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Technical and Economic Investigation of Urban Road Pavement Maintenance Methods

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Abstract

Pavement is considered as the national capital of countries spending a major part of development budgets of relevant organizations annually for its rehabilitation, reconstruction, and maintenance. Pavement management systems have been applied to enhance the efficiency of decision-making process and finding effective economic strategies to assessment, repair, and maintain at acceptable levels. Therefore, the asphalt pavement management principles and 19-fold asphalt pavement failures have been described. District 3 of Ardabil city was selected in the present study. Asphalt pavement failures at four levels of highways, main streets, local streets, and alleys were assessed through related forms and *MicroPAVER* software. Distress of crocodile cracks and weathering are the most quantity of failure expressing the lack or poor quality of materials and amount of bitumen. Pavement Condition Index (PCI) was calculated at 4 levels. According to software results, The PCI had a minimum value for main streets and maximum value for alleys. According to these values and PCI requirements, strategies were proposed to improve pavement conditions at each level and specific PCI values**.**

Keywords: Asphalt Pavement; MicroPAVER; Pavement Condition Index (PCI); 3rd District of Ardabil

Introduction

Pavement is considered as the national capital of countries spending a major part of development budgets of relevant organizations annually for its rehabilitation, repair, and maintenance. Pavement networks need to be managed, and the mere maintenance is not sufficient any longer. Recent advances in microcomputers and the pavement management technology have provided necessary tools for the economic pavement management.

A Pavement Management System (PMS) provides a systematic and coherent approach to select repair and maintenance requirements, and determine priorities and optimal time for maintenance by predicting future pavement conditions. The road pavement maintenance system is a tool that helps managers to achieve efficient economic policies for maintaining pavements in desirable service conditions. This system is a part of the Integrated Maintenance Management System of the Transport Infrastructures.

The extent of road network in a wide geographical area and its constant changes under the influence of the traffic, climate and environment has a great impact on the pavement condition in the coming years and the road maintenance operation. Pavement surface distress especially in cities has a huge impact on vehicle operating costs, and these effects are not predictable in the long term if they are not repaired.

Urban road pavement will be the subject to a variety of surface and structural distress due to the repeated vehicle traffic and various weather conditions especially the cold weather. Repairing this distress and provision of appropriate service for transportation in various city passages are significantly important in the urban management system.

The present study sought to provide solutions to optimize the distress repair cost and appropriate repair methods for different urban passages by investigating distress of passages in alleys, streets and highways of District 3 of Ardabil using MicroPAVER software and investigating different maintenance methods. In fact, the research aimed to reduce the urban road maintenance cost, and for instance, passages of Ardabil City were selected. Results of the present research will be very useful for various municipality districts in this city.

Research Literature and Background

Pavement Management System is a purposive tool for managers to improve efficiency in decision making and to find an effective and economical strategy for assessing, repairing, and maintaining pavement at an acceptable level. This system is an analytical-evolutionary information system in which the information should be continually reviewed and updated in a program based on the latest engineering sciences and economic technologies and development in order to optimize the engineering feasibility and strategy for repairing, rehabilitating and maintaining pavement (Ameri, 2005).

Pavement Management Process

The pavement management process is classified into five stages as follows:

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- Definition of pavement network
- Measurement of pavement condition
- Pavement condition prediction
- Network-level management
- Project-level management

Network identification and definition is the first step to establish a Pavement Management System (PMS). Some factors, which should be taken into account in designating different networks, are as follows: use; funding sources; and minimum operating standards. Once networks are identified, they divide into branches and parts.

Moazami et al. (2011) studied the prioritized urban pavement rehabilitation and repair using the fuzzy logic. They performed the prioritization based on a model including all important factors such as the pavement condition index, traffic volume, road width as well as the reconstruction, and cost maintenance. Since it was difficult to define a model in which all of the above-mentioned factors were introduced, a more advanced fuzzy logic model was used for the prioritization. The Analytic Hierarchy Process could also be used, but the fuzzy logic was used due to its greater accuracy. By the help of MATLAB software, they selected some streets in the 6th district of Tehran (131 zones) as a case study and applied a math model in those streets.

As the road pavement life cycle costs as the national capital of countries including the construction, maintenance and costs of users are affected by pavement types, Araghi et al (2013) predicted the growth trend of asphalt and concrete pavement costs in Iran until 1400 and compared with global estimates. Considering that the priority has been given to the asphalt pavement in recent years, some factors such as the dramatic increase in the prices of oil products have contributed to the loss of previous equations in selection of pavement types. Therefore, the present paper investigated roots of changes in prices of concrete and asphalt (Araghi et al., 2013).

Miraei Moqhaddam et al. (2013) evaluated the estimation of asphalt pavement condition by the help of MicroPAVER software and provided repair solutions for selected sample path. Estimation of the current pavement condition is a key step in the pavement management system which is characterized by indices such as the IRI and PCI. In this research, they used the PCI to determine the current condition of pavement of Valiasr Street in Tehran (between Mehregan Hospital and Shahid Hemmat Bridge) (Miraei Moghaddam et al., 2013).

Pirmoradi et al. (2005) studied the passage pavement and its management as important issues in the urban management. The pavement management system includes prediction of pavement network conditions and related prices that are carried out by applying various pavement construction strategies. A pavement management system provides a systematic and coherent approach to the selection of repair and maintenance requirements, prioritization and optimal time for repairs by predicting the pavement condition for the future. An efficient spatial information system provides a suitable platform for all details and branches that can be investigated by the PMS. Given the obtained result of the GIS-PMS combination, which leads to a powerful tool for upgrading all components and sections of the PMS, the researchers investigated the pavement condition by creating and setting up an urban management system and using GIS capabilities. This management system can optimize and update pavement repairs, reduce costs and operate its distribution (Pirmoradi et al., 2005).

Lee et al. (2014) conducted a laboratory study and an analysis of cutoff fatigue phenomenon at the middle pavement asphalt layers. They integrated the mechanical damage theory, the heat transfer theory and the finite element method and used to analyze characteristics of fatigue damage and the asphalt layer cracking mechanism. The research results indicated that the asphalt layer located at the transverse connection points of the rigid layer was subject to repeated traffic loading, and was prone to cracks due to the fatigue and its extension to the surface of the pavement due to the tensile stress. Finally, it was suggested using an asphaltic mixture that has characteristics such as the low thermal shrinkage, low modulus and high tensile strength to ensure the resistance to expected cracks and durability of asphalt.

Vaghizad et al. (2013) investigated the effective geotechnical factors in the early destruction of pavement systems in the outskirts of cities (case study: roads of Ardabil province). In this regard, necessary sampling was done on bed materials and pavement body through speculation on performing target experiments. After reviewing and interpreting results of test and field studies, it was declared that the use of materials with inappropriate technical characteristics (vegetable soil), the incorrect selection of a project line, the failure to implement aqueducts and bridges in the required locations, the coldness of areas, the failure to observe principles of pavement maintenance and protection, and excessive traffic volume were the main reasons for early pavement distress (Vaghizad et al., 2013).

Rahimi et al. (2011) investigated a decision-making model for optimal maintenance of asphalt pavement with the aim to reduce road accidents. They defined the maintenance operation as a set of operations that are permanent and conducted on a passage and technical buildings of the equipment, facilities and its surrounding area in order to maintain the passage service at a desirable level. Meanwhile, the pavement management could be considered as an appropriate and efficient tool for improving the set of passage maintenance measures. Considering systematic and organized methods including pavement construction and maintenance designing and rehabilitation planning, they proposed a decision-making model for optimal pavement repair with the aim to reduce accidents (Rahimi et al., 2011).

Economic evaluation methods of cost benefit have a long history in the engineering economics science like the cost benefit ratio, current value, annual cost, return rate. Therefore, Shafabakhsh et al. (2012) performed the economic evaluation of suggested periodic options for maintenance in the pavement lifecycle using the above methods, and then compared results of each method (Shafabakhsh et al., 2002).

Common distress in most urban pavement includes Longitudinal cracks, Transverse cracks, Edge cracks, Crocodile cracking, Bleeding, Recess, Patching, Polished aggregate, Potholes, Rutting, Shoving and Weathering.

Research Methodology

The present project sought to investigate the pavement condition in a part of the 3rd district of Ardabil and determine the amount of PCI for target passages using Paver software. In this regard, the pavement condition was randomly investigated at four levels of alley, local streets, main streets and highways, the PCI was calculated for the region, and the necessary solutions were provided for repairing the pavement.

District 3 of Ardabil Municipality, which was one of four large districts of Ardabil and a combination of areas with worn-out and modern textures, was selected as the case study and pilot. In order to examine these conditions and the pavement condition in alleys, main and local streets, and highways, 5 pieces were taken from each of them and four 30-meter samples were randomly taken from each piece. These pieces were placed next to each other and the PCI was examined for each of four levels.

Data analysis

1. *Summarization of distress*

After collecting distressed pieces at 4 levels, the collected distressed pieces and the following diagrams were created to examine the maximum impact on the pavement condition.

2. *Highway Distress*

According to results of Table (1), surface distress, especially weathering distress, were the most important causes of distress in the highway pavement. Among longitudinal distress, longitudinal and transverse cracks had the greatest impact on the longitudinal distress. These cracks were often due to the contraction and expansion of the pavement due to the heat and cold. Furthermore, the weathering, block cracking and Crocodile cracking were among the most damaging surface distress on highways.

Table 1- Amounts of distress and associated Deduct Weighting Values in highways

Row	Severity of distress	Highway distress					
		Severity of distress	**Amount of** distress	**Percentage of density**	**Deduct Weighting Value**	**Repaired** distress	**Impact percentage**
1	Crocodile cracking	Low	33	0.90410959	10	330	1.51
		Medium	92.1	2.52328767	30	763	12.67
		High	0	0	0	0	0.00
2	Bleeding	Low	0	0	0	0	0.00
		Medium	21.7	0.59452055	4	86.8	0.40
		High	0	0	0	0	0.00
3	Block cracking	Low	36	0.98630137	0	0	0.00
		Medium	233	6.38356164	12	2796	12.82
		High	0	0	0	0	0.00
4	Bumps and sags	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
5	Recess	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
6	Edge cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
7	Joint reflection cracking	Low	0	0	0	0	0.00
		Medium	11.5	11.5	3	34.5	0.16
		High	5	0.5	6	30	0.00
8	Lane/shoulder drop-off	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
9	Longitudinal cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
10	Transverse Cracking	Low	209.5	20.95	12	2514	11.52
		Medium	154	15.4	23	3542	16.24
		High	0	0	0	0	0.00
11	Patching and utility cut patching	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00

		High	0	0	0	0	0.00
12	Polished aggregate		0	0	0	0	0.00
13	Pathole	Low	11	0	3	33	0.00
		Medium	7	0	8	56	0.00
		High	0	0	0	0	0.00
14	Rail bypass	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
15	Rutting	Low	22	0.60273973	6	132	0.61
		Medium	31.3	0.85753425	16	500.8	2.30
		High	0	0	0	0	0.00
16	Shoving	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
17	Slippage cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
18	Swelling	Low	0	0	0	0	0.00
		Medium	5.5	0.15068493	0	0	0.00
		High	0	0	0	0	0.00
19	Weathering and raveling	Low	33	0.90410959	2	66	0.30
		Medium	245	6.71232877	16	3920	17.97
		High	167	4.57534247	30	5010	22.97
						21814.1	

Main street distress

Among the distress of main street asphalt pavement such as highways, the weathering had the greatest impact on the extent of distress according to Table 2. Crocodile cracks also had a great impact on the PCI of the pavement.

Table 2 - Amounts of distress and associated Deduct Weighting Values in the main street

Row	Severity of distress	Main street distress					
		Severity of distress	**Amount of** distress	**Percentage of density**	**Deduct Weighting Value**	**Repaired** distress	**Impact percentage**
1	Crocodile cracking	Low	29.5	0.80821918	9	265.5	1.81
		Medium	93	2.54794521	30	2790	19.06
		High	0	0	0	0	0.00
2	Bleeding	Low		0	0	0	0.00
		Medium	4	0.10958904	0	0	0.00
		High	0	0	0	0	0.00
3	Block cracking	Low	17	0.46575342	0	0	0.00
		Medium	80	2.19178082	8	640	4.37
		High		0	0	0	0.00
4	Bumps and sags	Low		0	0	0	0.00
		Medium		0	0	0	0.00
		High		0	0	0	0.00
5	Recess	Low		0	0	0	0.00
		Medium		0	0	0	0.00
		High		0	0	0	0.00
6	Edge cracking	Low		0	0	0	0.00
		Medium		0	0	0	0.00
		High		0	0	0	0.00
7	Joint reflection cracking	Low		0	0	0	0.00
		Medium	40	4	4	160	1.09
		High		0	0	0	0.00
8	Lane/shoulder drop-off	Low		0	0	0	0.00

		Medium		0	0	0	0.00
		High		0	0	0	0.00
9	Longitudinal cracking	Low		0	0	0	0.00
		Medium		0	0	0	0.00
		High		0	0	0	0.00
10	Transverse Cracking	Low	124	12.4	10	1240	8.47
		Medium	132	13.2	21	2772	18.93
		High	0	0	0	0	0.00
11	Patching and utility cut patching	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
12	Polished aggregate			0	0	0	0.00
13	Pathole	Low		0	3	0	0.00
		Medium	4	0.10958904	7	28	0.00
		High	0	0	0	0	0.00
14	Rail bypass	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
15	Rutting	Low		0	6	0	0.00
		Medium		0	16	0	0.00
		High	0	0	0	0	0.00
16	Shoving	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
17	Slippage cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
18	Swelling	Low	0	0	0	0	0.00
		Medium	7	0.191780082	0	0	0.00
		High	0	0	0	0	0.00
19	Weathering and raveling	Low	105	2.87671233	2	210	1.43
		Medium	344	9.42465753	19	6536	44.64
		High	0	0	30	0	0.00
						14641.5	

Local street distress

In local streets, weathering had the highest impact on the pavement distress. Longitudinal and transverse cracks also had the highest values among distress per unit length.

Table 3- Amounts of distress and associated Deduct Weighting Values in the local street

Row	Severity of distress	Local street distress					
		Severity of distress	**Amount of** distress	**Percentage of density**	**Deduct Weighting Value**	**Repaired** distress	**Impact percentage**
1	Crocodile cracking	Low	28.5	0.78082192	9	256.5	3.78
		Medium	9	0.24657534	12	108	1.59
		High	0	0	0	0	0.00
2	Bleeding	Low	12	0.32876712	4	48	0.71
		Medium	4	0.10958904	2	8	0.12
		High	0	0	0	0	0.00
3	Block cracking	Low	64	1.75342466	4	256	3.77
		Medium	0	0	8	0	0.00
		High	0	0	0	0	0.00
4	Bumps and sags	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00

		High	0	0	0	0	0.00
5	Recess	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
6	Edge cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
7	Joint reflection cracking	Low	0	0	0	0	0.00
		Medium	4	0.4	6	24	0.35
		High		0	0	0	0.00
8	Lane/shoulder drop-off	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
9	Longitudinal cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
10	Transverse Cracking	Low	128	12.8	11	1408	20.73
		Medium	9	0.9	4	36	0.53
		High	0	0	0	0	0.00
11	Patching and utility cut patching	Low	10.5	0.28767123	8	84	1.24
		Medium	64.5	1.76712329	22	1419	20.90
		High	0	0	0	0	0.00
12	Polished aggregate		0	0	0	0	0.00
13	Pathole	Low	4	0.10958904	6	24	0.00
		Medium	7	0.19178082	12	84	0.00
		High	0	0	0	0	0.00
14	Rail bypass	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
15	Rutting	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
16	Shoving	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
17	Slippage cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
18	Swelling	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
19	Weathering and raveling	Low	10	0.2739726	2	20	0.29
		Medium	201	5.50684932	15	3015	44.40
		High	0	0	30	0	0.00
						6790.5	

Alley distress

According to studies, the highest pavement distress rate in alleys was due to weathering because of patching and carving. This occurred by the connection of a variety of branches after the asphalted pavement and the lack of coordination leading to a significant reduction in the pavement service quality.

Table 4 - Amounts of distress and associated Deduct Weighting Values in alleys

Row	Severity of distress	Alley distress					
		Severity of distress	**Amount of** distress	**Percentage of density**	**Deduct Weighting Value**	**Repaired** distress	**Impact percentage**
1	Crocodile cracking	Low	28.5	0.78082192	9	256.5	3.78
		Medium	9	0.24657534	12	108	1.59
		High	0	0	0	0	0.00

2	Bleeding	Low	12	0.32876712	4	48	0.71
		Medium	4	0.10958904	2	8	0.12
		High	0	0	0	0	0.00
3	Block cracking	Low	64	1.75342466	4	256	3.77
		Medium	0	0	8	0	0.00
		High	0	0	0	0	0.00
4	Bumps and sags	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
5	Recess	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
6	Edge cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
7	Joint reflection cracking	Low	0	0	0	0	0.00
		Medium	4	0.4	6	24	0.35
		High		0	0	0	0.00
8	Lane/shoulder drop-off	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
9	Longitudinal cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
10	Transverse Cracking	Low	128	12.8	11	1408	20.73
		Medium	9	0.9	4	36	0.53
		High	0	0	0	0	0.00
11	Patching and utility cut patching	Low	10.5	0.28767123	8	84	1.24
		Medium	64.5	1.76712329	22	1419	20.90
		High	0	0	0	0	0.00
12	Polished aggregate		0	0	0	0	0.00
13	Pathole	Low	4	0.10958904	6	24	0.00
		Medium	7	0.19178082	12	84	0.00
		High	0	0	0	0	0.00
14	Rail bypass	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
15	Rutting	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
16	Shoving	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
17	Slippage cracking	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
18	Swelling	Low	0	0	0	0	0.00
		Medium	0	0	0	0	0.00
		High	0	0	0	0	0.00
19	Weathering and raveling	Low	10	0.2739726	2	20	0.29
		Medium	201	5.50684932	15	3015	44.40
		High	0	0	30	0	0.00
						6790.5	

Technical evaluation (PCI on the pavement)

According to sampling and use of this information in MicroPAVER software, the rate of PCI, which referred the pavement condition index, was extracted for four pavement levels. Results are presented in Figure (1).

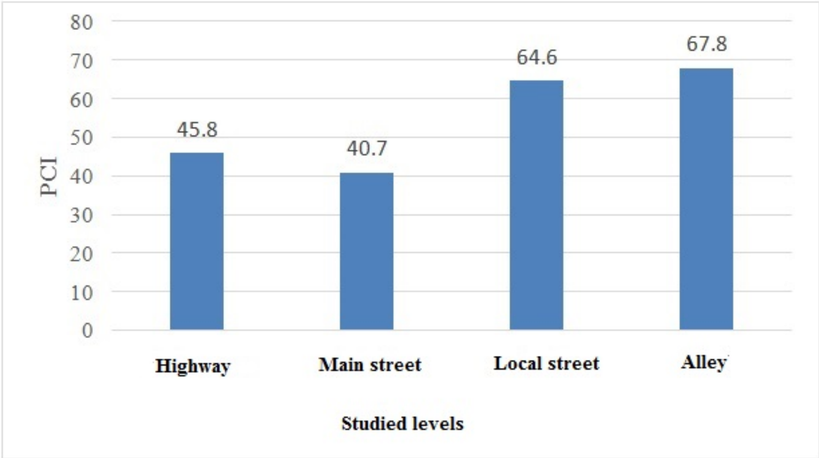

Figure 1- PCI for the pavement

The following measures are suggested for different levels of pavement using results of the above figure as well as recommendations related to each value of the PCI in the Figure (2) and Table (5).

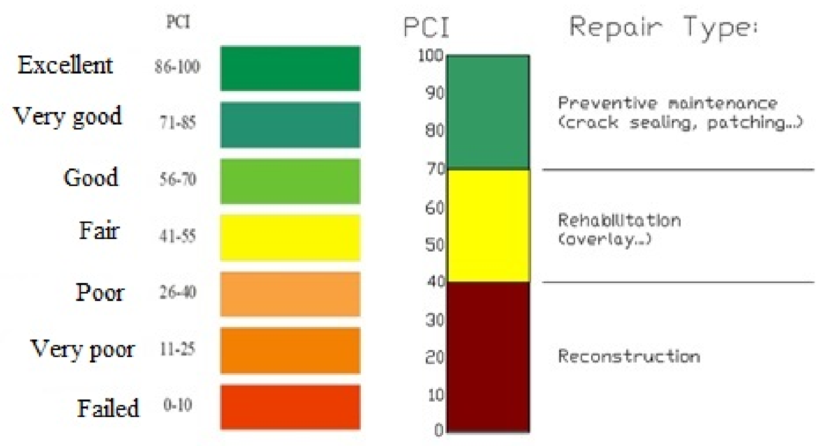

Figure 2- Proposed measures to maintain the pavement proportional to PCI values

1. Given that the rate of PCI on the highway is less than the minimum value of 50 for arterial roads, there is a need to use a new procedure in this place by taking a sample of main surface. Since the most distress in this area are weathering and crocodile cracks, it is suggested avoiding cold weather pavement and using the appropriate percentage of bitumen in the plan to prevent weathering deterioration.

Table 5- Decision matrix **of the** PCI

Importance duration	Highway	Arterial road	Collector road	Local street
Sufficient	>85	>85	>80	>80
6-10 years	76-85	76-85	71-80	66-80
1-5 years	66-75	56-75	51-70	46-65
Repair	60-65	50-55	45-50	40-45
Reconstruction	<60	<50	<45	<40

2. For the main street pavement, as the PCI rate is less than 45, there is a need for repair through taking some parts of the pavement and application of a new coverage or deep patching. However, prior to coverage, repairs should be done on the surface to prevent reflection of distress to newly repaired surface in the future.

3. For local streets and alleys, as the PCI rate is proper for the next 1 to 5 years, there is no need for major repairs in this

section as well as preventive measures such as sealing, etc. in this section to maintain the pavement condition at the current level.

Economic assessment

Based on the results of decision matrices in Table (5), the following suggestions are presented for four groups.

1. Alley

The PCI rate for alleys is equal to 67.8 indicating the good and almost good condition; hence, this passageway does not require much repair, and a partial sealing and restoration of pavement is proposed to prevent the expansion of distress area. The cost of minor repair is obtained for Vahdat neighborhood (alley) according to estimates of Ardabil municipality team for 2013 and based on Table (6). Its computational references are presented together with concluded contracts in the appendix.

2. Local Street

For local streets, the PCI value is equal to 64.6 which similar to alleys is in the favorable condition in terms of pavement; and its repair and restoration cost is according to Table (6). The experience of Ardabil municipality indicates that when the provision of materials (borrow pit) is made by the municipality, and the rehabilitation and restoration works are assigned to contractors, the quality of implemented pavement is far better than the other conditions. In this regard, supervisors should help to improve the pavement implementation quality by accurate qualitative control.

Table 6- Maintenance and repair costs for Alley (Vahdat neighborhood)

	Area (m^2)	**Type of repair operation**	**Operation cost per cubic meter**	**Total cost**
Sample 1	182.5	Sealing and minor repair	20000	3650000
Sample 2	182.5	Sealing and minor repair	20000	3650000
Sample 3	182.5	Sealing and minor repair	20000	3650000
Sample 4	182.5	Sealing and minor repair	20000	3650000
Total				14600000

3. Main Street

For main streets, the PCI rate is equal to 40.7. The rehabilitation of pavement surface is proposed as a solution. The cost of repair and restoration of the main street is estimated for the main street (located in the Ostad Shahriar neighborhood) according to estimates of Ardabil municipality team for 2013 according to Table (7). Its computational references together with concluded contracts are presented in the appendix.

Table 7- Maintenance and repair costs for the main street (Ostad Shahriar neighborhood)

	Area (m^2)	**Type of repair operation**	**Operation cost per cubic meter**	**Total cost**
Sample 1	182.5	Patching	66000	12045000
Sample 2	182.5	Patching	66000	12045000
Sample 3	182.5	Patching	66000	12045000
Sample 4	182.5	Patching	66000	12045000
Total				48180000

4. Arterial road

In arterial roads, due to the lack of proper handling of the pavement because of limited funding in Ardabil municipality since the previous years and the transit of heavy vehicles (city belt), its PCI rate is equivalent to 50, and thus taking the coverage and building a new coverage is proposed as a solution.

Conclusion

Results of the present research are as follows:

1. The distress taken at 4 levels of pavement indicated that the surface distress was the most common and effective type of distress.

2. Among the surface distress, the weathering distress was more important than other types of distress due to the nature of cold weather in the region, the inappropriate quality, and low bitumen consumption in the asphalt mixture. To solve this problem, the research suggested applying standard requirements in regulations for production of asphalt by installing laboratory units equipped with asphalt production plants, using bitumen in accordance with cold weather conditions, deploying a quality control unit at the site of asphalt production, and minimizing human intervention in the asphalt production by deploying advanced devices.

3. There were abundant crocodile cracks on the pavement caused by inappropriate and non-technical substructure in the past years. These cracks indicated the worn-out asphalt pavement due to the vehicle movement and the use of inappropriate equipment for snow removal during the cold seasons. To compensate for this defect, the research

suggested precise and laboratory control of mechanical characteristics of bedding materials and substructure (observance of the grain size range, the Liquid Limit (LL), the Plastic Limit (PL), the load bearing capacity of materials, the Sand Equivalent (SE), etc.), prohibiting the transport of heavy vehicles at alleyways, and using advanced and light snow removal machines.

4. Entering the collected data into MicroPAVER software, it was observed that there was a need for basic repair and reconstruction operations on highways and main streets with PCI of fewer than 50. In this reconstruction, the quality of consumed materials and bitumen should be evaluated according to AASHTO standards. The cost of reconstruction and restoration of pavement was equal to 66,000 Rials for the main street and 90.850 Rials for the arterial roads and it was predicted that those costs are resulted from the imposed high cost of the municipality and the improper pavement management.

5. In alleys and local streets, because of suitable PCI conditions, there is no need to repair for upcoming 5 years, but preventive measures such as patching and sealing should be done during this period. The cost per square meter of the pavement was estimated equal to 20000 Rials which was 20% of the figure spent on the arterial roads.

Suggestions

1. Investigating the pavement conditions in Ardabil by distress-taking vehicles and determining other pavement parameters such as IRI, RN.

2. Providing a model for forecasting the future pavement condition after major repairs using the HDM4 software.

3. Evaluating the application of concrete pavement in cold regions and comparing its maintenance costs with conventional asphaltic pavement.

4. Investigating the pavement conditions of Ardabil suburban roads as a case study with the pavement management system.

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