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ScienceDirect

Procedia Engineering 164 (2016) 127 – 134

Procedia Engineering

www.elsevier.com/locate/procedia

Creative Construction Conference 2016, CCC 2016, 25-28 June 2016

Maintenance Strategy of Multi-Equipment Network Systems Based on Topology Vulnerability Analysis

Lieyun DING, Qi FANG*, Chengqian LI

School of Civil Engineering & Mechanics, Huazhong University of Science and Technology, Wuhan, P.R. China

Abstract

A great variety of mechanical and electrical equipment are distributed along the whole metro line. Equipment maintenance plays a very important role for metro operation safety. But how to ensure the scientificity and rationality of the maintenance plan remains a problem. Maintenance plan is theoretically supported by existing maintenance strategies. This paper proposes a new maintenance strategy which focuses on multi-equipment network systems based on topology vulnerability analysis. BIM is used as an object-oriented database to store the topological relations of network devices, express the equipment maintenance plan, and form a maintenance information storage and data analysis platform. Then vulnerability analysis of the topological structure is carried out. According to the results of the vulnerability analysis, the maintenance plan of the equipment with high degree of topology vulnerability could be optimized. A case study shows that the optimal maintenance plan based on the proposed maintenance strategy can improve the system reliability and reduce cost.

Peer-review under responsibility of the organizing committee of the Creative Construction Conference 2016

Keywords: equipment maintenance; BIM; complex network; vulnerability

1. Introduction

With the rapid development of urbanization, metro has been the one of the main tools to solve the urban traffic problems in China now. Shanghai and Beijing metro transportation have entered into the network operation phase. However, the largest number of accident precursors (though not the largest number of injuries) during the metro operation is related to different technical failures [1]. Yeo and Oh [2] found out that the safety performance of equipment can be improved to avoid the safety accidents occurrence according to the statistics of the past years. During

* Corresponding author. Tel.: +86 18771046116; fax: +86 02787557124.
E-mail address: fangqi_hust@hotmail.com

Peer-review under responsibility of the organizing committee of the Creative Construction Conference 2016
doi:10.1016/j.proeng.2016.11.601

the lifetime of metro equipment, degrading will lead to its declining performance. Metro equipment maintenance plays a very important role to protect safety [3].

Adopting scientific and reasonable equipment maintenance strategy can improve the reliability of equipment, reduce operation and maintenance costs. Hastak and Baim [4] analyzed various types of urban infrastructure operation cost, and pointed out that the appropriate maintenance strategy has a great influence on the equipment deterioration degree and maintenance management costs. Some maintenance strategies might offer a cheaper and quicker solution to a problem but might lead to accelerated deterioration and need for higher rehabilitation costs [5]. Farran [6] used the Markov Decision Process Model to calculate the infrastructure maintenance costs change according to various maintenance strategies. Through analysis, it found equipment has more moderate deterioration curve, longer service life and lower life cycle maintenance cost when take scientific and reasonable maintenance strategy.

Maintenance strategy itself does not contain any specific maintenance objects. Maintenance strategy can support to make maintenance plan. Metro equipment maintenance plan is mainly divided into 3 parts: 1. Maintenance and repair list. The included equipment use the preventive maintenance, not listed equipment default to use the corrective maintenance; 2. Maintenance cycle. 3. Repair content. Such as visual inspection and functional testing.

Maintenance plan classify equipment. Different maintenance strategies are adopted for different equipment. A device with a high degree of importance need to use the preventive maintenance in shorter maintenance cycle and has more comprehensive maintenance content. The maintenance strategies for devices with low degree of importance is opposite.

At present, the problem of making equipment maintenance plan is the rationality of maintenance strategy. That is to say, how to distinguish the equipment importance more scientifically, to realize the high reliability and low cost.

Table 1
Different types of maintenance strategies given by the related literature

Strategy Type	Researchers	Optimality Criterion	Optimal Function
Age-dependent PM strategy	Chan and Downs (1978)[7]	Availability and cost rate	Fixed age T
Age-dependent PM strategy	Tahara and Nishida (1975)[8]	Breakdown cost	Fixed age T
Age-dependent PM strategy	Wang and Pham (1999)[9]	Maintenance cost rate and availability	Fixed age T or time
Periodic PM strategy	Liu et al. (1995)[10]	Failure-rate and cost	Periodic time and cost
Periodic PM strategy	Nakagawa (1986)[11]	Cost rate	Periodic time and number of failures
Periodic PM strategy	Chun (1992) [12]	Total cost	Periodic time and cost
Periodic PM strategy	Sheu (1992)[13]	Cost rate	Periodic time
Sequential PM strategy	Nakagawa (1986)[11]	Cost rate	Maintenance intervals
Sequential PM strategy	Nakagawa (1988)[14]	Cost rate	Maintenance intervals
Sequential PM strategy	Kijima and Nakagawa (1992)[15]	Cost rate	Maintenance intervals
Failure limit strategy	Malik (1979)[16]	Reliability	Maintenance intervals
Failure limit strategy	Canfield (1986)[17]	Failure rate and cost rate	Maintenance intervals
Failure limit strategy	Lie and chun (1986)[18]	Failure rate and cost rate	Maintenance intervals
Failure limit strategy	Chan and shaw (1993)[19]	Availability	Maintenance intervals

However, as listed in Table 1, the existing maintenance strategies only consider the performance of a single device. But the metro system can be seen as a network system. With the vulnerability of network structure, the vulnerability of each device in the network of the whole equipment will affect its important degree. Therefore, it is necessary to put forward a new maintenance strategy based on the network vulnerability. Optimizing the equipment maintenance plan with the more scientific classification of equipment importance will