Istanbul Bridge Conference (IBridge 2020)
November 16 – 17
Istanbul

Operation reliability index for maintenance decision making in bridges

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ABSTRACT

Maintenance management developed by several approach to optimize cost recently. Meanwhile decision making during operation is difficult task for mangers to keep them safe as well as stakeholder demands satisfaction and costs with regard to resources limitation. This paper presents an approach for decision making process to select alternatives based on their costs. For this manner, the uncertainty of defect probability combine with other availability and performance features to find priority of maintenance equipment and their reliability. This multi-dimensional decision making do not deal with the essential imprecision of subjective judgment based on quantitative evaluation. To demonstrate the use and capability of the model, a case study is presented. In this case, results shows the quality value combined by delay as an effectiveness parameters (91.08) and then decision tree will complete it by risk and reliability factors.

Keywords: Reliability, Bridge, Maintenance, decision making.

1 INTRODUCTION

Maintenance decision making is an important issue for managing resources with optimization vision. Decision making had been applied in several fields rely on mathematical tools and statistical approach. This maintenance management has been developed In order to find reliability and combine maintenance decision making with an emphasis on their ability to predictive [1]. In this field, big data analysis tools considered for representing their application in decision making [2]. If maintenance work packages considered as a project, these methods are an agile method for keeping infrastructure safe and sustainable [3, 4, and 5]. Data-driven decision-making also applied Building information modelling (BIM) and Geographic Information System (GIS) are integrated to support the acquisition and update of data required for the proposed RCM process [6]. Life-cycle cost analysis (LCCA) is another tools for maintenance planning [7]. Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA) and Bayesian network (BN) is also applied for maintenance management with emphasis on risk and reliability decision tools [9, 10 and 11]. According to a recent classification and risk assessment application, research in this field of area investigates the integration between

Structural Heath Monitoring (SHM) and Reliability Centered Maintenance (RCM). RCM is used for project management as an agile approach.

2 METHODOLOGY

For maintenance management it is necessary to consider three level of decision making layer. The first layer attempt to find the priority of members with regard to their quality level and their repair cost. For this step visual inspection database has been applied. For the next step it is necessary to choose the overall importance state and bridges comparison before the network and their state in the past. For this manner, present research apply Overall Railway Infrastructure Effectiveness (ORIE) to in this step of decision making. The final decision making step rely on maintenance method selection based on decision tree method. Case study

This research focuses on a bridge in Tehran subway which was located in a main line. For this reason, delay and operation time suppose in real case for a period of time. The case study analysis in a period of time which was start in the first month of winter till the end of that month. Some other items such as delay and operation time suppose in this real case based on the next slide table.

Table 1 Proposed item

Proposed item	Quantity	Unite
Delay for defected equipment	30	Min/Month
Delay for unserviceable status	240	Min/Month
Operation time	31500	Min/Month
Scheduled plan	31980	Min/Month
Head	4	Min
Average person in each car	40	Person
Number of Car in each train	8	-
Average ticket price without subsidy	2	$
Operation revenue	5040000	$
Operation revenue with delay	5035200	$
Operation revenue with unserviceable status	5001600	$
Operation revenue with run to fail status	0	$

2.1 Hypothesis

For this research it is necessary to represent the condition during the operation and case analysis. Therefore, the operation time start half pas five till twenty-three at the night. Based on the operation time, the Allocated Up Time (UT - minute per month) has been calculated. During a month there is a delay for maintenance due to unexpected infrastructure failure for half an hour, which has been considered as Down Time due to Infrastructure Failures (DTF). This maintenance activity has been done between 10 Am to 10:30 Am. Scheduled plan for train and other diesel vehicles considering as Scheduled Total Train Operating Time (TTOT) for a month two hours more than UT for round the clock. Delay due to speed reduction was considered six hours in that month based on the recorded events. Every emergency maintenance has been done during the night when the service operation had been stopped.

2.2 Calculation

Overall Railway Infrastructure Effectiveness will calculate the comparison base for second level of maintenance decision making. This index has been calculate the comparison tool based on the infrastructure equipment's availability (A), the infrastructure performance rate (P), and the infrastructure quality rate (Q). Based on bellow formula ORIE of this bridge has been calculated.

$$Q = \frac{Q_{val}}{Q_{lim}} \quad if \quad Q_{val} < Q_{lim}$$
$$Q = 1 \quad if \quad Q_{val} < Q_{lim}$$
Formula (1)

$$P = \frac{TTOT}{TTOT + TDNMR + TDSR}$$
Formula (2)

$$A = \frac{UT - (DTIF + DTOM)}{UT}$$
Formula (3)

$$ORIE = A \times P \times Q$$
Formula (4)

The quality rate (Q) is a function of the measured Q value (Qval) and its deviation from the stated Q limit (Qlim). In OEE and ORIE calculations, the quality rate varies between 0% and 100%. Therefore, the quality rate is not supposed to exceed one in the ORIE calculations as well, although the measured Q value can have a higher value than the stated Q limit if the track section standard is higher than the stated objectives.

For the next parameter (P), It is necessary to calculate the formula (2) based on some index rely on delay and operation times.

- TTOT = Scheduled Total Train Operating Time
- TDNMR = Train Delays due to No Maintenance Required
- TDSR = Train Delays due to Speed Reductions.

The availability (A) related to infrastructure failure which is a function of the allocated uptime (UT) and unplanned downtime due to infrastructure failure (DTIF) and unplanned downtime due to overdue maintenance activities (DTOM)

2.3 Results

As you could see in follow table, Beam, drainage and abutments are the highest value in this case based on Quality state and the cost for repairing.

Table 2 Equipment status and their cost repair

No	Item	Members	Defect	Total (number/length)	Qval	Material cost ($)	Repair action cost ($)	Total cost per equipment
1	Railway track	Rail	100	7800	99	45	74.87	119.87
2		Fastening	2	520	100	1	0.83	1.83
3		Guide rail	0	260	100	0	0.10	0.50
4		Travers	9	130	93	70	113.97	183.97
5		Ballast	1350	70200	98	3	547.87	550.87
6		Track subgrade	250	7800	97	0	2,000.00	2,000.00

		Welding and joint	1	260	100	20	66.67	86.67
8	Deck	Expansion joint	0	10	100	10	333.33	343.33
9		Foundation isolation	0	4	100	10	233.33	243.33
10		Barrier	0	7800	100	100	266.67	366.67
11		Beam	2	7	71	70	200.00	270.00
12		Drainage	2	5	60	5	166.67	171.67
13	Pier	Elastomeric bearing support	0	7	100	100	2,666.67	2,766.67
14		Pier cab	0	7	100	4	200.00	204.00
15	Retaining wall	Abutment	1	2	50	0	1,000.00	1,000.00
16	Foundation	Pedestal	0	7	100	0	3,333.33	3,333.33
17		Footing	0	7	100	0	2,333.33	2,333.33
Total Qval	92	Total cost repair	13,976.03					

This table result consider for the first step of maintenance decision making. For the next step it is necessary to calculate the ORIE for this case study. The Overall Railway Infrastructure Effectiveness value has been illustrated in follow table which consider the delay for availability, quality and the members' performance. This item will help decision makers for finding the degradation models and finding the bridge priority to compare other bridges in the rout.

Table 3 ORIE index

Railway bridge	Factor	Unit	Quantity	Factors	Total (ORIE%)
A	UT	(min/month)	31500	1.00	91.08
	DTIF	(min/month)	30		
	DTOM	(min/month)	0		
P	TTOT	(min/month)	31980	0.99	
	TDNMR	(min/month)	0		
	TDSR	(min/month)	360		
Q	Qval	(metre)/(meter)	92	0.92	
	Qlim	(metre)/(meter)	1		

The final decision making step rely on maintenance model determining. It is supposed 4 level or 4 models for maintenance method in this research.

- ✓ Run to fail level

In this level the equipment operate without any interval inspection and any preventive maintenance which is represented the poorest level of maintenance.

- ✓ Unserviceable level

This level representing the lowest level of preventive maintenance with emergency maintenance and several operation disorders and delay.

- ✓ Defected level

This medium level of quality lead to several defect with some seldom operation disorders.

- ✓ Prefect level

This costly maintenance which is prepare a high quality based on combination of condition monitoring for sensitive equipment and interval inspection for important and risky equipment.

This methods in three level of maintenance decision making, will demonstrate the capacity of the usage of this analysis model, for a case study with combination of decision tree and Overall Railway Infrastructure Effectiveness.

Based on the calculation, expected revenue for each level of maintenance with regard to delay calculated based on bellow table.

Table 4 Expected revenue

Item	Amount	Unit
Operation revenue	5040000	$
Operation revenue with delay	5035200	$
Operation revenue with unserviceable status	5001600	$
Operation revenue with run to fail status	0	$

Based on follow figure, we have the uncertainty of events which illustrate by percentage in each condition. Bellow the percentage of failure probability, the revenue based on table 4 illustrated and monitoring cost with opposite sign calculate the final value for each condition.

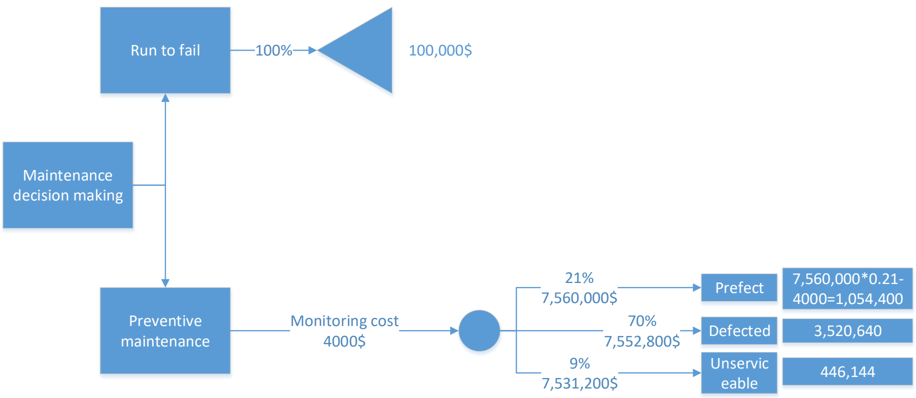

Figure 1: Caption of Example Figure

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Use 10-point Times New Roman font for the references and list them at the end of the paper. Include the following information (as applicable).

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