Computerized Maintenance Management System for the Philippine's Railway Transit

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Abstract

Railway transit operations in the Philippines are affected with numerous operational problems such as service interruptions and insufficient train coaches. These result to long queue of passengers in the station, passengers feeling anxious to be late in work and clamor of riding customers to replace the existing maintenance service provider of the railway transit. These scenarios have been regular occurrences specifically in a Metro Manila railway transit that traverses from Quezon City to Pasay City. To reduce the occurrences of these problems, this paper proposes to establish a computerized maintenance management system for the railway transit. To implement this, the researchers assessed the current maintenance system of the railway transit; identified causes affecting its maintenance system; developed an improved maintenance system of the railway transit comprising the maintenance planning, maintenance scheduling, performance measurement and spare parts management, and proposed a computerized maintenance management system for the railway transit. All of these were integrated to come up with a computerized maintenance management system for the railway transit. This computerized maintenance management system can effectively reduce service interruptions and improve the railway transit's service performance.

Keywords
Computerized maintenance management system, responsiveness, railway transit, service interruption, service level

1. Introduction

In recent years, the Philippine government has been pushing to improve the transportation system in the country through various infrastructure project (Dato, 2010). Rail transport in the Philippines is mostly used as to main transport mode of passengers in Metro Manila. Based on the data provided by the Philippine statistics authority on 2010 to 2015, The Metro Manila railway transit has the highest number of passengers which is 174.5 million and has an average daily passengers of 369,838 (PhilippineStatisticsAuthority, 2015).

Service interruption incidents during revenue hours are a common problem encountered by many commuters in riding the railway transit that affects the railway's systems up time. Under the contract with the service maintenance provider and the transit railway's management from January 2016 to February 2017, a total service interruption duration of 76 hours and 15 minutes from trouble shooting until getting the job clearance from the railway transit 's control center was recorded. Service interruptions causes delay of trips, long lines, and inconvenience (Ello, Paed, & De Goma, 2010).

Many studies on railway systems have been conducted in other countries which include railway reliability and its effects, such as the relationship between reliability and productivity in railroad services (Huissaman, 2005), the importance of railway reliability to convince drivers of passenger vehicles to switch to public transport (Erhart & Palmera, 2006), the effect of unreliability on travel time (Marin, 2014), and the effect of reliability on the availability of the service (Cheng & Tsao, 2007). Railway reliability can be measured in different ways, such as the punctuality of the service, cancellations and delays, and the number of realized connections between trains.

(Huissaman, 2005). Optimization models in terms of maximizing reliability and minimizing cost which is a contributing factor of maintenance scheduling (Hsiang, Yang, & Tsao, 2011). Previous studies about the railway transit and other railway systems in the Philippines have focused in the efficiency and service level of the railway operations. Continuous monitoring on the different maintenance procedures (maintenance schedule, performance measurement, maintenance plan, and spare parts availability) should be conducted in order to ensure to avoid into service interruptions (Ello, Paed, & De Goma, 2010).

In the study of Wienker et al (2016) computerized maintenance management system (CMMS) allows effective communication, improve planning and scheduling, and accessibility to existing data and report. These result to cost reduction with respect to maintenance activities. Generally, CMMS includes various applications such as asset management, work order management, preventive maintenance management, inventory control management, and report management (Cato and Mobbley, 2001), (O'Donoghue and Prendergast, 2004), (Zhang, Li, and Huo, 2006). Moreover, in the study of Lopes et al (2016) improvement opportunities are available in using CMMS such as analysis of failures to reduce it occurrence, access to information in real-time, support scheduling function, performance assessment, and track movement of spare parts.

Currently, there are no published studies on the application of computerized maintenance management on the mass railway systems in the Philippines.

The paper provides the country to be globally competitive in terms of developing the technology in the railway system of the Philippines by improving the communication between the railway transit's management and the maintenance service provider. Moreover, it becomes an economic advantage to the government since it could provide a good service for the commuters, minimizing the delays of conducting maintenance activities. This paper supports the environment advocacy in reducing the air pollution, since the convenience for commuters is well provided, less usage of cars is expected and less congestion of traffic is anticipated.

Since the service interruption incidents were subdivided into different parts, this paper covers the maintenance activities of service interruption from trouble shooting until getting the job clearance from the railway transit's control center. The paper focuses on the controllable sections of the railway transit under the maintenance service provider such as rolling stocks, tracks, signals, and overhead catenary cable.

2. Methods

This paper focused on the current maintenance systems of the five controllable sections of the railway transit handled by the maintenance service provider consisting of the rolling stocks, tracks, signals, and overhead catenary cable sections.

Data on service interruptions (January 2016 to February 2017), train specifications, daily ridership, maintenance forms and checklists, preventive maintenance schedule (actual and planned maintenance schedule), overview of the current maintenance system were gathered from the maintenance service provider. These data were analyzed to assess the performance of the maintenance activities undertaken on the railway transit.

Furthermore, an evaluation of the non-repairable component parts was undertaken using the failure rate, mean time to failure (MTTF), reliability, and probability of failure. On the other hand, the repairable component parts were evaluated using the mean time before failure (MTBF), mean time to repair (MTTR), and availability.

A service quality survey was used to identify the gaps between the expectation and perception of the current maintenance system of the railway transit. Two sets of questionnaires were provided, expectation and perception. The expectation questionnaire covered ideal maintenance practices on the railway transit system. On the other hand, the perception questionnaire comprised of actual experiences encountered on the maintenance activities. The respondents for this survey were 24 administration and 122 depot staff for the four sections of the railway transit

The why-why analysis was used to identify the root causes of the service interruptions and countermeasures were determined. The how-how analysis further extracted each corresponding countermeasure to come up with a proposed solution. Furthermore, the house of quality was used to determine the customer's requirements for the proposed computerized maintenance management system.

From the results of the proposed courses of actions and the requirements in generating computerized maintenance management system, the researchers were able to develop the following components: maintenance planning, maintenance scheduling, performance measurement and spare parts management. The components were the basis of the proposed maintenance management system for the railway transit which is integrated in the Computerized Maintenance Management System (CMMS). Furthermore, the systems design of the proposed CMMS was modeled as basis for the software development in order to create the desired output. Lastly, the documentation of the proposed systems and procedures of the computerized maintenance management system were established to monitor future problems that may be encountered in the implementation of the proposed CMMS of the railway transit.

3. Results

Metro Manila's railway transit has currently 66 cars in service with an average daily passengers of 369,838. The service interruptions are the most frequent problems encountered in riding the railway transit by many commuters. Service interruptions cause delay of trips, long lines, and inconvenience to passengers. A total of 61 service interruptions were experienced by the railway transit from January 2016 to February 2017. Table 1 presents the total duration of and average monthly service interruptions in the railway transit for the past fourteen months.

Table 1. Average Monthly Service Interruptions (in hours)
January 2016 to February 2017

Source of Interruptions	Total Service Interruptions	Average Monthly Service Interruptions	Percentage
Rolling Stock Section	46.82	3.34	61.40%
Tracks Section	10.53	0.75	13.79%
Signal Section	7.28	0.52	9.56%
Power Section	9.62	0.69	12.68%
Overhead Catenary Cable Section	2.00	0.14	2.57%
Total	76.25	5.44	100.00%

Considering the processes involved in servicing these interruptions, Table 2 shows the average response time once a service interruption has occurred. Response time is referred to as the total time spent by the railway transit and the maintenance service provider in checking possible causes of service interruptions, preparing of documents for the conduct of repair, and mobilizing resources such as manpower and material requirements before the actual repair is conducted.

Table 2. Average Response Time (in minutes) Per Service Interruption Prior to Actual Repair

Section	Response Time (in minutes)	Frequency of Service Interruptions	Average Response Time (in minutes)
Rolling Stock	402	33	12.18
Tracks	333	12	27.75
Signal	137	10	13.70
Power	266	3	88.67
Overhead Catenary Cable	41	3	13.67
Average	1179	61	19.33

Furthermore, during the actual repair, the service maintenance provider decides whether to replace or repair the parts. Table 3 shows the actions undertaken by the service maintenance provider for the 61 service interruptions.

Table 3. Actions Taken During Service Interruptions by the Service Maintenance Provider

Action Taken	Frequency	Percentage
Replacement of Parts	17	27.87%
Repair of Parts	44	71.13%
Total	61	100.00%

To determine the reliability and maintainability of the train parts, the failure rate, meant time to failure, reliability, and probability of failure of sampled replaced parts were analyzed for the rolling stock, tracks, and signal sections as presented in Table 4.

Table 4. Failure Rate, MTTF, Reliability, and Probability of Failure on Sampled Replaced Parts

Category	Car Number/ Specifications	Components Replaced	Failure rate per hour (18 hours per day(	MTTF (days)	Value of Reliability	Probability of Failure
Rolling Stock	19	Battery	0.007	135.0	0.105	0.895
	20	Drive Circuit	0.028	36.0	0.154	0.846
	26	Auxiliary inverter	0.003	297.0	0.105	0.895
	40	Battery	0.014	72.0	0.105	0.895
	69	Rear Static Converter	0.005	198.0	0.105	0.895
Tracks	East rail	C clamp and fish plate	0.003	315.0	0.105	0.895
	Track circuit 41	C clamp and fish plate	0.007	135.0	0.105	0.895
Signal	Point 19A	Detector pin	0.008	126.0	0.154	0.846

On the other hand, the mean time before failure and mean time to repair of repaired rolling stock cars were also determined as shown in Table 5.

Table 5. Average MTBF and MTTR of Repaired Rolling Stock Cars

Description	Number of Days
Average total up time (days)	29.98
Average Mean Tine Before Failure (MTBF) (days)	17.39
Average Mean Time to Repair (minutes)	29.12
Average Availability (%)	36%

In order to determine the quality of service provided by the railway transit and the service maintenance provider, a service quality survey was administered and the results indicated critical issues in connection with their service performance. Table 6 shows the details on the results of the service quality survey.

Table 6. Summary of service quality survey score results

Respondents	Section	Servqual Dimensions				
		Tangibles	Reliability	Responsiveness	Assurance	Empathy
Railway Transit	Rolling Stock	-1.80	-1.85	-1.82	-1.42	-1.78
	Tracks	-1.62	-1.65	-1.60	-1.56	-1.60
	Signal	-1.94	-2.01	-1.83	-1.45	-1.98
	Overhead Catenary	-1.43	-1.58	-1.26	-1.20	-1.55
	Average	-1.70	-1.77	-1.63	-1.41	-1.72
Commuters		-0.51	-0.59	-0.51	-0.52	-0.59

Using the why-why analysis, it was found out that the root causes identified were as follows: a) all records are in the logbook and do not contain the remaining number of available spare parts; b) no upgrade on the communication system and; and c) disorganized compilation of manual maintenance records. Furthermore,

For each root cause identified in the why-why analysis, a corresponding counter measures were proposed as shown in Table 7.

Table 7. Proposed countermeasures to address the identified root causes

Causes	Countermeasures
1) Disorganized compilation of Manual maintenance records	Upgrade the system in compiling all maintenance records
2) All records are in the logbook and do not contain the remaining number of available spare parts	Spare part management
3) No upgrade in the current communication system	Upgrade the communication system

Based on the results of the house of quality, the identified customer requirements are convenience, easy access, monitoring of cars, scheduling of the cars, spare parts management, easy communication system and early responsiveness.

The maintenance schedule was developed using the computed MTBF and MTTR in order to determine the appropriate number of days to conduct the maintenance for each spare parts. However, for the preventive maintenance, the researchers used the proposed interval schedule of Shinkansen Inspection System (Saxton, 2014).

Table 8 presents the proposed spare parts repair/replacement of critical components based on the estimated cost of repair and cost of replacement.

Table 8. Proposed spare parts repair/replacement of critical components

Section	Critical Component Parts	Probability of Failure	Decision (Replace or Repair)
Rolling Stock	Static Converter	0.98168	Replace
	Line Contactor	0.63212	Repair
	Wheel Set	0.63212	Repair
	Auxiliary Inverter	0.95021	Replace
	Chopper	0.99326	Replace
	Brake Registors	0.86466	Replace
	Regulator	0.99326	Replace
	Brake Actuators	0.99326	Replace
Tracks	Track Circuit	0.95021	Replace
	Rail Expansion Joint	0.86466	Replace
	Fish Plate	0.63212	Repair
	Anchor Insert	0.98168	Replace
	E-Clip	0.98168	Replace
	Check Rail Bolt	0.95021	Replace
	Crossing Bolt	0.63212	Repair
	C Clamp	0.95021	Replace
Signal	Signal Light	0.99326	Replace
	Detector Pin	0.86466	Replace
Overhead Catenary	Disconnector Switch	0.95021	Replace

After consolidating the results and identifying the requirements of a computerized maintenance management system (CMMS), six corresponding modules for the system were developed: dashboard, workflow, spare parts management, scheduling, monitoring, and add user. Below are the schematic presentations of the interfaces of the proposed CMMS.

Figure 1 shows the login where the user encodes his username and password. The dashboard module is presented in Figure 2 where the components of the CMMS are indicated.

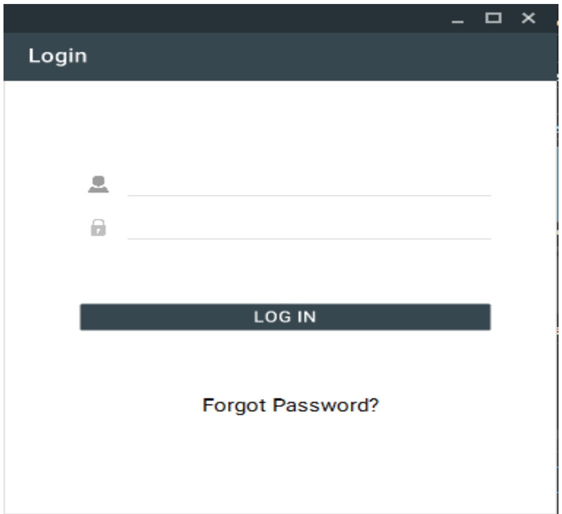


Figure 1. Login Menu

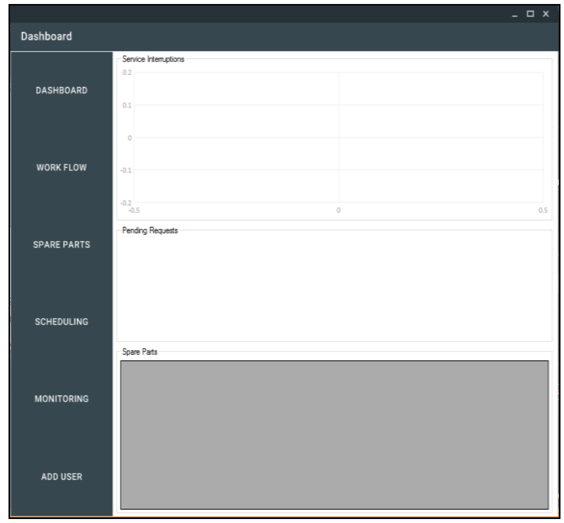
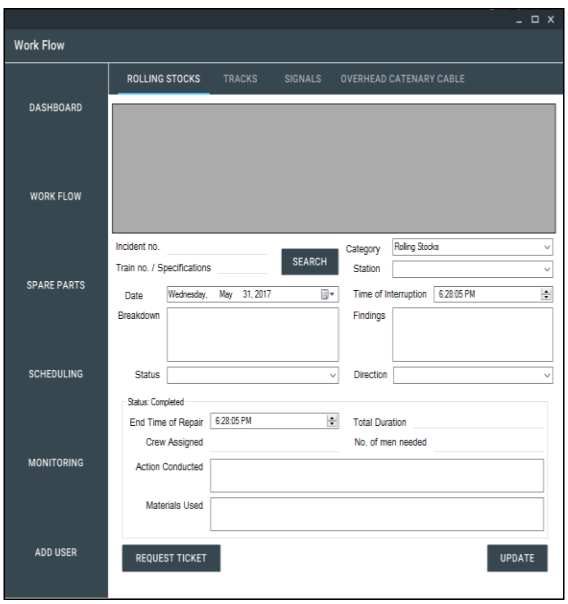


Figure 2. Dashboard Module

The workflow module shows the different maintenance activities of the rolling stock, tracks, signals, and overhead catenary cable as presented in Figure 3. Moreover, the workflow module includes the ticket request submodule as shown in Figure 4.



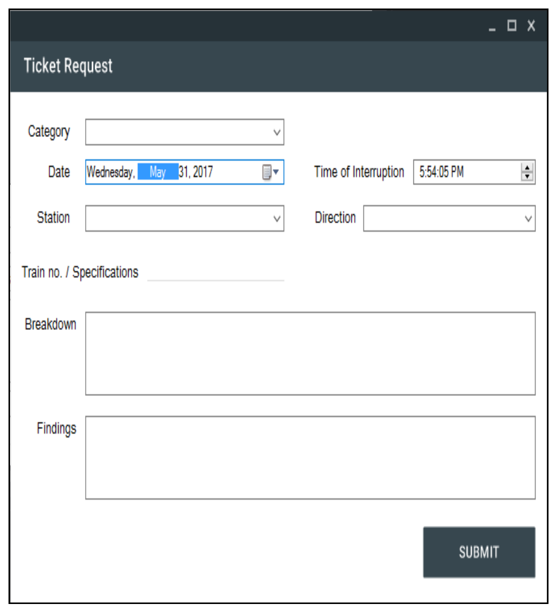


Figure 3. Workflow Module

Figure 4. Ticket Request Sub-Module

The spare parts management module, on the other hand, shows the availability of materials needed in the maintenance activities as shown in Figure 5 and the purchase order sub-module as presented in Figure 6 indicates the need to replenish the parts if needed.

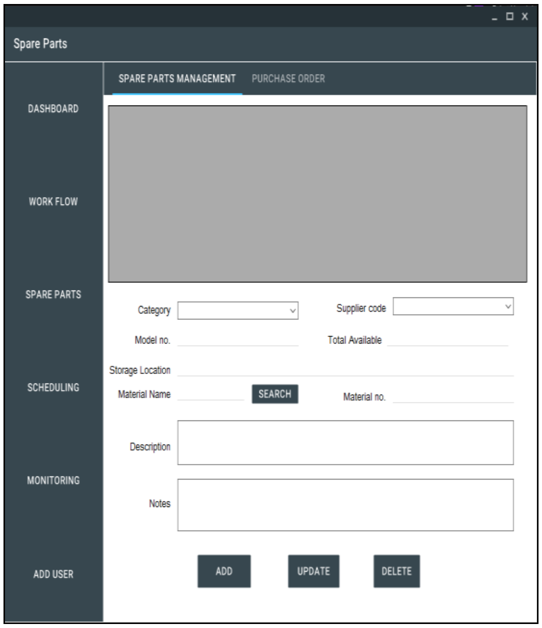


Figure 5. Spare Parts Management Module

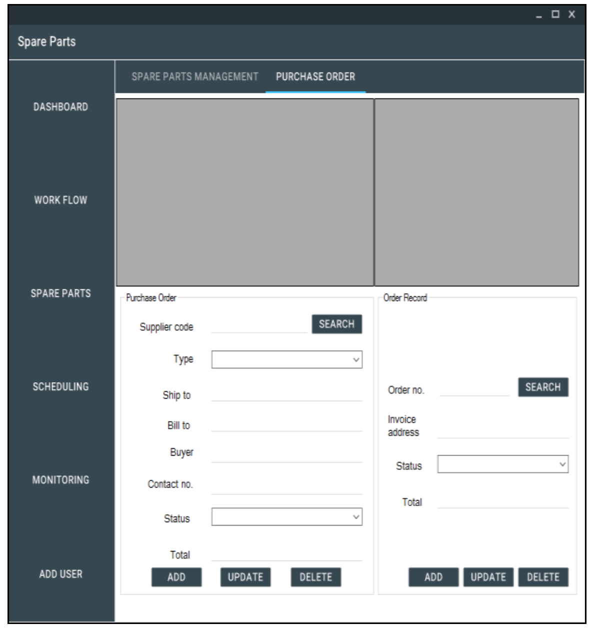


Figure 6. Spare Parts Purchase Order Sub-Module

The scheduling module is shown in Figure 7. The preventive maintenance schedule of train cars and its critical parts is recorded in this scheduling module. A monitoring module is also presented in Figure 8. This determines whether the train cars and critical parts have already underwent preventive maintenance based on the color-coded scheme.

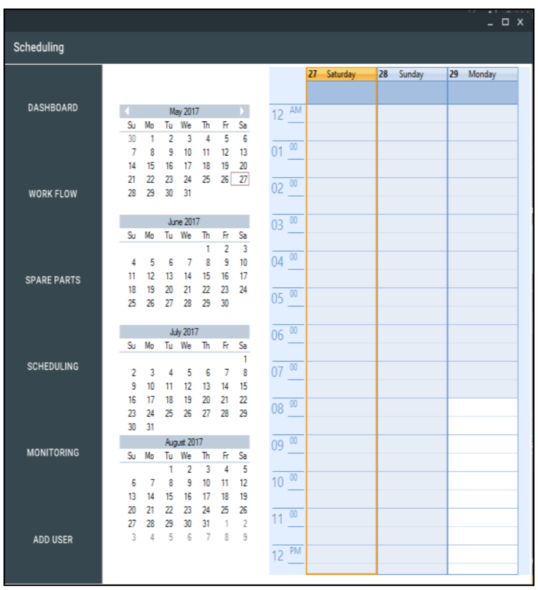


Figure 7. Scheduling Module

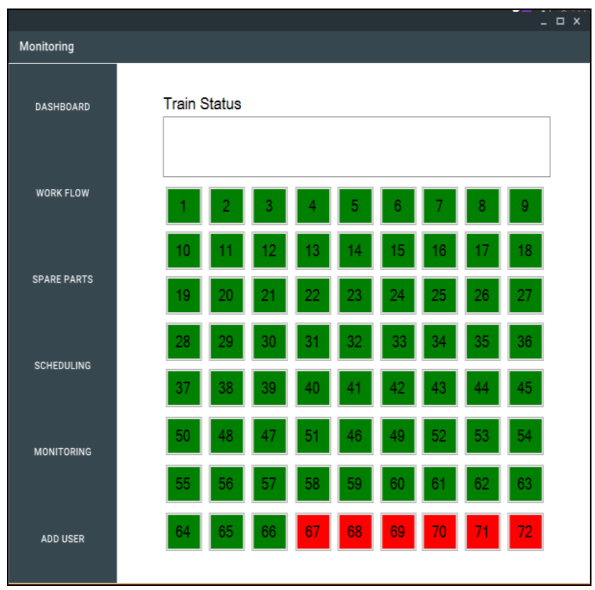


Figure 8. Monitoring Module

Lastly, the Add/User module, as presented in Figure 9, allows the user to be added by the administrator of the CMMS and can be able to login to use this application.

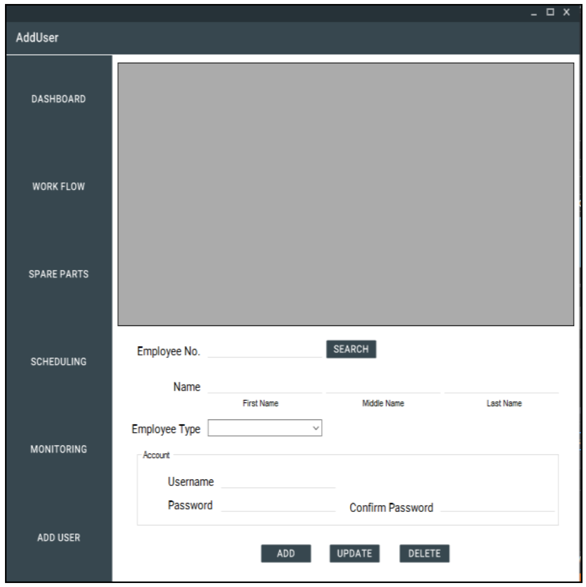


Figure 9. Add/User Module

4. Discussion

The service interruptions experienced by the railway transit was 76.25 hours from January 2016 to February 2017 or an average monthly service interruptions of 5.44 hours as shown in Table 1. Majority of the service interruptions occurred in the rolling stock section comprising 61.40% of the total service interruptions while the least interruption was in the overhead catenary cable section comprising of 2.57%.

Once a service interruption occurred, the train driver calls the duty personnel of the station to check the type of breakdown that occurred. Once the technician has identified the type of glitch, he immediately informs the control center and report the service interruptions. Duty personnel proceeds to the station control room and gets a clearance from the control center through phone call. Once the control center releases the clearance, the duty personnel goes to the location of the service interruption and conducts trouble shooting. After conducting necessary corrective actions, a clearance is given to the duty personnel by the control center. Low speed test is conducted to test the train's condition after repair. The repaired car is immediately turned over to the yard master who decides whether to return the car to the depot or resume for operations. Corrective actions are later recorded in the station logbook and trouble call report. The maintenance engineer of the section compiles all the maintenance checklist and reports and submit the summarized accomplishment reports to the Technical planning and Quality assurance department. The technical planning and Quality assurance section head compiles all the maintenance records.

Service interruptions are usually acted upon by the personnel of the railway transit and the service maintenance provider. The average response time (in minutes) per service interruption prior to actual repair is shown in Table 2. The power section entails the longest response time with an average response time of 88.67 minutes followed by the tracks with a response time of 27.75 minutes. The shortest response time occurs in the rolling stock with a time of 12.18 minutes. The average response time per service interruptions lasted for approximately 19.33 minutes.

During service interruptions, it was found out that the service maintenance provider usually repair the parts 71.13% of the time while total replacement of parts was observed to be 27.87% of the time as presented in Table 3.

An analysis of the train car component parts that were replaced indicated that their probability of failure showed a high percentage ranging from 84.6% to 89.5% as presented in Table 4. On the other hand, the component parts that have been repaired particularly for rolling stock cars, the average up time was approximately 30 days and the average mean time before failure was 17.39 days. This means that the parts are easily broken in just a little more two weeks (17.39 days). Moreover, the average mean time to repair was 29.13 days. Because of this, the average availability of the repaired rolling stock cars was only 36%. This signifies that almost 64% of the time the parts are broken down. Table 5 shows the details.

Since the service interruptions of the railway transit become a regular event, a survey was conducted to assess the quality service provided by the railway transit and the service maintenance provider. The results are shown in Table 6. The results indicated that the majority of the service quality dimensions are critical to the users of the railway transit. Reliability dimension showed the most critical both among the respondents of the railway transit and commuters. This means that this aspect of service quality dimension is not given importance by management of the railway transit or by the service maintenance provider.

In the why-why analysis, the main cause was the delay in preparing the needed spare parts and equipment for repair, information delay during service interruption and delay in preparing job order. The delay in preparing the needed spare parts for repair was due to unavailability of parts in the station because these items were not replenished on time. Furthermore, this results the inadequacy of monitoring availability of supply of the spare parts in the station. This is further compounded by the fact that records are only inputted in the logbook. The communication system between the railway transit and service maintenance provider is inadequate because the communication is only through two-way radio or phone call. The delay in preparation of job order was due to the manual recording of service interruption incident reports. Moreover, the compilation of maintenance records was done manually.

The designated counter measures were elaborated through the use of how-how analysis as presented in Table 7. To address these issues, an automated system is to be proposed in order to monitor the maintenance activities so that management is readily informed on issues that may happen on the day-to-day activities.

In software design, the results of the house of quality was used to identify the customer requirements. These requirements are convenience, easy access, monitoring of cars, scheduling of the cars, spare parts management, easy communication system and early responsiveness.

The proposed spare parts repair/replacement decision of critical components was identified as shown in Table 8. Moreover, the economic order quantity of each critical components were also determine to maintain availability of parts at any given time. Also the scheduling of preventive maintenance and corrective measures were also determined. These data are relevant in the development of the proposed computerized maintenance management system (CMMS).

The proposed computerized maintenance management system has six corresponding modules for the system: Dashboard, workflow, spare parts management, scheduling, monitoring, and add user.

All maintenance procedures conducted are automatically stored in the system once the job is done. Spare parts module contains the monitoring of spare parts when re-order point is reached by each component and the purchase order when needed for replenishment of materials. Scheduling includes the proposed schedule using the results of the mean time before failure (MTBF) and mean time to repair (MTTR) for preventive maintenance schedules and applying the Shinkansen Inspection System of Japan. The monitoring module includes the color-coded visualization of cars, green for running cars, red for cars interrupted and yellow for scheduled maintenance system for cars. Add-user module includes the adding of users by the administrator which enable the user to login and use the system. These modules are shown in Figures 1 to 9

The researchers provided a user manual which contains the step-by-step procedures on how to use the CMMS. The manual includes the eleven functions which are: Login, Dashboard, Work Flow: Rolling Stocks, Work Flow: Tracks, Work Flow: Overhead Centenary System, Spare Parts: Spare Parts Management, Spare Parts Purchase Order, Scheduling, Monitoring: Train Status and Add User.

5. Conclusion

This paper presents the current maintenance system of the railway transit in Metro Manila. Based on the tools used to analyze the issues faced by the railway transit and the service maintenance provider, a computerized maintenance management system (CMMS) is proposed. The CMMS provides a more systematic way of a faster resolution of service interruptions that will result to an increased uptime of the train operations. Furthermore, the CMMS is only a part of the improvement opportunities but there is also a need to look into the efficiency of the train system particularly in investing on new technology to improve the services of the railway transit. These plan of actions will result to a higher satisfaction level of customers.

To further enhance the application of the computerized maintenance management system, further study on the applicability of transforming the existing railway transit system to a more high technology based railway transit system should be looked into. Moreover, it is important that a benchmark study on the railway transit systems from other countries should be considered.

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Biography

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