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MAINTENANCE AND MANAGEMENT OF WASTEWATER SYSTEM COMPONENTS USING THE CONDITION INDEX SYSTEM, PREDICTION PROCESS AND COSTS ESTIMATION

KONSERWACJA I ZARZĄDZANIE SYSTEMEM KANALIZACJI ŚCIEKOWEJ ZA POMOCĄ SYSTEMU WSKAŹNIKA STANU, PROCESU PRZEWIDYWANIA I SZACOWANIA KOSZTÓW

Component maintenance management of public building is complex and dynamic as the execution of the engineering management system is subjected to sensitive staff and users' requirements and high expectation of the top management for supporting the business. This paper presents the practices and survey need for maintaining the facilities systems in the building. The purpose of this study is maintenance time optimization of building component using the USACERL condition index (CI) system. To achieve this objective, cast iron pipe within wastewater plumbing system is surveyed using the financial analysis for implementation of optimal maintenance time based on limited cost. The findings show how a best time approach to plumbing system maintenance can assist the owner for decision making in component maintenance time based on existing cost.

Keywords: *maintenance management process, component, optimization, cost analysis, case study.*

Zarządzanie konserwacją instalacji budynku publicznego jest złożone i dynamiczne z uwagi na fakt, iż realizacja systemu zarządzania technicznego poddana jest zarówno wymaganiom personelu i użytkowników końcowych jak i oczekiwaniom kierownictwa w zakresie wsparcia rozwoju przedsiębiorstwa. W niniejszym artykule przedstawiono praktykę oraz badania dotyczące potrzeb wiążących się z konserwacją instalacji w budynkach. Celem tego opracowania jest optymalizacja czasu konserwacji tej części budynku za pomocą systemu wskaźnika stanu (condition index - CI) USACERL. Aby osiągnąć ten cel, przeanalizowano za pomocą analizy finansowej system kanalizacji ściekowej oparty na rurach żeliwnych pod kątem przyjęcia optymalnego czasu obsługi w oparciu o ograniczone koszty. Wyniki pokazują jak optymalne podejście czasowe do konserwacji systemu hydraulicznego może pomóc właścicielowi w procesie podejmowania decyzji w aspekcie czasu konserwacji na podstawie rzeczywistych kosztów.

Słowa kluczowe: *proces zarządzania konserwacją, instalacja, optymalizacja, analiza kosztów, studium przypadku.*

1. Introduction

Wastewater plumbing is an infrastructure system that has maintenance and establishment problems which are more serious than other installations such as electrical, communication, exterior system, etc. On the other hand plumbing system management is very important as it is related to health, customer's safety and environment protection [9]. A survey was done to identify the important building components and its degradation with respect to defects and indications, and its effect on clients, staffs and users of building. First, the top nine building facilities including interior surface, exterior surface, mechanical system, electrical system, communication system, clean water system, wastewater plumbing system, structural system and roofs were identified through the literature and through discussions with engineers and inspectors in the industry. Second, information that is related to the degradation of the building components was collected from a large owner organization, the Iranian Society of Consulting Engineers (ISCE). Comprehensive survey was then performed between experienced personnel at the ISCE in order to understand the various problems of components and statistics related to the level of difficulty in replacing, repairing, cleaning, and inspecting among components and facilities. Assessments show that mismanagement in maintenance of wastewater plumbing systems affects increasing of the building cost and decreasing of the wastewater network's service life [3]. From the other side, control and inspection of the whole pipeline is often very costly and time-consuming, and sometimes simply impossible [21]. Wastewater pipeline degradation results in uneconomical damages and high cost of replacement [9]. Therefore, condition assessment (CA) of plumbing in wastewater system is very essential and necessary for the prediction of proper repair time based on limited budget in relation to increasing the component service life and preventing early replacement, degradation and penalty costs [9, 21]. Due to the limited budget in maintenance management of wastewater plumbing system in Iran, hence it is uneconomical to replace the pipeline and piping [12]. This issue is very important on how to spend the limited financial allocation available for facilities and components maintenance to achieve the best return for their spending. There is a lack of integration between components maintenance time and cost decision making process in a building. The objective of this paper is to present a process to optimize the maintenance time and cost of cast iron pipe component in wastewater system of hotel buildings in Iran using the condition index (CI) systems. The paper presents a financial analysis using the data collected through financial and technical information. The technical information was collected from 30 installations consultants firms in Iran, while the financial information was collected from hotel's financial managers. Data is analyzed and simulated using the MS Excel software. This process by using the financial analysis assists in controlling the existing investment in facilities maintenance increasing components service life and, subsequently, preventing early deterioration and components replacement in public buildings.

2. Component condition index system

Systematic prediction by condition assessment method offers help to researchers in understanding the cost decision making in the best time for building facilities maintenance. Condition index (CI) presents the ability to form a basis for measuring rates of deterioration and prediction of condition for each component or facility [4]. 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 indexes ranges from 0 to 100 and is divided into seven condition categories [10, 29]. The seven condition categories that set the arrangement of the index scale also need a guideline with the aim to set the computed maintenance time for a component concerning the each index definition (condition description for each CI value). Table 1 presents these guidelines. It is very important that the guideline (condition description) displays the condition categories. This is because the use of definitions would influence integrated constraints on the formulation and the indexes for predicting maintenance time of components condition over time [10, 30].

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.

Overtime, condition index (CI) moves from 100 to 0. When engineers install a component or material in a building, the condition index is 100 (excellent). Overtime, condition index for that component will reach below value 10. 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 [30].

3. Statement of the Problem

Most important issue to successful component maintenance activities is a suitable cost allocated for a project. One of the reasons for change in facilities maintenance management and planning is due to limited allocation of costs [6]. Furthermore, lack of suitable costs allocation in a component maintenance work could affect the maintenance implementation [28]. Quality of maintenance works on the buildings components is dependent on the amount of costs allocation in this sector. Sufficient capital including staffing, inspecting, and financial is required for components maintenance works in the buildings [15]. Therefore, building managers or owners are responsible for management and allocation of maintenance costs for good maintenance outcome [18]. The statistics indicate increasing importance of maintenance and rehabilitation (M&R) of building components. Many components and facilities investment strategies lack of enough cost for components managers during its service life [19]. Hence, estimations and computations for maintenance costs planning and allocation is difficult and complex [1]. With respect to the statistics illustrated, it is an essential process in allocation of maintenance costs especially on the relative involvement of various components maintenance. Delay of some maintenance works accrued due to the cost allocated is limited and not sufficient to cover the requirement for building maintenance [7, 20]. Any decision making is based on existing costs and resources allocation of the buildings in maintenance activities [2]. Some researchers argue that decision making for component maintenance cost is synonymous with management [1]. Decision making for maintenance cost is a necessary process in management of building components and facilities [23].

4. Purpose of the Study

The main objective of this study is to develop a new process to optimize the maintenance time and cost of wastewater network of public building using the condition index system as a measurement method. The framework is focused on process to optimize building component maintenance time that has limited cost with respect to component condition assessment method (condition index tools) and economical management. This process involves the analysis of technical and financial information for a sample of five-star hotel buildings from the Iran.

5. The Case Study

Esteghlal Hotel with history of 50 years is one of the five-star hotels in Tehran. This hotel was found in 1962. Esteghlal Hotel is located in the down foot of the Alborz mountain range with 70,000 m^2 area, having two towers each with 15 floors, a total of 550 luxurious rooms and suites, not only it is the biggest and the most glorious hotel in the Tehran city, but also from various aspects it is most exclusive in Iran [8]. Table 2 shows the pipe dimension information for wastewater system.

Table. 2. Pipe dimension data for wastewater network of Esteghlal Hotel [24]

Diameter (inch)	2	3	4	5	6
Length (m)	1700	800	900	200	150

6. Research methodology

This section describes the research methodology adapted in the study. It explains all methods requested to achieve the objectives. To achieve the objectives of the research, the methodology is divided into three stages:

- Stage I – gathering the information,
- Stage II – developing a draft process,
- Stage III – verification of the process.

6.1. Stage I – gathering the information

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 the component. The rating sessions were carried out in small groups and at the normal work locations of the raters. The raters were 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. The individual panel members ratings were averaged to obtain mean maintenance time for wastewater plumbing system. As depicted in Table 3, this predictive 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 plumbing system. The panel's opinion, indeed, represents a broad 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.

Table. 3. Gathering the information of technical data based on USACERL category (predictive data)

Index	Category	Maintenance year
100	Excellent	0
85	Very Good	9
70	Good	16.9
55	Fair	26.5
40	Poor	36.1
25	Very Poor	43.9
10	Failed	50

The financial information is related to the annual maintenance cost allocated for wastewater plumbing system in Esteghlal Hotel that is analyzed through gathering data by financial managers. The finan-

Table. 4. Financial information for wastewater system of Esteghlal Hotel

Historical data									
Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)
1990	≈0	1994	2500	1998	3900	2002	5500	2006	7000
1991	≈0	1995	2900	1999	4300	2003	6000	2007	7400
1992	≈0	1996	3100	2000	4800	2004	6200	2008	7900
1993	2000	1997	3300	2001	5000	2005	6700	2009	8200
Predictive data									
Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)	Year	Annual maintenance cost ($)
2011	≈0	2021	14600	2031	23800	2041	38800	2051	63300
2012	≈0	2022	15300	2032	25000	2042	40800	2052	66500
2013	≈0	2023	16100	2033	26300	2043	42800	2053	69800
2014	≈0	2024	16900	2034	27600	2044	45000	2054	73300
2015	≈0	2025	17800	2035	29000	2045	47200	2055	77000
2016	≈0	2026	18700	2036	30500	2046	49600	2056	80800
2017	≈0	2027	19600	2037	32000	2047	52100	2057	84900
2018	12600	2028	20600	2038	33600	2048	54700	2058	89100
2019	13200	2029	21600	2039	35200	2049	57400	2059	93600
2020	13900	2030	22700	2040	37000	2050	60300	2060	98200

Table. 5. Calculation of saving estimate for wastewater system of Esteghlal Hotel

Historical data			
Saving Condition Index	Maintenance Year/accidental	Computation basing on the Maintenance Year	Result ($)
Saving in Index 85	3.3	$\left(\sum_{i=1990}^{1992} FI_i\right)+\left((FI_{1993})\times(\frac{4}{12})\right)$	666.7
Saving in Index 70	6.6	$\left(\sum_{i=1990}^{1995} FI_i\right)+\left((FI_{1996})\times(\frac{6}{12})\right)$	8950
Saving in Index 55	9.9	$\left(\sum_{i=1990}^{1998} FI_i\right)+\left((FI_{1999})\times(\frac{11}{12})\right)$	21641.7
Saving in Index 40	13.2	$\left(\sum_{i=1990}^{2002} FI_i\right)+\left((FI_{2003})\times(\frac{2}{12})\right)$	38300
Saving in Index 25	16.5	$\left(\sum_{i=1990}^{2005} FI_i\right)+\left((FI_{2006})\times(\frac{6}{12})\right)$	59700
Saving in Index 10	20	$\left(\sum_{i=1990}^{2009} FI_i\right)$	86700
Predictive data			
Saving Condition Index	Maintenance Year	Computation basing on the Maintenance Year	Result ($)
Saving in Index 85	9	$\left(\sum_{i=2011}^{2019} FI_i\right)$	25800
Saving in Index 70	16.9	$\left(\sum_{i=2011}^{2026} FI_i\right)+\left((FI_{2027})\times(\frac{11}{12})\right)$	157000
Saving in Index 55	26.5	$\left(\sum_{i=2011}^{2036} FI_i\right)+\left((FI_{2037})\times(\frac{6}{12})\right)$	401800
Saving in Index 40	36.1	$\left(\sum_{i=2011}^{2046} FI_i\right)+\left((FI_{2047})\times(\frac{1}{12})\right)$	792100
Saving in Index 25	43.9	$\left(\sum_{i=2011}^{2053} FI_i\right)+\left((FI_{2054})\times(\frac{11}{12})\right)$	1279100
Saving in Index 10	50	$\left(\sum_{i=2011}^{2060} FI_i\right)$	1808800

cial sheet was designed basing on the data collection method covering annual cost information for maintenance of wastewater piping system in Esteghlal Hotel. The financial information includes historical and predictive data. In this study, financial managers fill financial information from 1990 to 2009 for historical data (existing financial documents) and from 2011 to 2060 for predictive data. The historical 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 20 years (Table 4). The predictive data is selected basing on period of 50 years that corresponds to the useful lifespan of cast iron pipe which is approximately 50 years [16] using the prediction process and the average inflation rate computed from 1990 to 2009 (historical data) (Table 4). The average inflation rate of annual maintenance cost is 5% in Esteghlal Hotel. The information collected are stored in the saving sector for calculating the saving and investment ratio (SIR) for the condition index (from 100 to 10). The data, information and calculations are implemented basing on value of money and inflation rate computed for Iranian Rials currency (1 IRR = 0.0001 $).

6.2. Stage II – developing a draft process

The saving is total annual maintenance budget until maintenance time. The saving is calculated basing on the maintenance costs allocated for repair, service, inspection and clean annually in part of component maintenance until year *i*. The saving is estimated basing on USACERL condition index and maintenance year (technical information) for wastewater plumbing system in Esteghlal Hotel (Table 5) through the following formulas for historical and predictive data:

Saving formula for historical data:

$$\left(\sum_{i=1990}^{n} \mathrm{FI}_i\right) \tag{1}$$

Here, FI presents financial information of historical data, and n is Year-end of annual maintenance cost in desired index (index 85 to index 10).

Saving formula for predictive data:

$$\left(\sum_{i=2011}^{n} \mathrm{FI}_i\right) \tag{2}$$

Here, FI presents financial information of predictive data, and n is Year-end of annual maintenance cost in desired index (index 85 to index 10).

In this study the predictive data is important for implementation of maintenance prediction process. The predictive data is verified by historical data basing on the past 20 years. Second column of Table 5 (maintenance year – historical data) shows that the period of 20 years is divided into six parts basing on the USACERL condition index system. These data are accidental for verification of predictive data and prediction process during future years. The computation of saving estimate is done basing on the maintenance year in each condition index. For example in Table 5, in the first row of historical data (index 85) the saving is equal to sum of the financial information of historical data (Table 4) from 1990 to 1992 (3 years) plus 4/12 of 1993 (3 months) or in the third row of predictive data (index 55), the saving is equal to sum of the financial information of predictive data (Table 4) from 2011 to 2036 (26 years) plus 6/12 of 2037 (6 months).

Simulating economic analysis is carried out basing on the saving the investment ratio (SIR) for maintenance at various condition index values for the cast iron pipe component in the wastewater plumbing of Esteghlal 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. Repair cost is required cost for components restoration to excellent condition (operating period) after corrosion, broken, and other. Repair and maintenance cost is dependent on condition of weather, maintenance method, components functions, and management quality. Therefore, cost quantities have high standard deviation and there may not be any methods for accurate prediction of cost variation during future years [31]. Repair and maintenance cost of facilities and components is very low during first month (approximately 0). Function and lifespan enhancement result in increasing repair cost and repair cost is equal to replacement cost during final years. The market price fluctuation is a problem in relation to the accurate prediction of repair and maintenance cost. Therefore, accurate information and suitable statistics are very complex for computing component repair cost in field of component repair and maintenance [31]. The equations estimate repair costs as a percentage of the component purchase price (component replacement cost), so the equations should remain valid as long as the component purchase price goes up at the same rate as the cost of repairs [14]. The formulas for repair and maintenance costs estimate total accumulated repair costs based on accumulated hours of lifetime use. Repair and maintenance calculations are based on American Society of Engineers formulas [13]. There are other relevant studies in the field of repair cost computations including Sajadi and Moghadam in 2005 [26] and Means in 2008 [17]. In this study, the repair cost is computed basing on existing definition of repair cost and condition index method. This section defines the repair cost using the existing statistics of construction industry. The repair cost is analyzed by using the economic techniques and financial issues in repair and maintenance based on existing definitions. This equation is linear and uses the virtual variable:

$$C_r = C_p \times (Index\ a / Index\ b) \tag{3}$$

Table. 6. Pipe replacement cost C_p for wastewater system of Esteghlal Hotel

Historical data									
Year	Replacement cost ($)	Year	Replacement cost ($)	Year	Replacement cost ($)	Year	Replacement cost ($)	Year	Replacement cost ($)
1990	3805.3	1994	7890.8	1998	16362.5	2002	29088.9	2006	43954.5
1991	4566.4	1995	9469	1999	19635	2003	32321	2007	68177.5
1992	5479.7	1996	11362.8	2000	23562	2004	35349	2008	74995.3
1993	6575.7	1997	13635.4	2001	26180	2005	41073.5	2009	82494.8
Predictive data									
Year	Replacement cost ($)	Year	Replacement cost ($)	Year	Replacement cost ($)	Year	Replacement cost ($)	Year	Replacement cost ($)
2011	84800	2021	183076	2031	395249	2041	853313	2051	1842239
2012	91584	2022	197722	2032	426869	2042	921578	2052	1989618
2013	98910	2023	213540	2033	461018	2043	995304	2053	2148788
2014	106823	2024	230624	2034	497900	2044	1074929	2054	2320691
2015	115369	2025	249074	2035	537732	2045	1160923	2055	2506346
2016	124599	2026	268999	2036	580750	2046	1253797	2056	2706854
2017	134566	2027	290519	2037	627210	2047	1354100	2057	2923402
2018	145332	2028	313761	2038	677387	2048	1462429	2058	3157274
2019	156958	2029	338862	2039	731578	2049	1579423	2059	3409856
2020	169515	2030	365971	2040	790104	2050	1705777	2060	3682645

Table. 7. Repair cost C_r calculation for wastewater network of Esteghlal Hotel

Historical data				
Replacement cost ($)		Index/ Year	Calculation	Repair cost ($)
5479.7		85/ 3.3	5479.7× ((100-85) / (100-10))	876.7
9469		70/ 6.6	9469× ((100-70) / (100-10))	3124.7
16362.5		55/ 9.9	16362.5 × ((100-55) / (100-10))	8181.2
29088.9		40/ 13.2	29088.9 × ((100-40) / (100-10))	19198.6
41073.5		25/ 16.5	41073.5 × ((100-25) / (100-10))	34091
82494.8		10/ 20	82494.8 × ((100-10) / (100-10))	82494.8
Predictive data				
Replacement cost ($)	Index	Maintenance Year	Calculation	Repair cost ($)
156958	85	9	156958 × ((100-85) / (100-10))	25113
268999	70	16.9	268999 × ((100-70) / (100-10))	88769
580750	55	26.5	580750 × ((100-55) / (100-10))	290375
1253797	40	36.1	1253797 × ((100-40) / (100-10))	827506
2148788	25	43.9	2148788 × ((100-25) / (100-10))	1783494
3682645	10	50	3682645 × ((100-10) / (100-10))	3682645

Here, C_r presents repair cost in year i, and C_p is replacement cost in year i. *Index a* presents component condition in year i, and *Index b* is component condition in operating first year.

The unit replacement cost is according to the current price of cast iron pipe in the Iran's market. The replacement cost is calculated basing on dimension of wastewater plumbing system (size and length) of Esteghlal Hotel, price of cast iron pipe in the Iran's market, and average inflation rate for calculation of predictive data. The predictive data is calculated with inflation rate of 8% basing on average inflation rate of cast iron pipe in Iran's market from 2000 to 2010 (historical data) [11, 22]. The replacement cost is based on price index in Iran and including labor cost, transportation cost and the total cost of works [22]. The replacement cost was estimated through following formula and has been shown in Table 6:

$$C_p = L \times C \qquad (4)$$

Here, C_p presents replacement cost in year *i, L* is lentgh of pipe, and C is cost basing on $/m.

Repair cost C_r is computed basing on standard equation 3. Between these condition index scales a parametric model of component repair cost is described as a comprehensive estimation of the corrective repair cost as a percentage of the total replacement cost in wastewater plumbing system of Esteghlal Hotel. Table 7 shows the repair costs in two situations of historical and predictive data.

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 [25]. 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 [5]. The SIR is illustrated by following equation:

$$SIR = Saving / Investment \qquad (5)$$

Here, saving is total annual maintenance budget until repair time, and investment cost is 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 maintenance annually in part of component maintenance until year i. Table 8 and 9 and Fig. 1 and 2 present the SIR for maintenance at various condition index values for the cast iron pipe wastewater system of Esteghlal Hotel in situations of historical and predictive data.

Table. 8. Financial analysis of optimum maintenance time based on USACERL condition index (historical data)

USACERL Index	Maintenance year	Investment estimation ($)	Saving estimation ($)	SIR
100	0	0	0	0
85	3.3	876.7	666.7	0.76
70	6.6	3124.7	8950	2.86
55	9.9	8181.2	21641.7	2.64
40	13.2	19198.6	38300	1.99
25	16.5	34091	59700	1.75
10	20	82494.8	86700	1.05

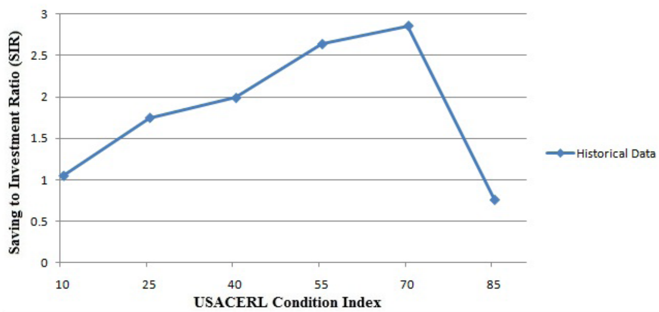

Fig. 1. Optimum maintenance time based on highest SIR (historical data)

Table 9 and Fig. 2 depict the analysis of optimum maintenance management of cast iron pipe in wastewater plumbing system for Esteghlal Hotel basing on a period of 50 years. The graph illustrates that when USACERL index reaches to 70, economic rate is high (SIR 1.76). Thus, the best time of maintenance occurs when USACERL CI is 70 with SIR 1.76. Building manager knows that the best decision for increasing cast iron pipe's service life based on existing maintenance cost is repair, cleaning, service, and renewal after 16 years (CI = 70 and SIR = 1.76). A ratio less than 1.0 indicates an uneconomic action

Table. 9. Financial analysis of optimum maintenance time based on USACERL condition index (predictive data)

USACERL Index	Maintenance year	Investment estimation ($)	Saving estimation ($)	SIR
100	0	0	0	0
85	9	25113	25800	1.02
70	16.9	88769	157000	1.76
55	26.5	290375	401800	1.38
40	36.1	827506	792100	0.95
25	43.9	1783494	1279100	0.71
10	50	3682645	1808800	0.49

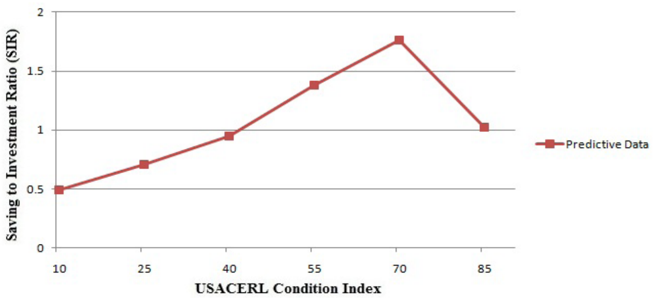

Fig. 2. Optimum maintenance time based on highest SIR (predictive data)

[25]. When the ratio is below 1.0, the economic efficiency of maintenance actions are nearly equal the replacement. Thus, if CI= 40, replacement close to the CI terminal value of 10 should be replaced. When CI reaches 40, maintenance time is 36 years basing on technical data. Thus, the wastewater system of Esteghlal Hotel should be replaced, no maintenance or repair after 36 years shall be done.

6.3. Stage III – verification of the process

Verification is the process of determining that a model implementation accurately represents the developer's conceptual description of the model and the solution to the model. Verification is concerned on identifying and testing historical data in the model by comparing historical data and predictive data to analytical or highly accurate benchmark solutions [27]. Verification of process model is required when a predictive process is the end product. The predictive accuracy of the process must then reflect the strength of the inference being made from the historical database to the prediction. The verification of process model is motivated by the need for highly accurate process models for making predictions to support the maintenance management process model and by the current lack of guidelines, standards, and procedures for performing model. The verification assessment of model determines the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model. This information is used to decide whether or not the model has resulted in acceptable agreement with the experiment. The acceptable agreement decision focuses only on the level of match between the analysis outcome of historical data and predictive data. Verification is processes that collect evidence of a model's correctness or accuracy for a specific scenario; thus, verification cannot prove that a model is correct and accurate for all possible conditions and applications, but, rather, it can provide evidence that a model is sufficiently accurate.

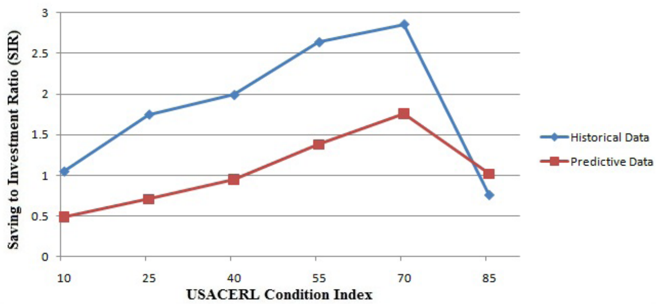

Fig. 3. Verification of process

Fig. 3 illustrates the financial analysis simulation of optimum index based on highest SIR in two situations of historical and predictive data. The results show that the highest SIRs occur when USACERL CI is 70 for two situations of historical and predictive data. The SIR systems soar from index 85 to index 70 and after that follow a downtrend from index 70 to index 10. The similarity of optimum index in two situations of historical and predictive data shows that this process is acceptable for prediction of maintenance time in wastewater system of Esteghlal Hotel.

7. Conclusion

This study presents the importance of survey of wastewater plumbing system using the USACERL condition index system in three stages including gathering the information, developing a draft process and verification of process for facilities correction maintenance in hotel buildings, in this case, cast iron pipe in the wastewater system of Esteghlal Hotel in Iran. This paper describes the development of a process for maintenance of building component using the USACERL condition index system. The systematic process was shown in a process framework for component maintenance for economical optimization for building component maintenance. This systematic process can provide a suitable decision making process on the maintenance time of building component based on existing budget for building owners and facilities managers.

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