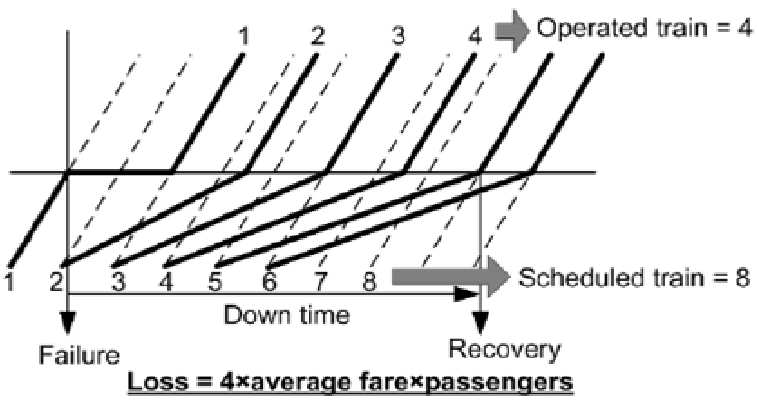

Fig. 2.7: outline of estimating the loss (Shigeto et al. 2008).

2.8 Summary

This chapter presents the overall concepts, methods and techniques of RAMS to identify the method suitable to use for train operation. This chapter has firstly reviewed the train operation of intercity train and freight service. Several concepts had to be study in RAMS engineering to establish the engineering concepts for this project. The activities of train operation have been reviewed in RAMS parameter to help the thorough understanding for establish of RAMS. In this chapter also were explain the RAMS tool can be used to determine in the train operation in order to solved it based on RAMS concept. Some literature related to this project has been reviewed, but the literature review will be continued during the entire project period of time in order to improve the developed research models.

CHAPTER 3

METHODOLOGY

3.1 Project Planning

This chapter outlines the methodology designed to perform the project effectively and efficiently. This project established a strong foundation through investigation, comprehension and analysis of various literatures. The literature review should be implemented throughout the whole project to obtain the source of knowledge of the research topic and to continuously improved and updated to help the researcher to obtain the quality of the results.

This chapter also explains the processes employed specifically to guide the research work from beginning till end. The justification of every stage on how this research was conducted will also be included here. Interview surveys and case study were the methods conducted to get more information about railway operations between Ipoh and KL Central. MYRA, KTM Depot, Ipoh Station and the headquarters were among the places that were contacted.

Planning of developing the overall project started from the selection of topic of the project. The discussion on the project title was carried out together with the supervisor to make sure it satisfied the field of project. Generally, the overall planning can be separated into two stages. The first stage is preparing the proposal of the project which consists of the title, the objective, the scope, the problem statement, the literature review and the methodology of the project. The second stage of the project is to come out with the analysis and the result of the study. GANTT CHART is a visual overview of the overall planning of a certain project. Therefore, a GANTT

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