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RELIABILITY, AVAILABILITY, MAINTAINABILITY AND SAFETY (RAMS) IN RAILWAY'S ASSURANCE SYSTEM AND IMPLEMENTATION CHALLENGES: A REVIEW

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Abstract— RAMS forms an integral part of railway's system assurance. It integrates reliability engineering, availability or performance calculation, maintenance strategies and system safety. While RAMS is widely implemented in other industries like petroleum, aviation and chemical, the practice in railway is relatively new. RAMS task needs to be implemented from earliest phase of system design, tendering, project execution, operation up to decommissioning. Due to its compulsory

System Assurance, Railway Stakeholder	extensive involvement of railway personnel as well as authorities, RAMS is not being fully utilized as an assurance tool in railway industry. This paper will introduce the core components of RAMS and their stakeholders.

I. Introduction

System assurance focuses on ensuring that the outcomes of processes meet system specifications. Reliability, Availability, maintainability and safety (RAMS) is one of an integral part of system assurance that ensure the reliability and safety of railway operation [1]. It is the responsibility of the client or project owner to suggest a comprehensive strategy encompassing RAMS and other system engineering activities such as Validation and Verification (V&V) or Configuration Management [2]. Thus, it is very crucial for the authorities or project owner to understand RAMS requirement and the significant of their parameters so that they could enforce right parameters in their tender or contract. RAMS is implemented throughout life cycle of railway project from tendering to decommissioning [3]. Safety and RAM demonstration activities must be carried out at commissioning and during the defect liability period to validate the predictive and analytical methods used throughout the design stages. RAMS deliverables or documents are required to confirm the system requirement at every stages. The implementation of RAMS in railway projects like Mass Rapid Transit (MRT) system are made compulsory for all new development [4].

II. RAMS

A. Reliability

A product's reliability is closely related to its quality. Reliability is a function of time, and it gets worse as time goes on [5]. Every railway asset has a very high acquisition cost; hence a long-lasting, high reliability product or system is required. Along with having a technical meaning, train operationality can also be used to define a railway's reliability. The punctuality of the train operation was used by Vromans, M. (2005) to investigate the railway's reliability [6]. When a train runs efficiently every single time, it is said to be reliable since it can deliver goods and other services on time. According to Durivage, M. A., reliability is "probability that an item will perform a required function without failure under stated conditions for a specific period of time [7]". According to this definition, to research the failure behavior of a system or component is to study its reliability. In investigating probability of failure, a population of product or system needs to be observed over a period. Gerokostopoulos et al., have proposed estimation approach and risk control approach for sample size calculation for reliability study [8]. With an adequate number of samples, a Probability Density Function (PDF) of failure event could be developed. The data of a PDF will contain the value of Time To Failure (TTF) of the samples which mean the time for an individual sample to fail. In Life Data Analysis (LDA) study it is known that there are a few distributions of failure that most likely fit to the collected data which are exponential, lognormal and Weilbull Distribution [9].

B. Availability

For an asset manager for railway system, availability of the required and relevant systems is very crucial for their train operation. Reliability and availability are tightly tied to one another [11]. Availability is defined as the sum of the total time the system is up and running, also known as Uptime, and the entire time the system is down, also known as Downtime.

Where ALDT stands for Administrative and Logistic Delay Time, TPM stands for Total Preventive Maintenance, TCM is for Total Corrective Maintenance. The availability concept can be understood from Figure 1 by combining reliability (Uptime) and maintainability (Downtime) [12].

Uptime is the amount of time the train was running and in standby mode at any one time. Downtime, on the other hand, includes all the administrative and logistical delays that were incurred while the maintenance program was being completed.

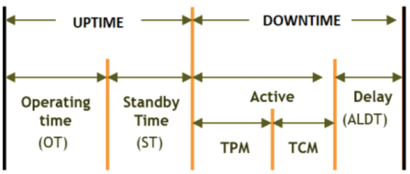

Figure 1: UP and Downtime

C. Availability

To ensure safety and uphold quality standards, the railway track must undergo maintenance and renewal [13]. When it comes to planning and scheduling maintenance, there are various philosophies that could be considered. A new model for reliability-centered maintenance (RCM) of electrical power distribution was put forth by Afzali et al. in 2019 [14]. Su et al. (2019) were researching condition-based maintenance (CBM), another strategy, for maintaining railroad track in the Netherlands [15]. While CBM also considers the machine's state, RBM determines the PM using failure analysis. Although the monitoring needed a little amount of specialized labor on a consistent basis, this method offers efficient use of the asset's useful life [16]. There are numerous approaches accessible to achieve the asset management philosophy. Corrective maintenance (CM) and preventive maintenance (PM) are the two basic approaches used frequently [17]. The CM is used to restore a broken system to its state just before a crash. While PM is being completed according to a timetable or at a set time. The term "opportunity maintenance" is another name for this form of maintenance [18]. Proactive Maintenance (PaM) and Predictive Maintenance (PdM) are two further techniques that could be considered. PaM aims to solve an issue before it becomes a failure. The PdM method, on the other hand, entails assessing and monitoring machine performance and operating parameters to spot and address developing issues before they result in failure and significant damage [19]. Techniques for PdM include oil analysis, mechanical ultrasound, vibration analysis, and wear particle analysis [20]. Total continuous monitoring is now possible thanks to advancements in information technology. A crucial part of the process is the Internet of Things (IoT), which enables many systems to work together to translate and analyze recorded data to forecast when maintenance should be carried out [21]. Additionally, as time passes, new machine-learning technologies can raise performance even further by increasing the predictive algorithms' accuracy [22]. The component's reliability would start to decline after it was repaired or replaced [23]. Repair can be divided into different levels: perfect repair restores a system or component to its original condition, minimal repair gets the system or component to the state shortly before maintenance, and imperfect repair puts the component in a state between perfect and minimal repair [24]. In practice, maintenance costs a lot of money. For instance, the TOC for the Rapid Rail network at Prasarana Malaysia Berhad spends RM350 million annually on maintenance costs [25]. The cost of technical maintenance will subsequently be used for roughly 30% of manual inspection and monitoring [26]. An analysis of maintenance costs can be used to calculate and plan maintenance rates [27].

D. Safety

In EN 50129, which serves as a standard for primarily electronic systems including signaling, communication, and processing system [28], safety in RAMS is specifically covered and evaluated. EN 50126-2 [29] is another standard that outlines the safety requirements for railroads. Risk analysis and hazard control are the two key subtopics in safety. For safety analysis, the Bowtie Model methodology is frequently used[30]. For system dependability and safety, common methodologies include FTA, FMEA, and event tree analysis (ETA) [31].

III. Significant of RAMS Parameter

Reliability (R) of system and subsystem in railway need to be defined as high as possible to make sure the system could do its designated function. The arrangement of subsystem also crucial to make sure the total reliability meet the RAMS requirement. Generally, there are three possible arrangements for subsystems or components.

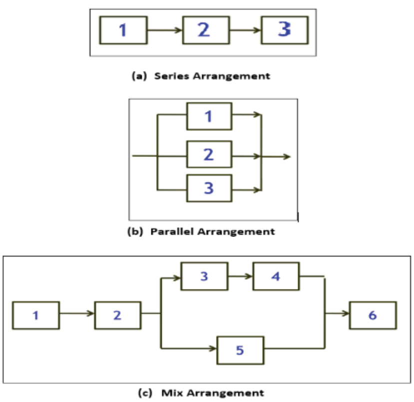

Figure 2: System and Subsystem Arrangement

To increase reliability, redundancy is needed. The higher the reliability of a system, the lower the rate of failure of the system. It means that, the probability of the system to fulfil its function is higher. For example, for a system with reliability of 0.98, at operation time of 1000 hours, the failure rate is 2.05 $x10^{-5}$ per hour. On the other hand, availability shows the performance of the system. To put into perspective, a 99% availability equal to 1% unavailability. Considering the train operation time for the whole year is 300 days or 432000 minutes. For a percent unavailability, it translates to 4320 minutes or 3 days of inoperable train in a year. In safety, all relevant system and subsystem are being observed and possible failure cases are being determined. By using Failure Mode Effect Critical Analysis (FMECA) or Failure Tree Analysis (FTA) [32], the failure node could be detected, and suitable litigation or maintenance activities could be proposed to eliminate or reduced the risk.

IV. Implementation Challenges

There are a few changes needed in a particular company to implement RAMS. As RAMS is part of system assurance, RAMS team members could come from system assurance team. They need to perform

RAMS related tasks and produce respective deliverables. At this stage, RAMS engineer will need to adhere to railway RAMS standards such as EN50126. The management needs to invest more resources in developing a new team and procuring new standards. These, in comparison with engaging foreign consultants, are a cheaper alternative in the long run. Implementation of RAMS at project level is to ensure the client receives a railway system that meets its predetermined requirement. While it would increase the cost of the project, it could significantly reduce maintenance and operating costs. At the operational and maintenance phase of a railway system, RAMS is harder to implement. To calculate real or operational MTTR or MTBF, railway operators need to record their operational parameter and maintenance activities in a detailed manner. At this level, operator RAMS engineer could compare the practical RAMS parameter with the one delivered by the manufacturer or contractor. To calculate a precise and standardized parameter, the engineer needs to understand when the parameter needs to be recorded. Should the parameter differ more than tolerated deviation, the manufacturer or contractor could be held accountable and relevant compensation could be awarded to the operator. Most of Malaysian railway operator do not record their maintenance activities that could perfectly being used to calculate RAMS. It does not mean that they are doing the maintenance falsely, but rather they are not aware of the RAMS requirement in recording maintenance data. On the other side, the train personnel would need to take up a new training or seminar to understand RAMS that could affect their current workload. Increase in duration for documenting the maintenance activities could probably affect the time for maintenance itself. Without clear understanding of the benefit of RAMS, the top management would not without due diligent approve the introduction of this assurance activities.

V. Conclusion

Implementing RAMS in railway projects and operation is currently not an option that could be ignored. All train operators and suppliers around the world are slowly integrating RAMS into their product and operation. Seminars, conference, and training on RAMS need to be organized regularly to make sure all relevant departments could add RAMS task into their respective departmental task. However, implementing RAMS would require a holistic approach up from the authority that managing rail transport to the suppliers and manufacturers as well as train owner or operator.

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