System Performance Condition Curve Estimation Based on Data Analysis of the Taipei Metro System

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Abstract—**The Taipei Metro is still very young compared to the other metropolitan metro systems in the world. The data provided by Taipei Rapid Transit Corporation (TRTC) is analyzed, including: air conditioner, communication system, switcher, platform door, 22kV switchboard, Automated fare collection (AFC) door, Wenhu Line traffic control computer, Transmission system, elevator and escalator. The research objective is to assess the performance based on the one-year-long data from TRTC, to determine the equipment stage of its lifetime, and estimate the asset's remaining life and maintenance condition. Reported analysis of the data shows minute indication of the system current status; further analysis is in progress.**

Keywords-degradation; maintenance; metro; MRT; performance analysis.

I. Introduction

We analyze the maintenance record of the Taipei Mass Rapid Transit (MRT) system, which is a well maintained system renown worldwide for its tidiness, stability and efficiency. If the maintenance data can be analyzed to yield information about how to perfect the performance of the Taipei MRT system, the analysis can provide useful information to improving Taipei MRT, or, more generally, to assess the performance of other systems.

Since the MRT system of Taipei Rapid Transit Corporation (TRTC) is relatively young (began operation on March 28, 1996, a total of 22 years to date [1]), most of the equipment has not yet been replaced; the records of repair and maintenance are detailed and are stored in digital form. Thus, our research goal is to establish a degradation curve based on the maintenance and performance record, and use to assess the Taipei MRT system, and equipment of other metro systems.

The performance and degradation of metropolitan metro systems have been the focus of general public. Various studies have been reported, including technical issues of the MRT. Rail track condition monitoring is an important technical concern of the MRT system [2]. However, it is infeasible to constantly inspect track conditions; an inspection once a month or less is more or less the usual maintenance. Severe track condition degradation that isn't detected early is a potential threat to the railway system. Hence, more attention has been devoted to monitoring track condition via in-service vehicles [3-5]. The general goal of the research and technical modifications is to improve the performance and reliability of a mass rapid transit system.

We also looked into some older subway systems on the Internet. As reported in [6], train R36 serviced from 1964 to 2003, a total of 39 years. R160s were used to replace 45-year-old trains. In another news report about the old trains [7], the oldest trains for New York City Subway were planned to serve for 58 years, and now this type of trains are actually found too old with very high failure rate and not appealing to meet passengers. From the limited reference that we can access, an estimate of the subway train lifetime is estimated to be around 40 to 50 years. For example, some lines of Singapore Mass Rapid Transit (SMRT) have been operating since 1987, 30 years from today. On the other hand, TRTC operated from 1996, which is only 21 years ago. There is a difference of 9 years. The assets' actual wear-out period may lie somewhere between 20 years (the oldest TRTC asset), and 40 years (New York City Subway). All these metropolitan metro systems are different in various aspects, thus, the characteristics of these MRT systems are expected to differ; the predictability and accuracy of the estimation and extrapolation based on TRTC to assess other MRT systems using the TRTC system data is understandably incomplete; with unknown number of variables involved, the accuracy of assessment may be very limited.

Assessment and quantification of the system current status is essential to enhance performance. The degradation curve is commonly employed for estimation of the system current status. Analysis of the reliability is commonly based on failure rate and maintenance records [8]. Based on the status of the system, possible improvement of the maintenance and performance can be assessed. By means of the degradation analysis the research objective is to shed light on enhancing the metro system performance.

To study the maintenance and performance characteristics, various approaches have been reported [9-18], including the popular bathtub curve analysis [19]-[24]. The Bathtub curve is commonly employed for system performance analysis [25]. Analysis based upon the bathtub curve has been extensively applied to various problems; various modifications to improve applicability have been reported [11][26]-[29]. It is suggested that bathtub curve could be interfered by human factor [30]; for example, if the asset retired in its early stage, the curve may not rise up during the wear-out period and may even descend. If properly maintained, the curve may not rise in the wear-out period, similar to the situation in airline industry. However, few MRT systems in reality exhibit degradation behavior similar to the bathtub curve model [31].

The rest of this paper is organized as follows. Section II describes the goal of this research project. Section III describes the research method. Section IV summarizes the data analysis; finally, a summary is presented in Section V, followed by an acknowledgement.

II. Research Goal

We proposed to thoroughly analyze the Taipei MRT data. We have data from Taipei MRT consisting of 11 systems: electric multiple unit (EMU), EMU air conditioner, EMU communication, switcher, platform door, 22kV switchboard, Automated fare collection (AFC) door, Wenhu Line traffic control computer, Transmission system, elevator, and escalator. By analyzing the dataset with various state-of-the-art approaches, such as deep learning, the research objective is to analyze the equipment present status and identify possible tendencies or features that may be indicative of the system performance.

III. Method

Ideally, analysis of the maintenance data would yield a simple bathtub-shaped degradation curve for each equipment. However, the bathtub-shaped degradation curve is a theoretical model; degradation curve of most cases do not follow the same degradation curve, not to mention each equipment may exhibit different characteristics. Furthermore, each equipment in the Taipei metro system consists of various brands and various models that may possess different intrinsic characteristics. Furthermore, since each equipment is maintained by human, the degradation curve is unlikely to be a simple universal bathtub-shaped curve. Thus, it is infeasible to come up with a universal bathtub-shaped degradation curve for each Taipei MRT equipment. Based on the experience we had from the initial attempt to analyze the data, we propose the following steps:

First, based upon the original maintenance records, calculate the duration between: 1) when the equipment was first engaged in operation, and, 2) the failure date. This time interval represents the duration of malfunction-free operation, which is also the time for a malfunction to take place. By analyzing the malfunction-free duration instead of the number of malfunctions each month may yield more realistic relationship.

Second, calculate the failure times per month to acquire the failure rate for each individual equipment. (For the equipment related to EMU, the failure rate is acquired by the failure time divided by the train mileage.)

Third, average each equipment's failure times to get the average failure rate. Use a statistical software to calculate the regression curve, and extrapolate for comparison with other metro system performance data.

Continue these steps to process another set of data accordingly; then compare the regression behavior. Analyze the difference between the two datasets.

IV. Data Analysis

Initial attempt of analysis is performed. We use the failure statistics for monthly failure rate provided by TRTC. The AFC gates statistics is shown in Figure 1; the averaged malfunction rate is calculated and shown in Figure 2. As shown in Figure 1, the equipment consists of mixed brand, model, age; thus, the total number of malfunctions is not representative of individual equipment.

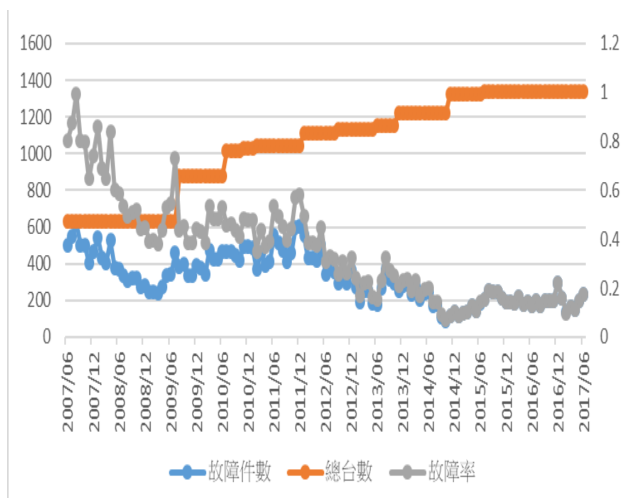

Figure 1. Failure rate of AFC gates vs. time. The failure rate decreases monotonically with time.

Based upon the trend of the data, the failure rate has been declining yearly until it reaches low and stable end tail. Possible factors are speculated, this mostly likely is due to the improvement of MRT maintenance. On the other hand, since the age of each equipment and the number of samples for each equipment are not consistent, the total failure rate is not a fair representation of a specific individual equipment. Thus, we target to analyze the age's effect of the individual equipment as far as possible.

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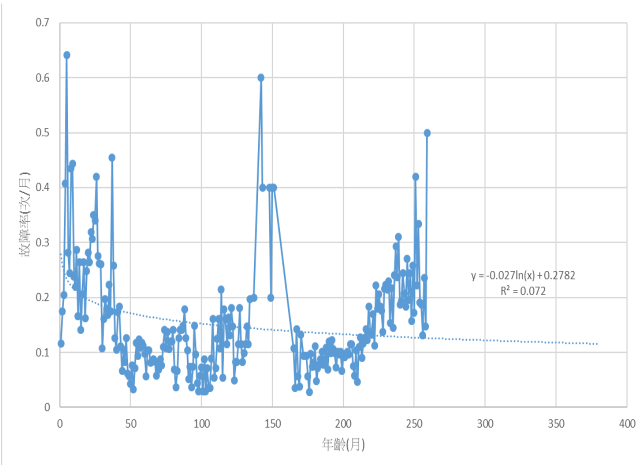

Figure 2. The averaged malfunction rate of the AFC gate *vs*. time.

With sufficient data for escalators and elevators, we try to quantify the failure rate vs. the age for each individual equipment with correlation analysis. On the other hand, for some equipment that seem to have no variation among one another, e.g., EMU, platform door, switcher and 22kV switchboard, we propose to calculate the failure rate vs. failure date. As shown in Figure 2., for the Wenhu line Central control computers, AFC gates and Transmission system, due to lack of sufficient data, the failure rate vs. failure date is analyzed. The malfunction rate decreases then later increases, exhibiting behavior similar to a bathtub curve. The spikes at the center is likely due to lack of sufficient data points to reveal detail trend.

V. CONCLUSION

The data provided by TRTC contains no more than malfunctions each month; furthermore, there is no severity information of the malfunction event. For a complex system, such as MRT, which involves enormous number of factors including human, there are all kinds of characteristics exhibited by the system in complex ways. Thus, it is infeasible to determine the system status with just a single variable. Nevertheless, undoubtedly a rich amount of information is contained in the maintenance data. We believe the data contains rich information and can be further harnessed, possibly with big data analysis, to yield more information that may be essential to enhance the MRT performance.

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