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OPTIMIZATION OF TIME AND COST OF BUILDING COMPONENT MAINTENANCE: A CASE-STUDY IN A FIVE STAR HOTEL

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Abstract: Building component maintenance management is one of the most important issues in management of building lifecycle costs. Key to successful maintenance management is the ability to survey present condition and predict the future condition for each component and facilities present in a building. The paper presents a process to optimize maintenance cost and time of caste iron pipe component in wastewater plumbing system of hotel building in Iran as a case study using the condition index (CI) method. The research uses a systematic assessment field as followed by the USACERL condition index method. To achieve this objective, cast iron pipe within wastewater plumbing system is surveyed using the economical tools for implementation of optimal maintenance time and cost based on highest saving to investment ratio. The research presents a financial analysis using the existing data. The data was collected through financial and technical sheet. Data is analyzed using the economical tools and financial analysis is simulated with simulation software. The purpose of this paper is to develop a financial analysis simulation for component maintenance assessment during its service life based on highest interest rate. The analysis results in to identify optimum maintenance time basing on the limited cost. This method helps to facilities managers and engineers to make better decisions for reducing maintenance costs and increasing the component's service life.

Keywords: *Building component maintenance, cost, wastewater network, optimization, time.*

1.0 Introduction

Recent requirements in component maintenance management of building have focused on the requirement for improving methods and metric tools to support component condition assessment and appropriate measurement for component condition. Although engineers and researchers have focused on developing methodologies for component assessment in recent years, there is not enough attention dedicated to facilities and components that have been constructed (Ahluwalia, 2008). Component condition assessment by condition index (CI) is the most important work in the component maintenance process as this method is the base or the first step for other tasks such as the decisions regarding timing and cost of building components maintenance (repair, replacement, renewal, restoration and other) (Amani *et al*., 2012a & 2012b). On the other hand, the most important issue to successful component maintenance activities is a suitable cost allocated to a project. One of the reasons for change in component maintenance management and planning is due to limited allocation of cost (Boyle, 2003). Furthermore, lack of suitable cost allocation in a maintenance work could affect the maintenance implementation (Tilley and McFallen, 2000). Systematic prediction by condition assessment method offers help to researchers in understanding the cost decision making in the best time for building component maintenance. Condition index (CI) presents a method for measuring rates of deterioration and prediction of condition for each component or facilities. The purpose of this paper is to manage maintenance time and cost of the cast iron pipe in wastewater network of five star hotels in Iran.

2.0 Condition Index Method

The USACERL condition indexes were designed to support a purpose and quantitative means for component condition assessment while supplying a common language and explanation among users (assessor, engineer, and inspector). The scale that is used in all of the USACERL indices ranges from 0 to 100 and is divided into seven condition categories (Uzarski, 1993). The seven condition categories that set the arrangement of the index scale also need a guideline with the aim to set the computed repair time for a component concerning the each index definition (condition description for each CI values). Table 1 presents these guidelines (Uzarski, 1991). It is very important that the guideline (condition description) displays the categories. This is because the use of definitions would influence integrated constraints on the formulation and the indices for predicting repair time of component condition over time (Uzarski, 1991).

The condition index is used to historically map the component condition over time (Figure 1) to determine the rates of degradation (Uzarski, 1993). Overtime, condition index (CI) moves from 100 to 0. When engineers install a component or facilities in a building, the condition index is 100 (excellent). Overtime, condition index for that component will reach below 10 value. Basing on the definition of the CI scale, useful component failure happens when the CI falls around 10, which founds a functioning threshold limit for the model. For the unrepaired component lifecycle model, CI=10 when the time in service equals the expected service life. Hence, the profit of repair permits the deference of found rehabilitation required from component failure.

Table 1: USACERL condition index guide

Index	Category	Condition Description
86 - 100	Excellent	Very few defects. Component function is not impaired. No immediate work action is required, but routine or preventive maintenance could be scheduled for accomplishment.
71 - 85	Very Good	Minor deterioration. Component function is not impaired. No immediate work action is required, but routine or preventive maintenance could be scheduled for accomplishment.
56 – 70	Good	Moderate deterioration. Component function may be somewhat impaired. Routine maintenance or minor repair may be required.
41 - 55	Fair	Significant deterioration. Component function is impaired, but not seriously. Routine maintenance or minor repair is required.
26 - 40	Poor	Severe deterioration over a small percentage of the component. Less severe deterioration may be present in other portions of the component. Component function is seriously impaired. Major repair is required.
11 - 25	Very Poor	Critical deterioration has occurred over a large percentage or portion of the component. Less severe deterioration may be present in other portions of the component. Component is barely functional. Major repair or less than total reconstruction is required.
0 - 10	Failed	Extreme deterioration has occurred throughout nearly all or the entire component. Component is no longer functional. Major repair, complete restoration, or total reconstruction is required.

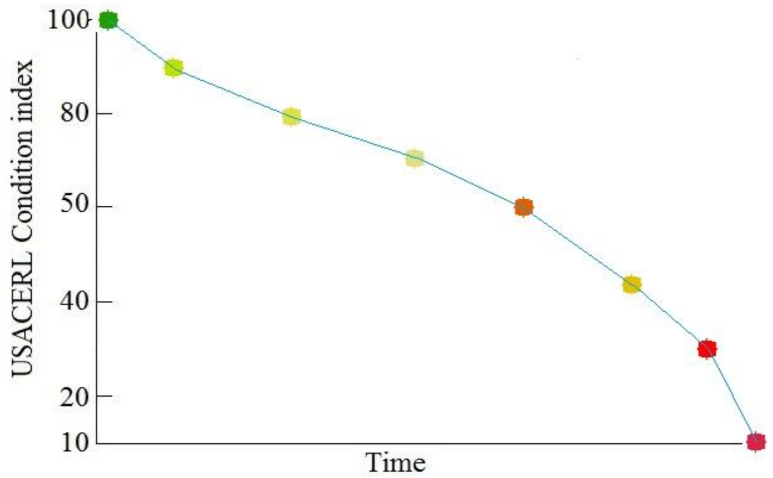

Figure 1: Condition index over time

3.0 The Case-Study

The Laleh International hotel a five star hotel located in the Laleh Park area convenient to business district, spectacular views of mount Damavand and Alborz. This hotel was found in 1946 and is in the centre of the Tehran (Laleh Hotel, 2011). Laleh hotel provides the best access and easy transportation with these services such as banking, handicraft, travel agency, 24 hours communication services. Laleh hotel was built in 13 floors, and consists of 400 single, double, and suit rooms with 16000m2 (Laleh Hotel, 2011). Table 2 depicts the pipe dimension data (length and internal diameter) for Laleh hotel wastewater network (Rashidi, 2011).

Table 2: Pipe dimension data for wastewater network of Laleh Hotel

Diameter (inch)	**2**	**3**	**4**	**5**	**6**
Length (m)	2418	1200	1300	200	350

4.0 The Analysis by Research Case-Study

The first step is gathering sufficient information on technical data related to the maintenance time of cast iron pipe from engineers' and inspectors' experiences over the past years with respect to moving the index from 100 to 10 during service life of component. The rating sessions were carried in small groups and at the normal work locations of the raters. The raters are first given general instructions by the researcher. This instruction is about the method of rating and determination of maintenance time for wastewater plumbing system during its service life. Each rater is then given a copy of the rating guidelines to use as rating cues (USACERL condition description), and a set of component rating sheets, given one at a time. As each rater completed a given sheet, it was collected by the researcher. After a given set of sheets was completed, the researcher reviewed the data during the session. Any rating and assessment of maintenance time that is different more than required standard deviations from the mean were flagged for a re-rate. This was done to allow raters the opportunity to correct certain ratings that may had been marked by mistake because of misunderstanding, distraction, misinterpretation or some other reason (Uzarski, 1993). The individual panel members ratings were averaged to obtain mean maintenance time for wastewater plumbing system. As depicted in Table 3 this data is to achieve the information related to the maintenance time of cast iron pipe from stand point of engineers and inspectors' experiences in past years with respect to the moving the index from 100 to 0 during component's service life.

The rating panel members that contributed to this development are consisted from contractors firms and related consultants on the wastewater piping system. The panel's opinion, indeed, represent a board variety of experiences from commercial piping companies, installations firms, and consulting firms. Their various position titles include directors and assistant directors of maintenance, piping foremen, piping inspectors, planners and estimators, civil engineers, and installations engineers. As a group, the panel has experience regarding hot, cold, temperature, wet, and weather condition of related regions (Uzarski, 1993).

Table 3: Gathering technical data and re-rate based on USACERL

Index	Category	Repair year	Condition Description
85	Very Good	9	Minor deterioration. Component function is not impaired. No immediate work action is required, but routine or preventive maintenance could be scheduled for accomplishment.
70	Good	16.9	Moderate deterioration. Component function may be somewhat impaired. Routine maintenance or minor repair may be required.
55	Fair	26.5	Significant deterioration. Component function is impaired, but not seriously. Routine maintenance or minor repair is required.
40	Poor	36.1	Severe deterioration over a small percentage of the component. Less severe deterioration may be present in other portions of the component. Component function is seriously impaired. Major repair is required.
25	Very Poor	43.9	Critical deterioration has occurred over a large percentage or portion of the component. Less severe deterioration may be present in other portions of the component. Component is barely functional. Major repair or less than total reconstruction is required.
10	Failed	50	Extreme deterioration has occurred throughout nearly all or the entire component. Component is no longer functional. Major repair, complete restoration, or total reconstruction is required.

The next data set required is the financial sheet supplied based on annual budgeting information for maintenance and repair during service life of cast iron pipe in the wastewater network of Laleh hotel by financial managers of hotel. The financial data was collected for annual maintenance cost allocated at various condition index values for the cast iron pipe component in the wastewater plumbing system based on maintenance cost information in past years and the average inflation rate of 6% in Laleh Hotel (FDLH, 2011).

Table 4: Financial data for wastewater network of Laleh Hotel

Year	Annual mainten -ance cost ($)	Year	Annual mainten -ance cost ($)	Year	Annual mainten- ance cost ($)	Year	Annual mainten- ance cost ($)	Year	Annual mainten- ance cost ($)
2011	-	**2021**	20500	**2031**	36800	**2041**	66000	**2051**	118200
2012	-	**2022**	21800	**2032**	39000	**2042**	70000	**2052**	125300
2013	-	**2023**	23100	**2033**	41400	**2043**	74200	**2053**	132900
2014	-	**2024**	24500	**2034**	43900	**2044**	78600	**2054**	140800
2015	-	**2025**	26000	**2035**	46500	**2045**	83300	**2055**	149300
2016	-	**2026**	27500	**2036**	49300	**2046**	88300	**2056**	158200
2017	-	**2027**	29200	**2037**	52300	**2047**	93600	**2057**	167700
2018	17200	**2028**	30900	**2038**	55400	**2048**	99300	**2058**	177800
2019	18300	**2029**	32800	**2039**	58700	**2049**	105200	**2059**	188500
2020	19400	**2030**	34700	**2040**	62300	**2050**	111500	**2060**	199800

Financial sheet was designed basing on the data collection method covering annual cost information for maintenance of wastewater piping system in Laleh hotel. Financial managers fill financial information from 2011 to 2060. Financial information is selected basing on period of 50 years that corresponds to the useful lifespan of cast iron pipe which is approximately 50 years (Lose Angeles HOA Management 1993). The information collected are stored in the saving sector for calculating the saving and investment ratio (SIR) for the condition index (100 to 10).

Simulating economic analysis is carried out basing on the saving to investment ratio (SIR) for maintenance at various condition index values for the cast iron pipe component in the wastewater plumbing of Laleh hotel. By using the simulation software the building managers are able to model and analyze the information without even knowing the complex mathematical models. Data required is collected through technical and financial information that is distributed among engineers, inspectors, and financial managers. Maintenance year is calculated from the technical data and saving is calculated from the financial data gathered. After data collection was completed, repair cost is computed. From these CI values, a parametric model of material repair cost, which is a comprehensive estimation of the corrective repair cost, is described as a percentage of the total replacement cost (Vafai *et al.*, 2007; Means, 2008). A unit repair cost is calculated based on the annual repair is presented by the following Eq. (1):

$$Cr = Cp \times (Index\ a / Index\ b) \qquad (1)$$

Where Cr = repair cost in year i, Cp = replacement cost in year i, Index a = component condition in year i, Index b = component condition in operating first year. The replacement cost was computed based on dimension of wastewater plumbing system (size and length) of Laleh Hotel, price of cast iron pipe in the market, and average inflation rate. The inflation rate is 8% basing on average inflation rate of cast iron pipe in Iran’s market from 1990 to 2010 (Index Mundi, 2011; Price Index , 2011). In order to estimate the economic value of various component repair or replacement options, a saving to investment ratio (SIR) method is obtained. SIR is a numerical ratio and its size exhibits the economic execution of an investment. The SIR is saving divided by investment costs (Ruegg and Marshall, 1990). This model is selected due to; 1) each option results an individual ratio that shows the economic execution of that task action, 2) options can be used with various time horizons for comparing properly (ASTM 2002). The SIR is illustrated by following Eq. (2):

$$SIR = Saving / Investment \qquad (2)$$

Where saving = total annual maintenance budget until repair time, investment cost = repair cost in the year i. for a repair performance, the investment is the parametric evaluation of repair cost based on the condition index at year i. The saving is calculated based on the budget collected for repairs annually in part of material repair until year i. Table 5 presented the SIR for repair at various condition index values for the cast iron pipe wastewater network of Laleh Hotel.

Table 5: Financial analysis for wastewater network of Laleh hotel

USACERL Index	**Maintenance year**	**Investment estimation($)**	**Saving estimation($)**	**SIR**
85	9	37340	35500	0.95
70	16.9	131990	225000	1.70
55	26.5	431755	608900	1.41
40	36.1	1230407	1279700	1.04
25	43.9	2651853	2187000	0.82
10	50	5475676	3240000	0.59

Where USACERL index: Component condition assessment method, Maintenance year: prediction of maintenance and repair time by technical data, Investment estimation: Pipe repair cost data for wastewater network of Laleh Hotel, Saving estimation: Computation of annual maintenance cost allocated for wastewater network of Laleh Hotel by information of financial data, SIR: Numerical ratio that size indicates the economic performance of an investment. The Figure 2 illustrates an economical simulation with respect the calculations performed in Table 5.

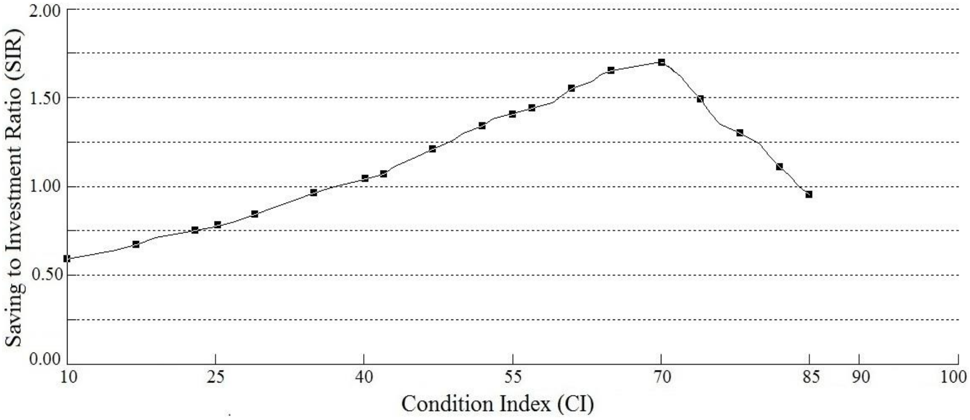

Figure 2: Optimum maintenance time and cost of cast iron pipe based on USACERL CI

5.0 Result and Discussion

Table 5 and Figure 2 depict the analysis of optimum repair management of cast iron pipe in wastewater plumbing system for Laleh Hotel. The graph illustrates that when USACERL index reaches to 70, economical rate is high (SIR 1.70). Thus, the best time of maintenance occurs when USACERL CI is 70 with SIR 1.70. Building manager knows that the best decision for increasing cast iron pipe's service life based on existing maintenance cost is repair after 16 years (CI = 70 and SIR = 1.70). A ratio less than 1.0 indicates an uneconomic action (Ruegg and Marshall, 1990). When the ratio is below 1.0, the economic efficiency of repair is nearly equal the replacement. Thus, if CI< 40, replacement close to the CI terminal value of 10 should be replaced. When CI is less than 40, maintenance time is 36 years based on technical data. Thus, wastewater network of Laleh Hotel should be replaced, no maintenance or repair after 36 years shall be done.

6.0 Conclusions

This study investigated USACERL condition index metric, data collection methods and economic analysis simulation for component correction maintenance in hotel buildings, in this case, cast iron pipe in wastewater network of Laleh hotel in Iran. This paper describes the development of a process for maintenance of building component using the USACERL condition index metrics. The systematic process was shown in a process framework for component maintenance for economical optimization. The presented analysis is a comprehensive research that is capable to optimize the process of building component maintenance. This research can provide a suitable decision about component appropriate maintenance based on existing resources for building owners and facilities managers.

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