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Factor and Influential Variables Affecting Maintenance Cost of Urban Rail Rolling Stock

Mohd Firdaus Mohamad Idris[1], Nor Hayati Saad[1*], Mohamad Irwan Yahaya[2], Wan Mazlina Wan Mohamed[3], Adibah Shuib[3], Ahmad Nizam Mohamed Amin[4]

[1]School of Mechanical Engineering, College of Engineering,
Universiti Teknologi MARA (UiTM), 40450 Shah Alam, MALAYSIA

[2]School of Mechanical Engineering, College of Engineering,
Universiti Teknologi MARA (UiTM), 13500 Permatang Pauh, MALAYSIA

[3]Malaysia Institute of Transport,
Universiti Teknologi MARA (UiTM), 40450 Shah Alam, MALAYSIA

[4]Keretapi Tanah Melayu Berhad,
Headquarters, Jalan Sultan Hishammudin 50621 Kuala Lumpur, MALAYSIA

*Corresponding Author

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Abstract: It is a known fact that the cost of maintaining rolling stock is huge due to its higher acquisition cost and maintenance activity needed to sustain its reliability, availability, maintainability, and safety. This research paper aims to analyse, evaluate, and rank the variables that influence the rolling stock maintenance cost. A quantitative research method was adopted for data collection. Data collection involving five train operating companies that include Malaysia's rolling stock practitioners was accomplished using a survey. The research first identified the influential variables associated with rolling stock maintenance cost through systematic literature review. Then, 14 influential variables and five groups of factors that affect rolling stock maintenance cost were identified. Variables identified were used as basis for designing the survey. Judgmental sampling was utilized for sampling purposes. The data collected from survey were analysed using importance index to accomplish ranking analysis. The research has discovered that spare part cost, manpower cost and equipment cost are the highest ranked influential variables contributing towards rolling stock maintenance cost. This study has highlighted the possibility of future major studies concerning influential cost in establishing cost predictive model for rolling stock maintenance.

Keywords: Rolling stock, maintenance cost, railway, operation research, urban rail, importance index

1. Introduction

Railway is the largest man-made transportation networks in the world and plays a vital role in driving economic growth of any country [1]. It has been identified as a vital service sector and the importance of this service's sector to the economy both in production and employment which cannot be denied [2]. Meanwhile the rolling stock is the most visible segmentation under railway development. Rolling stock conditions directly affects the safety, the efficiency, and the reliability of railway operations [3]. Failure to sustain the railway service will not only contribute to the lower ridership but also tarnish the company's brand name, country productivity and economic growth. Maintenance is performed to maintain the system reliability and ensuring it is safe. All maintenance activity performed by train operating companies consume multimillion dollar of expenses [4]. This research specifically focuses on influential

*Corresponding author: norhayatisaad@uitm.edu.my

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costs involved in rolling stock maintenance. The findings of this study will help rolling stock practitioners to identify, manage and further minimise the cost for organisation to gain short-term and long-term competitive advantage and sustainable financial strategy.

Motivation to conduct this research is based on literature reviews which have indicated that papers focusing on convincing influential variables in rolling stock maintenance costs are lacking. In addition, within the Malaysian railway context, there are no research found that identify the influential variables for rolling stock maintenance cost. The aim of this paper is to evaluate the influential costs associated with rolling stock maintenance.

Research conducted by Nielsen [5] has shown that the average annual maintenance cost amount is about 3.3% of the acquisition cost. The acquisition cost for any railway in the world is huge due to mega infrastructure with complex interfacing system. Typically, the acquisition cost for rolling stock is budgeting and funding under the country's infrastructure development. Research showed that "in an estimated time period of 25 - 30 years, the costs of rolling stock maintenance may be equal to vehicle investment cost"[6]. In addition, "the life cycle costs are roughly 1/3 of the new built investment and 2/3 of subsequent maintenance and further investments" [7].

Our study has been conducted involving urban rail train operating companies (TOCs) where the scope and findings focus on influential costs on urban rail maintenance. From systematic literature review, 14 influential costs were identified consisting of, spare part cost, workforce cost, equipment cost, training cost, cleaning cost, hazard cost, cost of quality, sunk cost, logistic cost, insurance cost, inspection cost, space cost, shunting cost and loss of opportunity cost. The five groups of factors that affect rolling stock maintenance cost were established and consist of human resource, maintenance activity, supply chain, facilities, and other related costs.

2. Research Background

Rolling stock is a generic terminology in railway industry referring to locomotives, wagons, carriages, or any type of vehicles used on track [8]. Recently, Erguido, et al. [9] contributed significant information to the existing body of knowledge on maintenance cost structure, specifically for rolling stock. The knowledge of the maintenance cost in cost structure is important for the understanding of the main influential variables in rolling stock maintenance cost. Authors emphasized that cost for rolling stock maintenance is divided in two categories as illustrated in Figure 1, that consist of Capital Expenditure (CAPEX) and Operational Expenditure (OPEX). CAPEX is further divided by development cost and investment cost. Meanwhile, OPEX is classified into three types of costs which are operation cost and preventive maintenance, corrective maintenance and failure impact, and decommissioning. However, the theory given is not sufficient for rolling stock practitioners to use as a guideline. Therefore, our research further explores the influential variables affecting rolling stock operation cost.

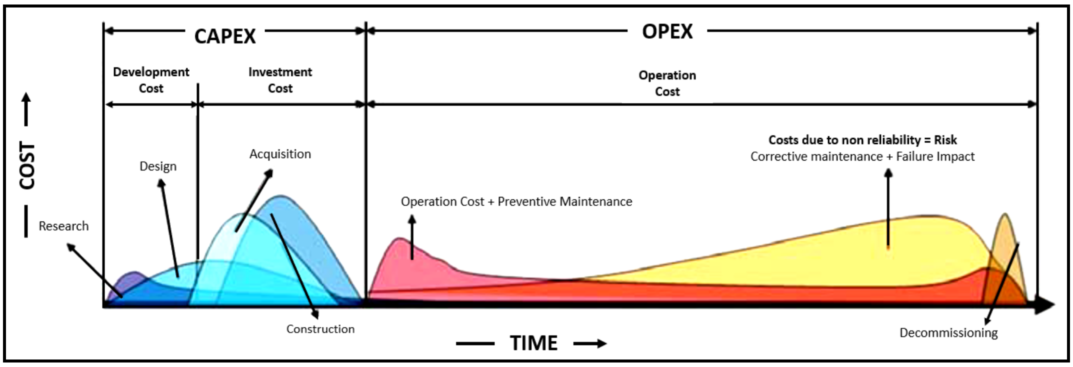

Fig. 1 - Cost structure in the assets' life cycle. Source; [9]-[10]

A research by Khan, et al. [11] partition the rolling stock maintenance cost into three parts, which are acquisition and installation cost, operation and maintenance cost and disposal cost (phase-out). It is crucial to properly plan and execute the selected maintenance strategy and activity to sustain the asset's life cycle. This requires comprehensive understanding on influential variables contributing towards operation costs.

Table 1. shows the acquisition cost for Malaysia's rolling stock. The government allocates almost 268 billion to deliver high class rail transportation to Malaysian. It is estimated that 40 billion from the total cost is for rolling stock acquisition and maintenance. Based on the in-progress project, the least rolling stocks acquisition cost is 1.3 billion for Penang light rail transit project and the highest rolling stock acquisition cost is 9.3 billion for high-speed rail project.

2.1 Influential Variables for Rolling Stock Maintenance Cost

The identified influential variables from systematic literature review consist of spare part cost, workforce cost, equipment cost, training cost, cleaning cost, hazard cost, cost of quality, sunk cost, logistic cost, insurance cost, inspection cost, space cost, shunting cost and loss of opportunity cost were organized using Affinity diagram. The use of Affinity diagram enables deeper analysis to uncover insights for important influential variables as illustrated in Figure 2. The influential costs were clustered into five groups by adopting the method by Rahmat Nurcahyo , et al. [12] and Márquez [10]. Those researchers mentioned that the influential variables could be grouped together based on established industries' practices. Influential costs related to rolling stock maintenance are classified into five groups of factors which are human resource, maintenance activity, supply chain, facilities, and other related costs. The five-factors represent five functional departments such as, human capital department, rolling stock department, procurement department, facilities department, and strategic department. The importance of Figure 2 was supported by Heizer, et al. [13] which stated that an organization tends to create a few functional departments to strategically manage and focus on the needs.

Table 1 - Malaysian urban rail investment cost (adapted from Idris and Saad [14])

No.	Asset Owner	Train Services	Current	In Progress	Project Cost (RM)	* Rolling Stock Cost (15%)
1	Prasarana Malaysia Berhad	Rapid Rail Sdn Bhd - Subsidiary of Prasarana Malaysia Berhad 1. LRT Kelana Jaya Line 2. LRT Ampang Line 3. Monorail Line [15]	/		4.4 Billion 3.5 Billion 1.18 Billion	0.66 Billion 0.25 Billion 0.177 Billion
		LRT 3 [16]		/	9 Billion	1.35 Billion
		The Johor Bahru-Singapore Rapid Transit System [17]		/	10 Billion	1.5 Billion
2	Mass Rapid Transit (MRT) Corp	MRT 1 Sungai Buluh Kajang Line [18]	/		23 Billion	3.45 Billion
		MRT 2 Serdang Sungai Buloh Kajang Line [19]		/	23 Billion	3.45 Billion
		MRT 3 Circle Line [20]		/	40 Billion	6 Billion
3	Malaysia Railway Asset (MRA)	Keretaapi Tanah Melayu Berhad (KTMB)	/		N/A	NA
		Ipoh-Padang Besar Northern double-track [21].	/		12.5 Billion	1.875 Billion
		Gemas-Johor Bahru Electrified Double-Tracking [21]		/	8.5 Billion	1.275 Billion
4	Express Rail Link Sdn. Bhd	KLIA Transit [15]	/		2.4 Billion	0.36 Billion
5	High Speed Rail (HSR) Corp	High Speed Rail [22]		/	62 Billion	9.3 Billion
6	Malaysia Railway Link (MRL)	East Cost Railway Link [23]		/	55 Billion	8.25 Billion
7	Suruhan Jaya Pengankutan Awam Darat (SPAD)	SPAD to propose Tram service for Putrajaya, Cyberjaya, Bangi and Kajang [24]	Proposal Stage		N/A	N/A
8	Putrajaya Corporation (PjC)	Monorail Project in Putrajaya [25]	Proposal Stage		N/A	N/A
9	Penang State Government	Penang LRT Project [26]	Proposal Stage		8 Billion	1.2 Billion
10	Sarawak Metro	Sarawak's ART Public Transport System [27]		/	5 Billion	0.75 Billion
		Kota Samarahan to Sungai Baru - Line 1 [27] Serian to Senari - Line 2 [27] City Dispersal Line - Line 3[27]		/ / /	10.8 Billion	1.62 Billion

* Note: Important assumption - estimation acquisition cost is based on 15% cost spending ([28] - [30])

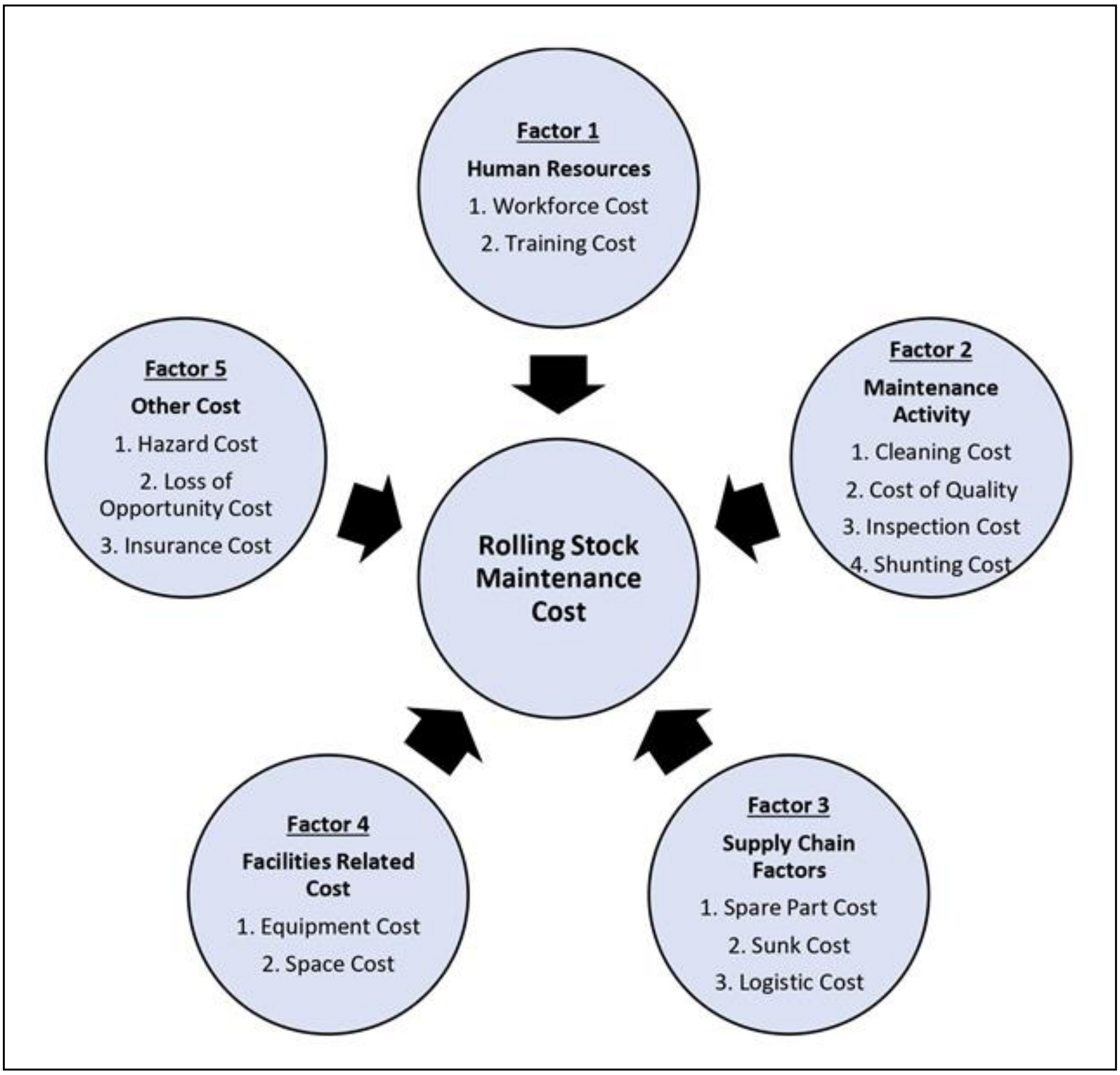

Fig. 2 - Five group of predictor factors and fourteen influential variables

2.1.1 Human Resource

Based on the study by Brage-Ardao, et al. [31], the conclusion drawn was that the TOCs typically tend to either hire less workers with higher salaries or hire more workers with lower salary. This aspect can be mutually modulated. However, as metros with very high salary can prefer to use less workforce, while low salary places can hire more people. Hence the final impact on cost management to rolling stock could be balanced between these two approaches. Hence there appears to be strong evidence of economies of scale in per-car rolling stock operations, most likely due to workforce specialization and maintenance routine automation. Raczyński [6] found that workforce will depend on the region where the maintenance work is conducted. In addition, Fourie and Tendayi [32] highlighted that it is necessary to maintain high availability of the fleet and retains cost-effective measures on the workforce and spare parts.

According to Asekun [33], workforce, equipment, and material are the three key resources required for maintenance execution. These tools vary in their beneficial effects and are treated differently. Workforce has proven to be the most vulnerable resource, making it incredibly difficult to manage. Maintenance management does not require the direct workforce costs of personnel, but it can be used to plan, i.e., how, when and where maintenance work is to be done and ultimately has an impact on the task assigned. However, to meet the workforce requirement by hiring additional employee, TOC cannot simply reduce the salary of the current workforce or underpay new employee due to the need to satisfy current job market salary scheme. Generally, workforce members with several years of experience are often paid more than the market wage. Therefore, the TOC may have to decide its workforce cost in response to its workforce requirements and productivity in the short-run [34].

Anupriya, et al. [34] stated that one of the most significant costs after workforce is trainings that need to be provided. Authors emphasized that most members of the workforce are required to undergo training to increase their skills and competency. The trainings provided also help to increase workforce knowledge on the tasks given and to elevate the workforce level of thinking in solving any upcoming issues. Sarkar and Shastri [35] discovered, trainings costs are not limited only to maintenance workforce, but also cover the train crews and administrative employees at stations, offices, operation control centre and the trainers at the training centre. Therefore, huge cost needs to be considered by TOC with respect to training cost.

2.1.2 Maintenance Activity

Research by Brage-Ardao, et al. [31] discovered that rolling stock maintenance cost is inclusive of all vehicle cleaning activities, comprised of regular and in-depth cleaning activities. The trains stored at depot or train returning from service require cleaning. The cleaning involves exterior water wash and interior cleaning by sweeping and vacuuming [36]. In addition, cost of quality is also significant for a railway planner. The planner must provide a high-quality schedule to lower down the operating cost [37]. The trains' down time should be minimised through appropriate agreed maintenance policy and schedule, such that the operating time could be maximised. Brage-Ardao, et al. [31] also found routine inspection such as checking key parts, to evaluate the parts' condition must be considered in maintenance cost. It was also discovered by Palo [38], that the process of degradation can be inspected and tracked to identify the faults before they change into defects.

The typical corrective maintenance cost comes from maintenance actions resulting from inspection and review of corrective maintenance activity [39]. Szkoda, et al. [40] identified that the performance of inspection activity in the rolling stock maintenance correlates with the arrival of rolling stock by shunting activity. A higher number of locomotives were used for shunting operations such as to replace the vehicle not in operation (i.e. storage mode) or for vehicle movement during maintenance activity. This finding is supported by Tönissen and Arts [41], that the shunting cost might be a result of the need to change the train during operation due to some reason, such as train failure or system breakdown and activities related to maintenance of rolling stock. However, the interchange is possible, and is dependent on rolling stock maintenance schedule and shunting infrastructure. Mira, et al. [42] agreed to minimise the shunting while fulfilling the maintenance action. It is significant to minimise those shunting activities because it is expensive to the TOC. The shunting activity also falls under operation within control, especially activities that involve train maintenance and operation schedule.

2.1.3 Supply Chain

Rolling stock supply chain is not limited only to procurement process but covers the whole ordering, procuring, inspecting, registering, and storing the require spare part. Thus, for example procurement of spare parts can be considered as an important supply chain process to fulfil operational needs. As mentioned earlier, Asekun [33] listed workforce, equipment, and spare parts as three key resources required for maintenance execution. As highlighted by Butler [43], due to the demand to reduce cost of spare parts, British Railway has reviewed procurement process and method of distribution of spare parts. The review is a result of the establishment of TOC material management to manage supply of rolling stock spare parts for each depot through a national store or a centralised method. British Railway has taken advantages of the centralised repair facilities and are able to reduce spare parts holding as compared to having many depots to perform similar activities. The centralised repair facilities are not only limited to a corrective maintenance but also extended to overhauls. Research has shown this centralised method is able to reduce spare parts holding cost.

Referring to the study done by Tendayi and Fourie [44], one of the findings indicate that obsolete parts and redundant parts also lead to high spare parts cost. This could be the consequences of having various types of inventories due to obsolete and redundant spare parts and lag of real time stock monitoring system as illustrated in Figure 3. The research also emphasizes on delivery period of critical components such as long lead time and the aim of having safety margin for unforeseen circumstances. The organization is targeted to have safety stock of +/- 20%. This amount is considered high while many industries are now moving into Just in Time (JIT) approach. Figure 3 also reveals that the source of inventory could be from Original Equipment Manufacturer (OEM), first and second tier material suppliers, and first and second tier of spare parts traders. If organization is able to strategize the procurement process and establish a strategic partnership with those three types of sourcing level, the organization would be able to gain bargaining power of buyers as mentioned under porter's five forces model [45].

The next influential variable is sunk cost, referring to the cost that has already been incurred and cannot be recovered for long run cost. According to Wang and Liao [46], the TOC should consider on the sunk cost because it is common for rail industry to deal with, especially for asset such as rolling stock. In addition, interest payment and depreciation are usually not included in the short run cost.

Another influential variable under the supply chain is the logistic cost. For each spare part or component under inventory or supply-chain management, any purchasing activity is associated with logistic cost. Park, et al. [47] found that, as rolling stock begins purchasing the spare parts, the logistics cost incurred. For example, when procuring imported item such as from the European region, this logistic cost usually needs to be paid by buyer. This is called the Freight on Board (FOB) origin practiced. Usually, most of the international companies do not provide logistic services, and they would like for the buyer to arrange for collection and make any other logistic arrangements needed.

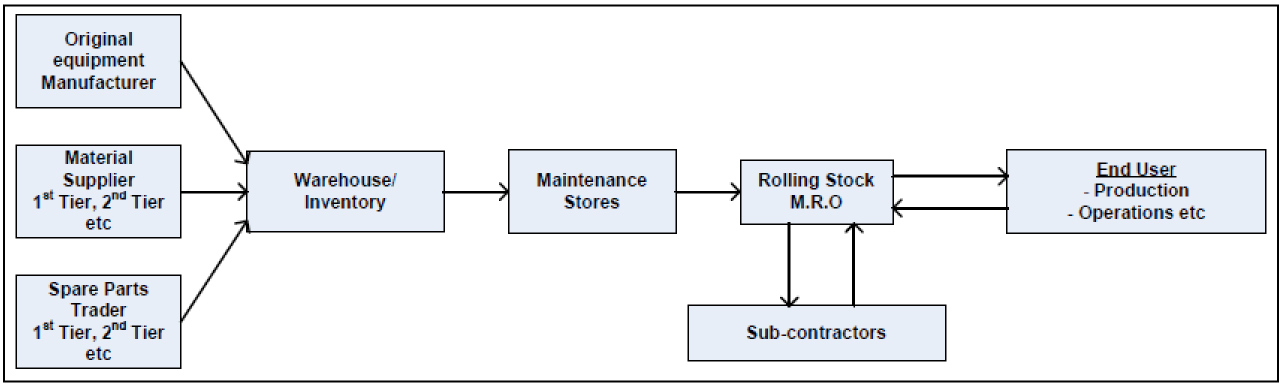

Fig. 3 - Stock holding cost (Source; [44])

2.1.4 Facilities Related Cost

One of the primary influential variables under facilities cost is the cost of equipment. Sarkar and Shastri [35] stated that other than construction cost, operation and maintenance cost, and if adding new rolling stock, replacement cost for replacing the equipment is also important. Many modern depots or workshops will be equipped with major equipment such as wheel profiling facility, train washer plant, and overhead crane [43]. Other important equipment include Bench Test Equipment (BTE), truck wash, lifting table and Portable Test Equipment (PTE). On the other hand, Avenali, et al. [48] stressed that maintenance cost must comprise not only cost of the spare parts and cost of personnel for in house-maintenance but it must also cover cost for depreciation of equipment and cost of maintaining facilities and building used for this in house-maintenance. Another influential variable is spacing cost. Raczyński [6] discovered if the space size of the spare fleet park is not sufficient, especially for maintenance purposes, it will impact the number of spare parts. In addition, the author emphasized that fewer spare parts in the inventory system could lead to higher size of fleet park due to the need for maintenance and unserviceable train storage. The cost to provide those maintenance spaces are huge and future expansion of the maintenance space is time consuming.

To perform rolling stock inspections and maintenance, special facilities are required. The repair team should be facilitated with a properly built building as special facility that is capable of handling the entire fleet either by fleet size, special layout with appropriate equipment and optimum scheduling. Special layout such as underneath a pit is needed for efficient maintenance activity. Access to the underneath of the train is necessary and must be constructed in such a way that is the convenient working conditions with safety as main priority [36]. When the maintenance team has limited space to park and to maintain the vehicle, rolling stock practitioners will have shorter maintenance windows to utilise that space. Consequently, the maintenance supervisor will need to have sufficient workforce and inventory, such as spares to proceed with repair work and for the long run, this will incur high-maintenance costs [37],[49],[50].

The study by Borndörfer, et al. [51] indicates that spacing allocation to perform maintenance involving maintenance pit (infrastructure capacity) is included in constraint for rolling stock practitioner to perform appropriate maintenance activity. According to the research conducted by Zhong, et al. [52] and Giacco, et al. [53], the location of the fleet part also contributes to the maintenance cost. These studies have shown that, TOC with mixed fleets has to find tune strategic location and size of the fleet park within their network.

2.1.5 Other Costs

The first other costs are hazard-related expenses in relation to workplace health and safety. For instance, companies will have expenditure for dealing with hazardous materials such as battery acid, air-conditioning gas and chemical used by the maintenance task. According to ISO 22628 and the European Rail Supply Industry Association (UNIFE) Guideline, companies must be able to manage constituent materials, hazardous materials and minimise the overall environmental effect [54].

Next in the other cost is the opportunity cost, which is related to any contractual issues such as procurement and contract management. When the procurement process is complex and time consuming due to uncertainties and delay in decision making process, the opportunity cost is considered a loss to the owner. For instance, when the terms and conditions of the procurement contracts lack clarity the owner or TOC lose the opportunity to use the rolling stock, especially during project delivery phase. Insurance cost is defined as cost referred to the fee managed by the organization for certain types of insurance to protect its assets, and operation cost normally include insurance cost in its costing [12].

3. Research Methodology

Our research started with identification of issue, problem statement and establishment of the research objective, followed by literature review to identify influential variables for rolling stock maintenance cost. The third process is primary data collection from the five TOCs. The fourth process is analysis of primary data using Importance Index (II) in identifying the rank of influential variables. Finally, discussion on the findings is conducted. The complete process flow is illustrated in Figure 4.

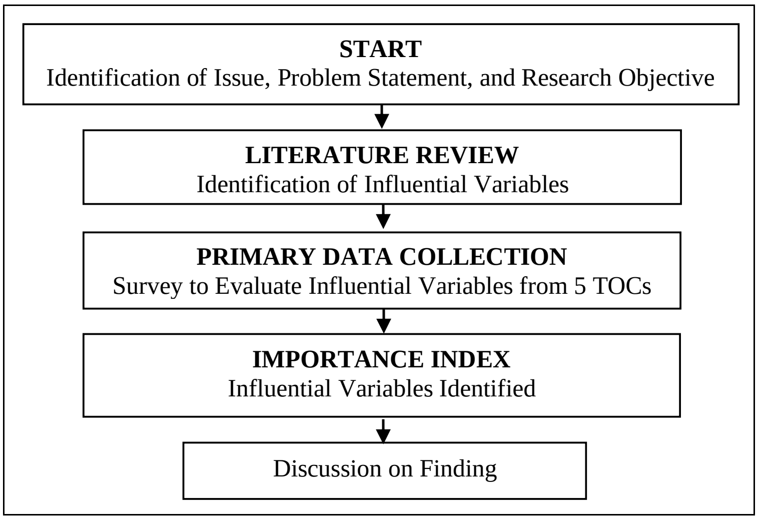

Fig. 4 - Research process flowchart

3.1 Survey

To determine the influential variables associated with rolling stock maintenance cost for Malaysia urban rail, a survey was conducted on July 1st, 2020, where questionnaires were distributed to five TOCs in Malaysia. The questionnaires was adapted from a research carried out by El-Haram and Horner [55] and Ali, et al. [56] who suggested that the five-point Likert scale (5 = a great deal; 4 = quite a lot; 3 = to some degree; 2 = a little and 1 = Not at all) is appropriate to measure respondents' agreement and able to rank the variables using II. The respondents based on judgemental sampling cover five TOCs in Klang Valley. Judgemental sampling is a non-probability sampling technique used when the generalization concerning the population is insignificant, and at the same time the sampling frame is not available or it is difficult to obtain [57]. The respondents were nominated by their organizations representing subject matter expert (SME) of the organization. The respondents consist of managers, engineers and executive at strategic level with experience managing the rolling stock maintenance. In total, 30 completed questionnaires, representing response rate at 100 per cent formed a database for ranking analysis. The respondents were asked to answer 14 questions related to influential costs. As highlighted by Forza [58], for operations research (OR) involving companies or organizations, the research survey cannot be simply answered by any random personnel within the company. The SME within the company must be chose as the respondents as they could provide the specific information needed. The collected data were systematically compiled using Microsoft excel version 2016 to ensure the integrity of survey data and further analysed using Statistical Software Package for Social Science (SPSS) version 26.

3.2 Ranking of The Influential Cost

The influential costs were ranked using an II derived from formula as illustrated in Equation (1).

$$Importance\ Index = \left(\sum_{i=1}^{5} w_i \text{ x } f_{xi}\right) \text{ x } \frac{100}{5n} \qquad (1)$$

where:

w_i = Weight
f_{xi} = Survey Scale
n = Number of respondents

For instance, calculation of II for the spare part cost is shown in Table 2. All influential costs were ranked in a descending order according to the II. In the questionnaire, the respondents were encouraged to suggest another influential factor which they consider as important in relation to rolling stock maintenance cost which was not listed in the questionnaire. Example of calculation of II is illustrated in Equation (2).

$$Importance\ Index = 133 \text{ x } \frac{100}{5 \text{ x } 30} = 88.67 \qquad (2)$$

Table 2 - Importance index for influential variable (spare part cost)

Level of importance	Weight (*w*)	Level of importance (*f*)	Importance Index (*w* x *f*)
A great deal	5	18	90
Quite a lot	4	9	36
To some degree	3	1	3
A little	2	2	4
Not at all	1	0	0
Total		30	133

3.3 Reliability Test

The finding for the Case Processing Summary in SPSS is shown in Table 3 in which the number of respondents was denoted by N and the number of valid data was 30 units. There was no missing data identified. This indicated that all the data have been successfully processed.

Table 3 - Case processing summary

	N	%
Valid	30	100.0
Excluded	0	0.0
Total	30	100.0

The reliability test has found that the Cronbach's alpha value of 0.902 was acquired from the output of reliability statistics as shown in Table 4. Taber [59] stated that Cronbach's alpha values in the range of 0.92–0.93 are considered strong. Therefore, for this survey, the Cronbach's alpha value of 0.920 is considered reliable. As conclusion, the result of the Cronbach’s alpha indicates that the survey was accurately designed and measured the variables of interest.

Table 4 - Reliability test

Cronbach's Alpha	N of Items
0.920	14

4. Result and Discussion

The demographic profile of survey respondents is illustrated in Table 5. As for the job titles breakdown, it can be seen that 47% of the respondents (14 respondents) were rolling stock engineers while 40% of the respondents (12 respondents) were rolling stock executives. Three respondents or 10% of the respondents were rolling stock managers and finally, 3% of the respondents (1 respondent) was an asset-management manager. The demographic profile for job title distribution showed that most of the responders were rolling stock engineers and executives.

Table 5 - Response from survey

Job Title	Number of respondents
Rolling Stock Engineer	14
Rolling Stock Executive	12
Rolling Stock Manager	3
Others	1
Total	30

Ranking analysis was used to identify the most important influential variables for rolling stock maintenance cost as shown in Table 6. The results showed that the spare part cost, workforce cost and equipment cost were the highest influential variables identified by having the II of 88.67, followed by training cost with the II of 84.00. The third rank was cleaning cost with the II of 82.00 while the fourth rank were hazard cost and cost of quality with the II of 81.33. Sunk cost ranked the fifth with the II of 80. The sixth rank were logistic cost and insurance cost with the II of 78.00

whereas the inspection cost and space cost ranked the seventh with the II of 76.67. The eighth rank was shunting cost with the II of 75.33. The loss of opportunity cost was ranked as the least important among the most influential variables for maintenance costs with the II of 74.00.

Table 6 - Ranking of influential variables contributing to rolling stock maintenance cost

Rank	Influential Variable	Operational Definition	Importance Index
1	Spare part Cost	Spare part cost or replacement part, is an interchangeable part that is kept in an inventory and used for the repair or replacement of failed units	88.67
	Workforce cost	Workforce cost is the workforce pool in employment	88.67
	Equipment cost	Equipment costs include all expenses associated with the acquisition of the equipment as well as those needed to ready it for use	86.67
2	Training cost	Training costs include the actual materials created or utilized for training and time spent in each training module inclusive of internal and external classes	84.00
3	Cleaning cost	Cleaning activity cost is to remove unwanted substances, such as dirt, infectious agents, and other impurities	82.00
4	Hazard cost	Hazard costs are related to hazards in relation to occupational safety and health	81.33
	Cost of Quality	Quality cost refers to any activities that prevent poor quality, that appraises the quality of the organisation's products or services, and that result from internal and external failures	81.33
5	Sunk cost	Sunk cost refers to whole-life costing, is the process of estimating how much money was spent by organisation on an asset over the course of its useful life	80.00
6	Logistic cost	Logistic costs are related to the charges for various transportation methods, including train travel, trucks, air travel and ocean transport	78.00
	Insurance cost	Insurance costs refer to the fee associated with certain types of insurance taken by organization to protect it assets	78.00
7	Inspection cost	Inspection cost covers the organized examination or formal evaluation exercise	76.67
	Space cost	Space costs are related to the facility which includes utilities, warehouse staff, storage racks, and materials-handling equipment	76.67
8	Shunting cost	Shunting cost is related to the process of sorting items of rolling stock into complete trains, or the reverse	75.33
9	Loss of Opportunity Cost	Opportunity cost is the benefit that is missed or given up when a stakeholder unable to fulfil the requirements	74.00

The ranking analysis outcome shows that the highest ranked influential variables reflect various factors involved, as depicted in Figure 2. The workforce cost represents human resource factor; spare part cost represents the supply-chain factor while equipment cost represents facilities maintenance factor. The influential variables with the highest II are further discussed. It is important to focus on the prominent influential variables as compared to the rest. The highest rank variables are the spare part cost, workforce cost and equipment cost. The spare part cost proved to be one of the highest rank influential variables that contribute to rolling stock maintenance cost. Spare part cost comes from multiple costs such as inventory cost, storing cost, spacing cost that are especially required for new warehouse system. Other than that, system need to carefully register and monitor spare parts under an inventory system such as Computerised Maintenance Management System (CMMS) is also important as part of the spare part cost. Training for the use of new spare parts and competency must also be taken into consideration. In addition, Gill [60] observed in many industries that the shortage of spare parts could contribute to 50% of the down time. Research also found that spare part cost contributes to more than 50% of industry maintenance cost. Studies have discovered, unnecessary procurement or wrong spare parts may contribute to a significant increase in the spare part holding costs [61]. Based on related data from TOCs, other related spare part costs that could be considered inclusive of lubricant, tyres and tubes, consumable spares, repairable spares, and freight charges.

The workforce cost is also one of the highest ranked influential variables. The human-resource (HR) department should ensure that there is a balance between salary given and quality of the workforce. According to Wirtz, et al. [62], the HR department should deliver a workforce that has the highest quality of service, safe working attitude, reliable and economical. The program to motivate and retain employees is considered a must. The functional manager's duty is to maximise productivity and leverage all of resources that are given. By making use of Maslow's hierarchy of needs [63], employees will retain if necessities like salary, annual leave, and essential medical benefit are fulfilled by the employer. Other related costs with respect to workforce which include allowance for call, laundry, meal, shift, medical, bonus, Employee Provident Fund (EPF), overtime, Social Security Organization (SOCSO), clothing, dental, hospitalization, professional membership, staff welfare, transport claims, mileage, subsistence for oversea and parking allowance can also be considered. These costs have been identified from related data provided by TOCs.

The cost of equipment is the final influential variables with the highest II. The cost of equipment includes the cost of the following items such as tools, instrumentation needed such as insulation tester and bench test equipment that is used to test the sub system such as propulsion control system tester. Other than that, equipment cost also covers portable test equipment (PTE) that is used to diagnose the system's health and help rolling stock engineer and technician to complete tasks. In addition to that, information technology (IT) related items such as laptop, desktop, and telecommunication requirement such as fixed telephone line and internet connection are also considered equipment cost. Equipment cost can also consider repair and overhaul bogie equipment, traction motor's equipment, air-conditioner equipment, brake and pneumatic equipment, train electrical equipment, train electronic equipment, suspension spring and battery.

5. Conclusion

The outcome of this research presents the 14 most influential variables contributing to urban rails' rolling stock maintenance cost in Malaysia. These influential variables have been represented in groups of five important factors. After critical review and data analyses based on II and Ranking Analysis, the research found that 14 influential variables can be partitioned into nine ranks according to II scoring. The most influential variables on the rolling stock maintenance cost are workforce cost, spare part cost and equipment cost (first-ranked). Meanwhile training cost is ranked in second (second-ranked), training cost (third-ranked), hazard cost and cost of quality (fourth-ranked), and sunk cost (fifth-ranked), logistic cost and insurance cost (sixth-ranked), inspection cost and space cost (seventh-ranked), shunting cost (eight-ranked) and the least importance contributing by loss of opportunity cost (ninth-ranked).

This research is the first research done pertaining to rolling stock maintenance cost for Malaysia's railway industry. Future studies on the inclusion of influential costs in the predictive cost model for rolling stock maintenance cost and the analysis on the interrelationship between the influential variables and the rolling stock maintenance cost have been further planned. There is also a need to investigate and analyse the model developed with the secondary data collected from the TOCs. This analysis leads to some useful conclusions; the most important is maintenance practitioner could focus on minimizing rolling stock maintenance cost related to the highest ranked influential variables, outlined as follows.

i. Minimising spare part cost by reducing the slow-moving inventory item. Items with lower limits should be at minimum safety stock while lead time for an item to be received should be taken into consideration. It is also important to ensure and enforce total quality management, especially on the supply-chain effort.
ii. Minimising workforce and training cost by leveraging the workforce knowledge, and capacity such as to be multitasking skill. This includes employing an optimum workforce with acceptable qualification and competency. Upon hired, members of the workforces must be equipped with functional competency from appropriate training programs such as possessing detailed knowledge for the system/asset that they will maintain after.
iii. Minimising cost of an equipment factors by applying effective maintenance management with appropriate maintenance strategy according to rolling stock condition. The selection of equipment should be reflected by the type of maintenance strategy applied.

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