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Priority of Flexible Pavement Failure Criteria in Jordan in Accordance with Clients', Consultants', and Contractors' Views

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ABSTRACT

Pavement deterioration is a critical issue for roads and highways in Jordan, because of the interrelation between factors of deterioration and for the high budgeted cost for construction, replacement and rehabilitation, and maintenance of roads that is about 484.3 M JD in the implementation programs in the period from 2007 to 2013). The current research aims to describe the proposed causes for road deterioration in Jordan by an inception questionnaire conducted on an arbitrary sample of contractors, consultants and clients involved in road construction and maintenance, and to study the difference between clients, consultants, and contractors ranking for causes of road cracks and deteriorations.

A list of causes was prepared through literature review, consulting and interviewing a group of 30 managers from contractors and experts clients in the field, they advised to study 51 of expected causes for road deterioration. Then a main questionnaire was directed to 150 of contractors, 150 of consultants and 150 of clients 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%) of contractors' responded, 50 (33%) of consultants responded, and 47 (31.33%) of clients' responded and data was sorted and analyzed. According to the contractors ranking, 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. While according to the clients' ranking, the criterions poor highway facilities took the highest rank of 4.13, and the lowest rank was for ground water level of 2.964. Considering the consultant, the highest rank was taken by the factor (inadequate sanctions for highway failure of 4.35), while the lowest rank was the factor (ice and snow effect of 3.29, and alignment which encourages drivers to travel on pavement edge of 3.29 also. The consultants and clients are consistent in their inceptions of 100%, and consultants agree with contractors in 82.4% (42 of 51). Clients and contractors are consistent in their inception of 90.2% (46 of 51) of factors. It seems that researchers and academics can consider the inception of any party to have their recommendations, suggestions, and proposals for the purpose of the study or any other similar study in the field.

Keywords: Deterioration, Defects, Road Construction, Maintenance, Highway, Pavement)

INTRODUCTION

Road construction and maintenance is an important desire for development especially in developing countries. Market accessibility, economic growth, natural resource exploitation, habitat fragmentation, deforestation, and the disappearance of wild lands and wildlife are all related to road existence and status. Road constructed and maintained that collapsed upon the need of local society and their extension in country. Also the priority of investment (political needs, industrial stations, or agricultural habitats and zones) is addressed when decision usually taken for new construction of road and for maintenance (Wilkie et.al. 2000).

Road transport is the moving engine for other sectors and activities in development countries. It provides access to industry, agriculture, investment, health services, and education through providing of goods and passengers. And the lack for god roads or the existence of poorly maintained or poor conditions of roads are barriers to development and investment in developing countries. 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).

The cost for inspection of road status is very high, complicated operation, and unsafe for working team especially on major roads and main routes. Also the visual inspection by map is not accurate only but for small scale range. There is a strong relation between the ground spectrometry, imaging spectrometry, and in situ pavement conditions and quality indicators (pavement condition index). Road aging, and material composition (defects and cracks and status of material) is related to spectral characteristics of road section that enable from mapping road conditions. Pavement condition of aging and erosion of the hot mix asphalt results in a gradual change from hydrocarbon to mineral absorption characteristics, with a general increase in brightness and changes in distinct small-scale absorption features. Structural road damage (e.g., cracks) indicates a contrary spectral variation. Cracking decreases the brightness and emphasizes hydrocarbon absorption features. The spectrometry testing is more sensitive and useful on new roads of early stages of deterioration rather than on old roads (Herold and Roberts, 2005).

The accurate and sensitive prediction of rutting development is an essential element for the efficient management of pavements systems by proper testing and maintenance to keep road in a good condition. Road defects are the visible evidence of an undesirable and avoidable condition in the pavement affecting serviceability, structural condition or appearance, performance and function. Also, 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; road defects are the most often cause injuries to people or damage to vehicles that include: inadequate road shoulders, lanes that are uneven, pavement that is uneven, improperly marked signs, malfunctioning stop lights, construction negligence, and municipal negligence (Okikbo, 2012).

Kaare, Kuhi and Koppel (2012) pointed that flexible pavement deteriorates under the effect of traffic loads and climate. This effect depends on the technology applied in material construction and application on the road, but the greatest effects depend on traffic loads and volumes proposed to be repeated on road section. Abhijit (2011) investigated 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.

It is obvious that roads globally deteriorate for several reasons. Roads and highways in Jordan are not exception, and deteriorate under the effect of the same reasons. So, the recognizing of causes for cracks and deterioration in road system is the first step in putting successful maintenance program that will keep roads and highways in good conditions. A concentrated literature review explored a list of 51 of causes for cracks and deterioration that were studied from contractors' perspective (Tarawneh and Sarireh, 2013) and currently studied from client perspective recalling results from contractors and clients perspective.

The current research aims on identifying the proposed factors that cause the deterioration of highway in Jordan from client perspective comparing them with the contractors' perspective and establishing their relative importance for the use by consultants and main road contracting firms. A questionnaire was designed including the 51 factors to examine these factors and ascertain their important index from client's perspective.

The current research highlights the factors for cracks and defects in highways and roads in Jordan from clients' perspective and comparing them with contractors' perspective (Tarawneh and Sarireh, 2013). The work will help in prioritizing the relevant importance for these factors to improve the programs for effective maintenance and surveying defects of highways and roads in future.

1. RESEARCH METHODOLOGY

Current research mainly highlights the factors proposed to have an effect on the highway pavement performance. Based on previous studies and face-to-face interviews for Jordanian firms in road construction and consultancy and operation, a list of 51 factors were proposed to have an effect on pavement performance and defects according to researchers and contractors in road construction. A questionnaire was prepared including these factors for road cracks and defects. The prepared questionnaire was initially presented to a group of experts in questionnaire preparation. Instantaneously, the proposed 51 factors which were recommended to cause pavement deterioration reviewed by 30 individuals; 10 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, consultants, and operational clients and firms in Jordan. The final step is to analyze the priority (importance) of the 51 factors according to the ranking given to these factors (from 1 to 5) by clients, and then comparing them with contractors ranking conducted in previous research.

2. PROCEDURES AND DATA COLLECTION

A sampling frame was prepared of clients, contractors, and client operators for traffic highways and roads in Jordan including engineers in consultancy, construction, and operational firms in Jordan. In addition to the consultation conducted with The Jordanian Association for Construction Contractors. The aim was to generate a list of (150) respondents who were involved in the operation of the construction and maintenance of roads. The list includes one key or senior manager from each of the top 150 Jordanian engineers and superintendents in consultants, contractors, and client operators' firms specialized in operation of road construction and maintenance.

To compensate the lack in information and knowledge for respondents, an in-depth literature review and in face-to-face interview was taken as the main instruments to recognize the list for deterioration factors. Also an initial interview was done through interviewing 5 construction firms selected randomly to have the initial perception about the research aim and methodology.

Then, a questionnaire was prepared for collecting data in parallel to the in-depth literature review and consultation with 15 Jordanian construction firms (10 contractors, 10 clients, and 10 consultants). The designed questionnaire was reviewed with the same consultancy group i.e. 30 construction firms. The questionnaire includes information about the research aim and procedure that will be followed in the questionnaire. Then the questionnaire was sent to the selected 150 experienced personnel from the contractors, consultants, and client operators' firms in Jordan.

Finally, collected data was reviewed with the consultancy group against satisfaction of aim and methodology to start analysis for the importance given for factors of cracks and deterioration for highways and roads in Jordan according to clients' perspective.

3. RESULTS OF ROAD DETERIORATION PROPOSED FACTORS

A sample of 150 personnel of managers, engineers, designers, supervisors, and superintendents were selected randomly in consultancy offices and services. 50 (33%) of questionnaires were received back from consultants. Table 1 presents the characteristics of consultants' response.

Table 1 Frequency and Ratio of Consultants Responses

Experience (Years)	Frequency of Responses	% of Responses
2 to 5	7	14
6 to 9	12	24
10 to 13	14	28
14 to 17	4	8
> 18	13	26
Sum	50	100.00

4. Road Deterioration Individual Factor Ranking

The questionnaire includes the 51 of factors related to road deterioration that were ordered randomly. The personnel in the Consultants, contractors firms, and client operators 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 the consultant's, contractors and client's given response scale (from 1 to 5) and clients, contractors, and consultant's personnel experience using the following equation.

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

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 client's personnel in the questionnaire, and X_i is the experience in years for the client's personnel.

Then the client's group factors is calculated by taking the average of factors covered under one group and factors ($F_{average}$) are related to each other; thickness group factors, traffic group factors, architecture group factor, etc.

Also, a comparative step between client, contractor, and consultant individual factor rank and will be conducted on the means of all ranks given by client, contractor, and consultant using the inference about the different in means (The Tukey Kramer Procedure), randomized design or simple comparative experiment . Following equations explain the procedure that will be applied in the calculations and results sections.

H_O: $\mu_1 = \mu_2 = \mu_3$ that all means are the same according to the null hypothesis against the rejection hypothesis that at least will be one mean is not equal to the others.

μ_1 and μ_2 and $\mu 3$ are the means in the null hypothesis H_O that were replaced by the averages $\bar{y}1$ and $\bar{y}2$ and $\bar{y}_3$ for factor ranking given by the client, consultant, and contractor respectively, $\delta 1^2$ and $\delta 2^2$ and $\delta 3^2$ are the variances for factor ranking given by the client, consultant, and contractor, n_1 and n_2 and n_3 are the number of clients', consultants, and contractors' samples respectively, α is the confidence interval of 5% considered (Walpole et.al., 2007). Table 2 represents the required calculations for The Tukey Kramer's rule for making an inference about the averages of samples tested.

Table 2 Tuckey Kramer Procedure Calculations

Source of Variation	df	SS	MS (Variance)	*P*-value	F-Ratio
Between Groups	c-1	SSA	MSA	P(X=F)	$F = \frac{MSA}{MSW}$
Within Groups	n-c	SSW	MSW		
Total	n-1	SST = SSA+SSW			

Where c is the number of groups, and n is the sum of all samples in the groups, and df is the degree of freedom at the respective level. Then the null hypothesis will be rejected if F will be greater than F tabulated at α = 0.05. So Averages, $\bar{y}_1$, $\bar{y}_2$, and $\bar{y}_3$ and $\bar{y}_{Total}$ are calculated. The critical range is calculated using the following expression:

$$\text{Critical Range} = Q_U \sqrt{\frac{\text{MSW}}{2}\left(\frac{1}{n_j} + \frac{1}{n_{j'}}\right)}$$

, where Q_U is Value from Studentized Range Distribution with c and n - c degrees of freedom for the desired level of α, and MSW is the Mean Square Within n_j and $n_{j'}$ = Sample sizes from groups i and j. Then the absolute differences $\bar{y}_1$- $\bar{y}_2$, $\bar{y}_1$-$\bar{y}_3$, and $\bar{y}_2$-$\bar{y}_3$ are calculated and compared to the critical range and if the absolute differences are greater than the critical range, then there will be a significance differences between two pairs of means respectively.

The total sum of squares (SST) can be calculated using the following excepression:

$$SST = (x_{11} - \bar{\bar{x}})^2 + (x_{12} - \bar{\bar{x}})^2 + \ldots + (x_{kn_k} - \bar{\bar{x}})^2$$

Where X_{11} X_{12}, …., X_{kn} are measurements from populations, and $\bar{\bar{x}}$ is the grand mean (the mean of all data values). And k is the number of populations, and n is the number of data in the population.

$SST = \boxed{SSB} + SSW$ where SSB can be calculated as $SSB = \sum_{i=1}^{k} n_i(\bar{x}_i - \bar{\bar{x}})^2$ and $\bar{x}_i$ is mean of the population i. Then MSB = SSB/(k-1) is the mean squares between levels of populations. And the sum squares within population (SSW) is calculated by the following equation $SSW = \sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij} - \bar{x}_i)^2$. Following the calculation of the mean squares within level of populations MSW = SSW/(n-k). Finally to calculate the F statistics F=MSB/MSW, and estimating F of table using k-1 and n-k degrees of freedom at α = 0.05. if the

4.1 CONSULTANT INDIVIDUAL RANKING

The mean of consultant, client, and contractor individual ranking for factors of cracks and deterioration on highways and roads in Jordan are illustrated in Table 2 in a descending order for consultant ranking, and the respective ranking of client and contractors (Tarawneh and Sarireh, 2013 a & b). According to the contractors ranking, 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. While

according to the clients ranking, the criterions poor highway facilities, poor maintenance policy / culture, large axial traffic loading took the highest rank of 4.13, 4.1, and 4.09 respectively. And the lowest rank was for ground water level of 2.964 according to clients rank. And according to consultants the high rank was taken by the factor (inadequate sanctions for highway failure of 4.35) followed by (inadequate rolling before opening to traffic of 4.33) and the factor (poor supervision of 4.27), while the lowest rank in the consultant's opinion were the factors (ice and snow effect of 3.29, alignment which encourages drivers to travel on pavement edge of 3.29, and lastly poor climate conditions of 3.19). After applying the statistical comparison between the mean of client rank and the mean of contractor rank for the factors of cracks and deterioration, the results are presented in Table 2 in the last column. The Table results show that clients and contractors are inconsistent and disagree on 41 of the factors for cracks and deterioration to have the same (equal rank) or importance level, while they are agree on 10 of those factors for cracks and deterioration.

Table 3 Client's Factor Rank for Road Deterioration and Statistical Comparison with Contractor's Factor Rank

Cause for Cracks and Road Deterioration	Consultant Individual	Client Individual Rank*	Contractor Individual Rank*	Means' Test Statistics		
				μ_1, μ_2	μ_1, μ_3	$\mu_2 = \mu_3$
Inadequate sanctions for highway failure	4.35	3.94	3.73	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 = \mu_3$
Inadequate rolling before opening to traffic	4.33	3.71	3.48	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor supervision	4.27	4.07	3.92	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Defects caused during construction due to poor construction quality	4.19	4.05	4.15	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor highway facilities	4.19	4.13	4.00	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Structural failure of base	4.14	3.86	4.01	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Seepage of water through asphalt to break bond between surface and lower layers	4.14	3.84	3.92	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Incorrect Blending of Binder	4.14	3.78	3.53	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Inadequate compaction in surfacing or sub / base	4.14	4.04	3.49	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Shrinkage & fatigue of brittle base or wearing course	4.12	3.88	3.55	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 = \mu_3$
Poor material quality on sub / base layers	4.10	3.95	3.2	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Low stiffness base and poor material	4.06	3.91	3.61	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Fatigue cracking of AC wearing course	4.06	3.95	3.39	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Reflection of a shrinkage crack or joint in an underlying base	4.06	3.93	3.81	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor laboratory and in situ tests on soil	4.06	3.91	3.73	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor local standard of practice	4.06	3.94	3.75	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor maintenance policy / culture	4.04	4.10	3.84	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor geometric design of the road	4.04	3.87	3.36	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor drainage design	4.04	4.01	3.31	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$

system						
Weak seal coat, loss of adhesion to base	4.02	3.69	3.52	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Large axial traffic loading	3.98	4.09	3.62	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Low knowledge base	3.98	3.73	3.20	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Deterioration of binder and / or stone	3.96	3.78	3.46	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Aging or absorption of blinder	3.94	3.64	3.41	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 = \mu_3$
Inferior asphalt mix design	3.94	3.60	3.08	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 \neq \mu_3$
Shrinkage & binder oxidation in AC or sprayed surfacing due to effect of age and environment	3.92	4.04	3.07	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Inadequate base thickness	3.9	3.98	3.22	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor blinder to stone adhesion	3.9	3.57	3.16	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 = \mu_3$
Inadequate cleaning or inadequate tack coat before placement of upper layers	3.9	3.97	3.55	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 \neq \mu_3$
Poor alignment of the road	3.85	3.71	3.05	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Construction joint or shrinkage crack (due to low temperature or bitumen hardening) in asphalt surfacing	3.83	3.67	3.87	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Inadequate compaction, construction during wet or cold weather	3.81	3.92	3.46	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Weak, loose layer immediately under laying seal	3.81	3.60	3.90	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 = \mu_3$
Poor bond between pavement layers	3.81	3.88	3.20	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Large traffic volume using the road	3.78	3.78	3.56	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 \neq \mu_3$
Inadequate sub base thickness	3.75	3.82	2.98	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 \neq \mu_3$
Inadequate edge support	3.73	3.83	2.80	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Lack of containment of pavement edge	3.73	3.74	3.26	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 = \mu_3$
Edge Drop-off	3.72	3.55	3.06	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 \neq \mu_3$
Use of naturally smooth uncrushed aggregate	3.71	3.31	3.18	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Low binder content	3.69	3.81	3.19	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Inadequate strength (stability) in surfacing or base	3.69	3.75	3.40	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Inadequate pavement thickness	3.62	3.88	3.32	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Inadequate resistance to polishing of surface aggregate	3.62	3.33	2.73	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Hydrophilic aggregate	3.62	3.84	3.28	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Stone deterioration	3.56	3.19	3.40	$\mu_1 = \mu_2$	$\mu_1 \neq \mu_3$	$\mu_2 = \mu_3$
Inadequate pavement width	3.56	3.74	2.95	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$

High ground water level	3.39	2.96	2.90	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Ice and snow	3.29	3.08	3.57	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Alignment which encourages drivers to travel on pavement edge	3.24	3.54	3.23	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$
Poor climate condition	3.19	3.38	3.64	$\mu_1 = \mu_2$	$\mu_1 = \mu_3$	$\mu_2 = \mu_3$

***Contractor Individual Rank (Tarawneh and Sarireh (2013)**

Table 4 presents some statistical descriptions for the consultant factors' rank on road deterioration, it has 29 (57%) of factors above the mean, 11 (21.6%) above the mode, and 25 (50%) above the median, and standard deviation of 0.265.

Table 4 Statistical Parameters for Consultant Factor Rank on Road Deterioration

Statistical Parameter	Value	Factors > Value
Mean	3.886	29 (57%)
Mode	4.0577	11 (21.6)
Median	3.933	25 (50%)
Standard Deviation	0.265	
Sample elements (n)	51	

4.2 CONSULTANT GROUPED RANKING

Individual factor rank for cracks and deterioration given by the clients and operators of highways and roads in Jordan can be grouped together in specific groups depending on relations between these factors and according to the recommendations of the experts consulted in this research. Table 5 presents the group of effect of standards/specifications and policy, the group scores 4.136 which is the average of factors in the group.

Table 5 Group of Effect of Standards/Speccifications and Policy in Client's Factor Rank

Effect of Standards/Specifications and Policy		
Cause of Road Cracks and Deterioration	**Consultant**	
	Individual	**Group**
Inadequate sanctions for highway failure	4.35	4.136
Poor supervision	4.27	
Poor highway facilities	4.19	
Poor local standard of practice	4.06	
Poor laboratory and in situ tests on soil	4.06	
Poor maintenance policy / culture	4.04	
Low knowledge base	3.98	

Table 6 presents the Effect of traffic load and volume group, the group ranks 3.88, and the group is interested in the capacity of traffic and the volume of traffic. It seems the traffic load and volume that have a high priority for clients and operators.

Table 6 Traffic Load and Volume Group in Consultant Rank

Effect of Traffic Load and Volume		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Large axial traffic loading	3.98	3.88
Large traffic volume using the road	3.78	

Table 7 presents the Effect of flexible pavement layers' thicknesses, the group ranks 3.757, and the group includes thickness of pavement's layers. Even though the design can control the thickness of layers, but clients still see the issue of material thickness is highly important.

Table 7 Flexible Pavement Layers' Thicknesses in Client Rank

Flexible Pavement Layers Thickness		
Cause Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Inadequate base thickness	3.9	3.757
Inadequate sub base thickness	3.75	
Inadequate Pavement Thickness	3.62	

Table 8 presents the group of cracks and structural failure, the group ranks 4.055 and related to reflection of cracks, construction joints, failure in base, and defects during construction.

Table 8 Group of Cracks and Structural Failure in Client Rank

Effect of Cracks and Structural Failure		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Defects caused during construction due to poor construction quality	4.19	4.055
Reflection of a shrinkage crack or joint in an underlying base	4.14	
Structural failure of base	4.06	
Construction joint or shrinkage crack (due to low temperature or bitumen hardening) in asphalt surfacing	3.83	

Table 9 presents the group of Compaction and Construction, the group ranks 3.993 and related to compaction and construction of sub-base and base layers and weather conditions during construction.

Table 9 Effect of Compaction and Construction

Compaction and Construction		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Inadequate rolling before opening to traffic	4.33	**3.993**
Inadequate compaction in surfacing or sub / base	4.14	
Inadequate compaction, construction during wet or cold weather	3.81	
Inadequate strength (stability) in surfacing or base	3.69	

Table 10 presents the Effect of Bond between Layers group, the group ranks 3.9, and the group represents bond between layers, surface contact of bitumen, and aggregate and filler material.

Table 10 Effect of Bond Between Layers

Effect of Bond Between Layers		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Poor bond between pavement layers	3.81	**3.9**
Low binder content	3.69	
Poor blinder to stone adhesion	3.9	
Incorrect blending of binder	4.14	
Aging or absorption of blinder	3.94	
Weak seal coat, loss of adhesion to base	4.02	
Weak, loose layer immediately under laying seal	3.81	
Inadequate cleaning or inadequate tack coat before placement of upper layers	3.9	

Table 11 presents the group of Effect of Pavement Width that ranks 3.685 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 11 Effect of Pavement Width

Effect of Pavement Width		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Lack of containment of pavement edge	3.73	3.685
Inadequate edge support	3.73	
Edge drop-off	3.72	
Inadequate pavement width	3.56	

Table 12 presents the group of Alignment and Geometry of Road that ranks 3.7. 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 Geometry of Road

Effect of Alignment and Geometry of Road		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Poor geometric design of the road	4.04	3.7
Poor alignment of the road	3.85	
Alignment which encourages drivers to travel on pavement edge	3.24	

Table 13 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 13 Effect of AC Properties and Construction Conditions

AC Properties and Effect of Construction Conditions		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Shrinkage & fatigue of brittle base or wearing course	4.12	3.716
Fatigue cracking of AC wearing course	4.06	
Shrinkage & binder oxidation in AC or sprayed surfacing due to effect of age and environment	3.92	
Ice and snow	3.29	
Poor climate condition	3.19	

Table 14 presents the group of Aggregate Properties, the group has the rank of 3.781, 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 14 Effect of Aggregate Properties

Effect of Aggregate Properties		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Poor material quality on sub / base layers	4.1 3	3.781
Low stiffness base and poor material	4.06	
Deterioration of binder and / or stone	3.96	
Inferior asphalt mix design	3.94	
Use of naturally smooth uncrushed aggregate	3.71	
Inadequate resistance to polishing of surface aggregate	3.62	
Hydrophilic aggregate	3.62	
Stone deterioration	3.56	

Table 15 presents the Effect of Drainage System and Ground Water, the group ranks 3.857. 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 15 Effect of Drainage System and Ground Water

Effect of Drainage System and Ground Water		
Cause of Road Cracks and Deterioration	**Client**	
	Individual	**Group**
Seepage of water through asphalt to break bond between surface and lower layers	4.14	3.857
Poor drainage design system	4.04	
High ground water level	3.39	

5.3 Summary of Grouped Deterioration Factor of Client and Contractor Response

Table 16 presents the rank for the group factor of client response at road deterioration. The effect of standards/specifications and policy has the maximum rank of 4.136, while the effect of pavement width has the minimum rank of 3.685. The consultants see that the standards and specifications are important to be considered in design and construction and have an effect on deterioration in road section as designer will apply the minimum requirements for design and construction. Also, the table presents the relevant client, and contractor

group factor respectively. Another important point of view that by conducting the difference in means of consultant, clients and contractors group factor, the test statistics gives that the means are different in some of the group factors as presented in the table.

Table 16 Grouped Deterioration Factor of Client and Relevant Contractor Grouped Factor

Road Deterioration Factor Group	Factors' Number in Group	Consultant Group Rank	Client Group Rank*	Contractor Group Rank*	Group Mean Test Statistics
Standards/Specifications and Policy	7	4.136	3.975	3.71	$\mu_1 = \mu_2 = \mu_3$
Cracks and Structural Failure	4	4.055	3.877	3.96	$\mu_1 \neq \mu_2$
Compaction and Construction	4	3.993	3.855	3.46	$\mu_1 \neq \mu_3$ $\mu_2 \neq \mu_3$
Bond Between Layers	8	3.9	3.721	3.43	$\mu_1 \neq \mu_3$ $\mu_2 \neq \mu_3$
Traffic Load and Volume	2	3.88	3.936	3.59	$\mu_1 = \mu_2 = \mu_3$
Drainage System and Ground Water	3	3.857	3.625	3.38	$\mu_1 \neq \mu_3$
Aggregate Properties	8	3.7814	3.635	3.24	$\mu_1 = \mu_2 = \mu_3$
Flexible Pavement Layers Thickness	3	3.757	3.893	3.14	$\mu_1 \neq \mu_3$ $\mu_2 \neq \mu_3$
AC Properties and Construction Conditions	5	3.716	3.665	3.41	$\mu_1 = \mu_2 = \mu_3$
Alignment and Geometry of Road	3	3.71	3.706	3.21	$\mu_1 = \mu_2 = \mu_3$
Pavement Width	4	3.685	3.715	2.93	$\mu_1 \neq \mu_3$ $\mu_2 \neq \mu_3$
Sum	**51 Factors**	3.861	3.782	3.43	

***Tarawneh and Sarireh, 2013.**

5. DISCUSSION AND CONCLUSIONS

The study aims to introduce the perspective and vision of the parties of road construction (consultants, clients and contractors). All parties have different interests and areas to be considered during design, construction, and operation and maintenance.

According to the consultant ranking, it seems that inadequate sanctions for highway failure (4.35), inadequate rolling before opening to traffic (4.33), Poor supervision (4.27), Defects caused during construction due to poor construction quality (4.19), Poor Highway Facilities (4.19), and Structural Failure of Base 4.14. While the following factors have the lowest rank which they are: Inadequate pavement width (3.56), High ground water level (3.39), Ice and snow (3.29), Alignment which encourages drivers to travel on pavement edge (3.24), Poor climate condition (3.19).

By testing the difference in means of individual ranks of factors studied by consultants, contractors and clients respectively, differences between consultants and contractors are existent in Shrinkage & fatigue of brittle base or wearing course, Inadequate sanctions for highway failure, Aging or absorption of blinder, Inferior

asphalt mix design, Poor blinder to stone adhesion, Inadequate cleaning or inadequate tack coat before placement of upper layers, Weak, loose layer immediately under laying seal, Lack of containment of pavement edge, Edge Drop-off, Stone deterioration (i.e. consultants and contractors are agreed on 80% of factors and disagreed on 20% of factors).

While contractors and clients are disagreed in 10% of the factors that include: Inferior asphalt mix design, Inadequate cleaning or inadequate tack coat before placement of upper layers, Large traffic volume using the road, Inadequate sub base thickness, and Edge Drop-off. And they are agreed on the rest of factors in 90% of factors and cases.

In the group rank consultants and clients have differences in ranking Cracks and Structural Failure. Consultants, clients, and contractors have differences in ranking Compaction, Construction, Bond between Layers and Flexible Pavement Layer Thicknesses, and Pavement Width. On the other hand; consultants and contractors have differences in Drainage System and in Ground Water Level.

The clients have interests differs from contractors during design (specifications and standards, tests, and cost). Also, they have different interests during construction including specifications, supervisions, cost, material properties, and adequacy of structure design and performance). Because of the difference of interests between clients and contractors, the need appears for a mediator such as an engineer or/and consultant to have the mission of quality control and quality assurance and to close the gap between two parties.

6. RESEARCH LIMITATIONS

Even though, the current research has useful results for the parties of road construction and maintenance as it conducted a completed program that included consultants, clients, and contractors, the research has some faults and shortcomings:

1- Even the confidence of information and data are guaranteed, not all contractors, clients and consultants accept to give personal or/and subjective information and data about their perspective in road deterioration.

2- Highway construction materials, soil, weather, and ground water level have great effects on the road deterioration in roads in Jordan, as the study implemented on different areas in Jordan.

3- The need for new geographical and detailed study is a point of priority to cover the difference in construction materials, soils, weather, and ground water level clearly.

4- The study needs to determine the level of road and highway in terms of the existing facilities including furniture, drainage systems that include channels and culverts, and the adequacy of these systems.

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