

Causes of Cracks and Deterioration of Pavement on Highways in Jordan from Contractors' Perspective

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Abstract

Pavement deterioration is a serious problem for road and traffic highway sector in Jordan. The allocated cost for construction of new roads, replacement and rehabilitation, and maintenance was 292.1 M JD in the implementation program (2007-2009) and 192.2 M JD in (2011-2013). The current research aims to describe the most affecting causes for road deterioration in Jordan by a questionnaire designed and directed to contractors in road construction and maintenance. A list of causes was prepared through conducting literature review, consulting and interviewing a group of 15 managers from contractors and experts in the field, they advised to study 51 of expected causes for road deterioration. Then a questionnaire was prepared and directed to 150 of contractors in road construction and maintenance. The mission was involving to give a scale (rank) from 1 (strongly disagree), 2 (disagree), 3 (do not know), 4 (agree), and 5 (strongly agree) to the expected causes. 38 (25.33%) responses were received and analyzed. The criterion (defects caused during construction due to poor construction quality) takes the highest rank of 4.15, while the lowest factor is (Inadequate resistance to polishing of surface aggregate) of 2.73. Also, the causes for deterioration were reorganized into 11 consistent groups of relevant causes. The first group (Effect of Cracks and Structural Failure) ranks 3.96 and the last group (Effect of Pavement Width) ranks 2.93 in group comparison. The research is helpful in highlighting the causes for road deterioration in Jordan, and in avoiding of these causes or mitigating their effect during design, construction, and maintenance through operation.

Keywords: Deterioration, defects, road construction, road maintenance, highway

1. Introduction

The developing countries have lost precious infrastructure worth billions of dollars through the deterioration of their roads. If they do not immediately begin to do much more to preserve their roads, they will lose billions more. In Jordan the cost for road construction and maintenance consumed about 292.1 M JD in the implementation program (2007-2009) and about 192.2 in (2011-2013). Large roads networks, built at great expense, have been under maintained and more heavily used and abused than expected. If this neglect continues, the deterioration of roads will accelerate as old pavements crumble and new ones outlive the initial period during which the effects of neglect are barely noticeable (CSIR 1997). The cost of restoring these deteriorated roads is going to be three to five times greater than the bill would have been for timely effective maintenance and restoration is only part of the cost.

A comprehensive literature review was conducted with literature related to both local and international context to determine the road deterioration factors, road defects, and causes of cracks and deterioration etc. in both locally and foreign countries. Furthermore, the literature review presents many factors which lead to highway pavement crack and deterioration as discussed below.

Road deterioration is very common in developing countries. Keeping roads in good condition is the most cost-effective way to save Jordan's highways. The accurate prediction of rutting development is an essential element for the efficient management of pavements systems. Okikbo (2012) refers to road defects as the visible evidence of an undesirable condition in the pavement affecting serviceability, structural condition or appearance. He also indicates that the definition of "road defect" includes any part of a road, highway, or construction site that does not meet the regulations for a safe road. In addition to that; in his paper on road defects in Nigeria he indicates that the defects that most often cause injuries to people or damage to vehicles include: inadequate road shoulders, lanes that are uneven, pavement that is uneven, improperly marked signs, malfunctioning stop lights, construction negligence, and municipal negligence.

Traffic volume and size (especially for overloading) contributes to road safety and conditions. Recognizing of vehicles' uses and applications (industrial transports) is the key for decreasing road deterioration. Legal framework and transportation management are the national aims in decreasing road deterioration (Nordenegen and Oberholtzer, 2006).

Kaare, Kuhl and Koppel (2012) emphasized that flexible pavements deteriorate under traffic loads and climate effects. This effect depends on the technology and materials of the road, but the greatest effects depend

on traffic loads and volumes. Abhijit (2011) investigate the effect of poor drainage on road condition and found that the increase in moisture content decreases the strength of the pavement. Therefore, poor drainage causes the premature failure of the pavement. On the same line, pavement tends to crack at some point of their life under the combined action of traffic and the environment and climate conditions (Wee et. al., 2009). Wisconsin Department of Transport investigates the pavement fatigue as a result of the number and weight of axle loads. They also discusses how wheel loads, number of truck axles, number of truck tires, quality of sub-grade, pavement thickness and changing seasons contribute to pavement fatigue.

In addition, climate conditions were seen to have an effect on road deterioration, vehicle operating costs, road safety and the environment (Anyala et.al. 2011). Transport Canada (2005) indicated that climate factors are a major cause for pavement deterioration. It is a fact that temperature, frost and thaw action as well as moisture are factors that can cause certain types of pavement deterioration (Transport Canada, 2005). These factors can also intensify pavement deterioration caused by heavy vehicles.

Harischandra (2004) found that potholes, cracks, edge defects, depressions and corrugation are significant road defects observed in the field. At the same time he emphasized that traffic, age, road geometry, weather, drainage, construction quality as well construction material, maintenance policy play the major role as road deteriorate agents. Korkiala-Tanttu and Daeson (2007) suggested that in the pavement or embankment, water plays a primary role in giving shorter service life and in increasing the need of rehabilitation measures.

Abdulkareem and Adeoti (2004) examined the method of road maintenance in Nigeria. To do so, they defined and analyzed the causes of structural failure of highway pavement and suggest some factors; action of weather, rain and heat, unstable ground conditions and poor drainage, poor construction material and methods, post construction activities like digging of trenches along the road etc., poor workmanship and inadequate maintenance. On his study on Nigeria highway, Okido (2012) has indentified some of the factors that cause highway failure. These factors were; poor design and construction, poor maintenance of already built highways, use of low quality materials in construction, poor workmanship and poor supervision of construction work and the applying of heavy traffic that were not meant for the road. Furthermore, he also suggest that the following will lead to highway failure such as; poor highway facilities, no knowledge base, in adequate sanction for highway failure, no local standard of practice, poor laboratory in situ tests on soil and weak local professional bodies in highway design, construction and management.

However, it is clear that highway pavement globally deteriorate for a number of reasons and factors as indicated earlier. Jordan highway is no exception and may deteriorate due to these reasons. Therefore, understanding the causes for highway pavement failures is essential and important step towards minimizing risks to good performance. An intensive literature review revealed a list of 51 factors that may lead to highway pavement cracks and deterioration.

The current paper aimed on identifying the factors that cause the deterioration of highway in Jordan and establishing their relative importance for consultants and main road contracting firms. However, a questionnaire was designed including the 51 factors to examine these factors and ascertain their important index.

2. Research Methodology

Current research mainly focuses on the factors influencing the highway pavement performance. Based on previous researches and face-to-face interviews for Jordanian firms in road construction and maintenance, a collection of 51 items were mentioned by different researchers and contractors expected to causes pavement cracks and deterioration. A questionnaire was designed including these causes for road deterioration. The design questionnaire was preliminary presented to a group of expertise in questionnaire design. At the same time the suggested 51 which were seen to lead to pavement deterioration reviewed by 15 individuals; 5 of each party involved in a highway project construction and maintenance, i.e., from clients, consultant and contractors firms.

The final copy of the questionnaire was sent out to 150 respondents selected from a pre prepared list of experienced engineers from main contractors' firm.

2.1 Sampling Frame

A national, cross industry study investigating the concept of road deterioration in the context of Jordanian road construction industry was undertaken. A sampling frame was prepared from the Construction Contractors Directory in Jordan 2012 which provides a detailed list of Jordanian contractors. The aim was to generate a list of (150) respondents who were involved in the implementation of the construction and maintenance of roads. The list includes one key or senior manager from each of the top 150 Jordanian contractors specialized in road construction and maintenance.

The exploratory nature of the study obliged the selection of a judgmental sample. This indicated that one key or senior individual was judged to be a reliable source of information on their organizations' activities than lower-ranking managers (Philips (1981). In concord with Philips' conclusion Patterson et al. (1997) reported that one key respondent is appropriate if he/she has a senior or ownership position. They added that

such respondents and their direct involvement in their organizations' "boundary-spanning activities" qualify them to respond on behalf of their companies. Conant et al. (1990) indicated that "in the face of time and resources constraints the single informant approach allows for a large number of organizations to be surveyed". Likewise Patterson et al. (1997) stated that it would be very difficult to hunt multiple respondents over several months and it may decrease the response due to respondents changing functions within the company; leaving the company altogether or becoming too busy to continue participation.

However, a senior respondent approach was selected to obtain data for a number of reasons. First, care was taken to ensure that the respondent has a senior occupation, knowledge and they were suitable and willing to participate in the study. Generally the respondents occupy senior positions in their organizations such as owners, chairman, managing directors, executives, directors, and senior managers.

2.2 Procedures of Data Collection

Giving the exploratory nature of the research, semi-structured, in depth literature review and in face-to-face interview was taken as the main instruments to define the list for deterioration causes. Also an initial pilot interview was conducted through interviewing 5 construction firms selected randomly to have the initial perception about the research aim and methodology.

A semi-structured interview was selected in order to set a framework and not to deviate from the main research topic due to the lack of understanding and different interpretations of those concepts from the people working within Jordanian road construction and maintenance. It was also appropriate to start with a relaxed discussion of such new topic to Jordanian road construction, i.e., detecting of road deterioration causes. However, at the beginning of each interview respondent was told about the aims of the research. Further, all respondents were asked for their permission to record the interview and assured that their identity and the given information will remain confidential.

The interviews were taped, transcribed and analyzed to determine the common themes and key phrases related to respondents' general perceptions and assessments of their activities in construction and maintenance of roads in Jordan.

Then a questionnaire was designed for the purpose of data collection following through the deep literature review and thorough consultation with 15 Jordanian construction firms (5 contractors, 5 clients, and 5 consultants). The designed questionnaire was conducted and checked through the same consultancy group i.e. 15 construction firms. The questionnaire includes information about the research aim and procedure that was explained through the introduction of the questionnaire. Then the questionnaire was sent to the selected experienced personnel from the construction firms of (150) Jordanian contractors chosen from the directory of Jordanian Contractors.

After the data collection stage, again the random group of 5 construction firms was contacted to evaluate the satisfaction about the aim and the methodology of the research.

2.3 Design of the Questionnaire

For an interview which required the minimum possible time from each interviewee, taking into consideration the nature of the interviewees, semi-structured in-depth face-to-face interviews were considered appropriate for the first exploratory phase of this study as explained earlier.

Given the exploratory nature of the research and the sparse literature on road deterioration, open ended questions were used to identify the most important aspects of the research topic and to seek any relevant suggestions from the participants. Therefore, a national, cross road construction investigating the concepts of road deterioration was undertaken. A sampling frame was prepared from the Construction Contractors Directory in Jordan (2012).

The research questions, related to the research objectives, were directed toward experienced and senior managers within contractors' organization who were specifically involved in the construction and maintenance of road and highway sector.

Following the same framework adapted by Parasuraman et al. (1985) and Baker and Lamb (1993); respondents were asked to give background information for themselves and their companies. They also asked to rank each of the 51 items that may cause road deterioration on a five point likert scale.

2.4 The Pilot Interviews

Piloting is essential for any research to enhance the reliability and validity of the finding of the main research. Initially (5) firms involved in the provision of contracting services were contacted randomly. The aim was to aid our understanding of how to define and perceive deterioration at a time where nothing has been published about in Jordanian road deterioration, except worldwide literature review about deterioration.

Based on the results of the piloting interviews, the main data collection technique was modified to take into account the suggestions made by the interviewees. By doing so the authors hoped that the interview questions became face valid, and therefore, ready to be used in the main data collection stage through the in depth face-to-face interviews (15 construction firms) and through the designed questionnaire.

The pilot interview was conducted at the end of data collection by consulting the same random group of the 5 construction firms to go over data collected by the questionnaire for more satisfaction before starting analysis.

2.5 Collected Data of Questionnaire from Contractors' Perspective

Sample of contractors for road and highway construction and maintenance was selected from the directory of The Jordanian Association of Construction Contractors (150 contractors), piloting group of 5 random construction firms, and the exploratory group (15 contractors) were interviewed and consulted to design the questionnaire, then finally the full group of 150 contractors were asked to fill the questionnaire, a 38 responses were received (25.33%), Table 1 illustrates frequencies of responses and ratios considering contractors' experience.

Table 1 Frequencies and Ratios for Contractors'" Response

Experience (Years)	Frequency of Responses	% of Responses
2 to 5	14	36.84
6 to 9	5	13.16
10 to 13	8	21.05
14 to 17	3	07.90
> 18	8	21.05
Sum	38	25.33

3. Road Deterioration Individual Factor Ranking

The questionnaire includes the 51 of factors related to road deterioration and ordered randomly. Contractors responded by giving a scale from 1 (strongly disagree), 2 (disagree), 3 (not known), 4 (agree), 5 (strongly agree) to these factors depending on their experience for expecting the importance of a specific factor for road deterioration. Then the weighted average was calculated for each factor using contractor's given response scale (from 1 to 5) and contractor's experience using the following equation.

$$F_{\text{average}} = (\sum F_i \times X_i) / \sum X_i \quad \text{Equation (1)}$$

Where F_{average} is the calculated average for the factor of deterioration and indicated as individual rank, F_i is the rank (from 1 to 5) given to the factor of deterioration by contractor in the questionnaire, and X_i is the experience in years for the contractor.

3.1 Contractor Individual Factor Rank

Contractors' individual ranking for factors related is illustrated in Table 2, ordered from the most important to the lowest important as received by respondents and calculated via equation (1). It seems that the factor (Defects caused during construction due to poor construction quality) takes the highest rank of 4.15, followed by the factor (Structural failure of Portland cement concrete base) that takes 4.01, and poor highway facilities of 4 as the maximum 3 factors that came at the top causes for road deterioration. The lowest factor rank is (Inadequate resistance to polishing of surface aggregate) of 2.73 in the contractors' individual rank. The rest of results are presented in Table 2.

Table 2 Contractors' Factors Rank for Road Deterioration

Causes Road Cracks and Deterioration	Individual Rank
Defects caused during construction due to poor construction quality	4.15
Structural failure of base	4.01
Poor highway facilities	4
Seepage of water through asphalt to break bond between surface and lower layers	3.92
Poor supervision	3.92
Weak, loose layer immediately under laying seal	3.9
Construction joint or shrinkage crack (due to low temperature or bitumen hardening) in asphalt surfacing	3.87
Poor maintenance policy / culture	3.84
Reflection of a shrinkage crack or joint in an underlying base	3.81
Poor local standard of practice	3.75
Inadequate sanctions for highway failure	3.73
Poor laboratory and in situ tests on soil	3.73
Poor climate condition	3.64
Large axial traffic loading	3.62
Low stiffness base and poor material	3.61
Ice and snow	3.57
Large traffic volume using the road	3.56
Shrinkage & fatigue of brittle base or wearing course	3.55
Inadequate cleaning or inadequate tack coat before placement of upper layers	3.55
Inferior asphalt mix design	3.53
Weak seal coat, loss of adhesion to base	3.52
Inadequate compaction in surfacing or sub / base	3.49
Inadequate rolling before opening to traffic	3.48
Inadequate compaction, construction during wet or cold weather	3.46
Deterioration of binder and / or stone	3.46
Aging or absorption of binder	3.41
Stone deterioration	3.4
Inadequate strength (stability) in surfacing or base	3.4
Fatigue cracking of AC wearing course	3.39
Poor alignment of the road	3.36
Inadequate pavement thickness	3.32
Poor drainage design system	3.31
Hydrophilic aggregate	3.28
Lack of containment of pavement edge	3.26
Alignment which encourages drivers to travel on pavement edge	3.23
Inadequate base thickness	3.22
Poor bond between pavement layers	3.2
Low knowledge base	3.2
Poor material quality on sub / base layers	3.2
Low binder content	3.19
Use of naturally smooth uncrushed aggregate	3.18
Poor binder to stone adhesion	3.16
Incorrect blending of binder	3.08
Shrinkage & binder oxidation in AC or sprayed surfacing due to effect of age and environment	3.07
Edge Drop-off	3.06
Poor geometric design of the road	3.05
Inadequate sub base thickness	2.98
Inadequate pavement width	2.95
High ground water level	2.9
Inadequate edge support	2.8
Inadequate resistance to polishing of surface aggregate	2.73

Table 3 presents some statistical descriptions for the factors of road deterioration, it has 25 (50%) of factors above the mean, 35 (69%) above the mode, and 25 (50%) above the median, and standard deviation of 0.33.

Table 3 Statistical Parameters for Road Factors deterioration

Statistical Parameter	Value	Factors > Value
Mean	3.43	25
Mode	3.22	35
Median	3.41	25
Standard Deviation	0.33	
Sample elements (n)	51	

3.2 Road Deterioration Grouped Factor

The factors related to road deterioration basically are parts of partial groups (relevant factors gathered in one group). These groups include (1) Effect of Cracks and Structural Failure, (2) Effect of Standards/Specifications and Policy, (3) Effect of Traffic Load and Volume, (4) Compaction of Layers During Construction, (5) Effect of Bond Between Layers, (6) AC Properties and Effect of Construction Conditions, (7) Effect of Drainage System and Ground Water, (8) Aggregate Properties, (9) Effect of Alignment and Geometry of Road, (10) Flexible Pavement Layer Thickness, and (11) Effect of Pavement Width. The rank for each group is calculated by taking the average of the factors or elements in the same group. Table 4 presents the group factors of Effect of Cracks and Structural Failure.

Table 4 Effect of Cracks and Structural Failure Group for Road Deterioration

Cause of Road Cracks and Deterioration	Effect of Cracks and Structural Failure	
	Individual	Contractor
Reflection of a shrinkage crack or joint in an underlying base	3.81	3.96
Construction joint or shrinkage crack (due to low temperature or bitumen hardening) in asphalt surfacing	3.87	
Structural failure of base	4.01	
Defects caused during construction due to poor construction quality	4.15	

Table 5 presents the Effect of Standards/Specifications and Policy Group, this group rank 3.71, and the group is interested in the standards, specifications, sanctions and supervision, tests during construction, and maintenance program.

Table 5 Effect of Standards/Specifications and Policy

Cause of Road Cracks and Deterioration	Effect of Standards/Specifications and Policy	
	Individual	Contractor
Low knowledge base	3.2	3.71
Poor highway facilities	4	
Inadequate sanctions for highway failure	3.73	
Poor local standard of practice	3.57	
Poor supervision	3.92	
Poor laboratory and in situ tests on soil	3.73	
Poor maintenance policy / culture	3.84	

Table 6 presents the Effect of Traffic Load and Volume, the group ranks 3.59, the group includes traffic load and traffic volume.

Table 6 Effect of Traffic Load and Volume Group on Road Deterioration

Cause of Road Cracks and Deterioration	Effect of Traffic Load and Volume	
	Individual	Contractor
Large axial traffic loading	3.62	3.59
Large traffic volume using the road	3.56	

Table 7 presents the group of Compaction and Construction, the group ranks 3.46 and related to compaction and construction.

Table 7 Compaction and Construction Group

Cause of Road Cracks and Deterioration	Compaction and Construction	
	Contractor	
	Individual	Group
Inadequate compaction in surfacing or sub / base	3.49	3.46
Inadequate strength (stability) in surfacing or base	3.4	
Inadequate compaction, construction during wet or cold weather	3.46	
Inadequate rolling before opening to traffic	3.48	

Table 8 presents the Effect of Bond between Layers group, the group ranks 3.43, and the group represents bond between layers, surface contact of bitumen, and aggregate and filler material.

Table 8 Effect of Bond Between Layers

Cause of Road Cracks and Deterioration	Contractor	
	Individual	Group
Poor bond between pavement layers	3.2	3.43
Low binder content	3.19	
Poor blinder to stone adhesion	3.16	
Incorrect blending of binder	3.53	
Aging or absorption of blinder	3.41	
Weak seal coat, loss of adhesion to base	3.52	
Weak, loose layer immediately under laying seal	3.90	
Inadequate cleaning or inadequate tack coat before placement of upper layers	3.55	

Table 9 presents Asphalt Cement (AC) Properties and Effect of Construction Conditions. The content of bitumen in the flexible pavement has two issues: the first is the quantity of AC, and the second is the weather conditions that should be faced by improving the properties of bitumen.

Table 9 AC Properties and Effect of Construction Conditions

Cause of Road Cracks and Deterioration	Contractor	
	Individual	Group
Shrinkage & fatigue of brittle base or wearing course	3.55	3.41
Fatigue cracking of AC wearing course	3.39	
Shrinkage & binder oxidation in AC or sprayed surfacing due to effect of age and environment	3.07	
Poor climate condition	3.64	
Ice and snow	3.57	

Table 10 presents the Effect of Drainage System and Ground Water, the group ranks 3.38. Road deterioration in some cases is due to the accumulation of water on road surface that seeps into pavement layers, because of inadequate drainage system, and/or because of the absence of sectional, and/or longitudinal slopes.

Table 10 Effect of Drainage System and Ground Water

Cause of Road Cracks and Deterioration	Contractor	
	Individual	Group
Poor drainage design system	3.31	3.38
Seepage of water through asphalt to break bond between surface and lower layers	3.92	
High ground water level	2.9	

Table 11 presents the group of Aggregate Properties, the group has the rank of 3.24, the group also presents the strength and soundness of aggregate, which is function of stone origin or type, such as crushed limestone or round natural aggregate.

Table 11 Aggregate Properties

Cause of Road Cracks and Deterioration	Aggregate Properties	
	Contractor	
	Individual	Group
Stone deterioration	3.4	3.24
Low stiffness base and poor material	3.61	
Poor material quality on sub / base layers	3.2	
Deterioration of binder and / or stone	3.46	
Hydrophilic aggregate	3.28	
Inadequate resistance to polishing of surface aggregate	2.73	
Use of naturally smooth uncrushed aggregate	3.18	
Inferior asphalt mix design	3.06	

Table 12 presents the group of Alignment and Geometry of Road that ranks 3.21. The geometry and alignment of road is important to protect the surface and section of the road. The elements of geometry and alignment should be met during design phase of highway.

Table 12 Effect of Alignment and Road Geometry

Cause of Road Cracks and Deterioration	Effect of Alignment and Geometry of Road	
	Contractor	
	Individual	Group
Alignment which encourages drivers to travel on pavement edge	3.22	3.21
Poor alignment of the road	3.36	
Poor geometric design of the road	3.05	

Table 13 presents the Flexible Pavement Layers Thickness that ranks 3.14, the thickness of layer is standard and must be met in design and construction, so it should not be a cause for road deterioration when met in accordance with standards and specifications.

Table 13 Pavement Layers Thickness

Cause Road Cracks and Deterioration	Flexible Pavement Layers Thickness	
	Contractor	
	Individual	Group
Inadequate pavement thickness	3.32	3.14
Inadequate base thickness	3.22	
Inadequate sub base thickness	2.98	

Table 14 presents the group of Effect of Pavement Width that ranks 2.93 at the last rank of all groups. It should not be a point of discussion that should the pavement width greater than the width of vehicle plus a separate space, or should the pavement have an enough support edge, or should the pavement have enough shoulders or embankment.

Table 14 Effect of Pavement Width

Cause of Road Cracks and Deterioration	Effect of Pavement Width	
	Contractor	
	Individual	Group
Inadequate pavement width	2.95	2.93
Inadequate edge support	2.28	
Edge drop-off	3.23	
Lack of containment of pavement edge	3.26	

5.2.1 Summary of Grouped Deterioration Factor of Contractor Response

Table 15 presents the rank for the group factor of contractor response at road deterioration. The effect of cracks and structural failure has the maximum rank of 3.96, while the effect of pavement width has the minimum rank of 2.93. The contractors see that the factors when covered by standards and specification will not have an effect on deterioration in road section as designer will give the minimum requirements for design and construction.

Road Deterioration Factor Group	Factors' Number in Group	Contractor Group Rank
Effect of Cracks and Structural Failure	4	3.96
Effect of Standards/Specifications and Policy	7	3.71
Effect of Traffic Load and Volume	2	3.59
Compaction and Construction	4	3.46
Effect of Bond Between Layers	8	3.43
AC Properties and Effect of Construction Conditions	5	3.41
Effect of Drainage System and Ground Water	3	3.38
Aggregate Properties	8	3.24
Effect of Alignment and Geometry of Road	3	3.21
Flexible Pavement Layers Thickness	3	3.14
Effect of Pavement Width	4	2.93
	51 Factors	Mean = 3.43

4. Data Analysis and Discussion

The study goal is to introduce a further understanding of the concept of road deterioration in the Jordanian construction of road sector. The contractors are one of the important parties in road and highways sector study and design, construction, and maintenance and operation. So their vision for road sector is reputable and taken in consideration in development process for the sector.

The individual contractor perspective ranking for causes of road deterioration in Jordan is presented in Table 2. It is seen from Table 2 that defects caused during construction due to poor construction quality takes the maximum rank of 4.15, followed by the structural failure of base that takes the rank of 4.01, and followed by poor highway facilities that takes the value of 4. On the other hand, the minimum rank was taken by (Inadequate Resistance to Polishing of Surface Aggregate) that takes the rank of 2.73. Also, the factors for road deterioration were organized into groups of relevant and homogeneous factors that have similar nature and/or effect. These groups are 11 of similar group-factor, and the group of (Effect of Cracks and Structural Failure) has the maximum rank of 3.96 and it has 4 factors in it. Followed by the group (Effect of Standards/Specifications and Policy) of 3.71 rank, and the final 11th group (Effect of Pavement Width) of 2.93 rank as presented earlier in Table 15.

5. Conclusion and recommendation

Road deterioration is a critical situation for road sector in Jordan because of the high cost for construction of new roads and maintenance of existing roads and routes. Contractors have a well knowledge and capacity to expect the place of errs and problems in the sector. According to the contractors, the cause for deterioration and defects in road sector is because of the followings:

A- Contractor Individual Rank for Factors:

Contractors see that the construction process is poor because of the specified quality for materials, and it has poor supervision.

- 1- The highway facilities are negligible or not exist including drainage systems and manholes and channels and other accessories such as handrails, and curbs because of the poor design and the high cost for construction and maintenance.
- 2- Poor maintenance policy, cracks in base, sanction system, local standards, supervision, laboratory tests, operation by high traffic volume and load, and construction in bad conditions are all causes for road deterioration.
- 3- High traffic axial load and volume is a cause for deterioration, and institutes and organizations in traffic highway and transportation areas should have to update rules and regulations and enforce their implementation in fact. Many of heavy traffic enter residential areas and takes unpermitted routes of roads and highways.
- 4- The prepared schedules for maintenance and construction usually start or happen during bad weather conditions at winter mainly.
- 5- Thicknesses of surface, base, and sub-base, width of pavement, geometry and alignment of road are direct causes for deterioration of road as they specified during design and preparation of contract documents, also construction operation is not an area for a question as it is a direct implementation and application for the specifications, standards, and contract documents.

B- Contractor Grouped Rank for Factors:

- 1- Structural failure of base, construction and shrinkage joints, defects caused during construction are causes for deterioration of road in crack and structural failure group.
- 2- Poor supervision, maintenance program, and tests during construction, poor local standards, highway facilities, and data base and sanction system are causes for deterioration of road, and should be updated and developed to keep up with the new requirements for construction.
- 3- Large traffic axial loading and volume also has a grouped rank of 3.59 among groups of factors.
- 4- Compaction during construction, bond between layers, and construction conditions rank 3.46, .43, and 3.41 respectively among groups.
- 5- Drainage systems, aggregate properties, align and geometry of road, layers' thicknesses, and pavement width are all ranking below the mean of the grouped factor.

6. Limitations and Requirement of the Study

During collection of data and analysis, many of problems raise up that include:

- 1- Not all contractors interviewed accept or able to give information clearly through the questionnaire.
- 2- The need to discover the opinion and perception of other parties in road construction and maintenance such as clients and consultants, that relevant information and data will be gathered in the future.

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