Evaluation of Road Pavement Maintenance by Contract in Jordan

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ABSTRACT

In this research, road pavement maintenance by contract in Jordan was investigated. For this purpose, a subjective procedure (the Present Serviceability Rating (PSR)) was used to evaluate pavement serviceability. Three major highways (Jarash-Amman highway, Naour-Dead Sea highway and Zarqa-Syrian borders highway) that were maintained by contract were selected. The developed data base included information on pavement characteristics, traffic type and volume and routine maintenance cost. The effect of maintenance cost on pavement serviceability was estimated by developing a statistical relationship between maintenance cost and pavement serviceability rating before and after maintenance. The results showed that the pavement serviceability of Jarash-Amman highway and Naour-Dead Sea highway was adversely affected after applying maintenance by contract. The pavement serviceability of Zarqa-Syrian borders highway was slightly improved after applying maintenance by contract, but the improvement was not up to expectations. It is believed that the reasons for such results are a combination of the contractor's poor experience and qualification and the timing of maintenance where the pavement was left without maintenance until it reached fair or poor condition.

Keywords : Maintenance, Contract, Pavement , Highway, Serviceability.

INTRODUCTION

As the nation's highways age and deteriorate, some types of treatment is eventually required to provide a safe and serviceable facility for the users. The types of treatments can range from simple maintenance to complete reconstruction, it also may be performed in different ways, among which is maintenance by contract. Regardless of the type and method of treatment, maintenance strategies should be based on accurate understanding of pavement condition and maintenance needs (Khader, 1991). Furthermore, maintenance function objectives should be expanded to accommodate

the increased operational requirements due to the numerous increasing numbers of motor vehicles using the highway networks. Due to this fact, it is believed that the function objectives of maintenance should include (Transportation Research Board, 1986); maintaining the investments spent on constructing the highway facilities, keeping adequate levels of service, decreasing the operating costs of the users and increasing the safety of the traveling public.

In both developed and developing countries, maintenance of highway networks was mainly the responsibility of the government direct labor. The inefficiency of the direct labor operation encouraged the decision makers to involve the private sector in highway maintenance. Not only this, but increasing the size and scope of operations of private sector involvement in

highway maintenance became a priority in many developing countries (International Labor Organization, 2004). Highway agencies in many developed countries have successfully switched from direct labor to contract

maintenance. Different approaches were adopted worldwide in implementing maintenance by contract (Parkman et al., 2001).

Table 1. Distribution of the Evaluated Pavement Sections.

Highway	Number of Sections	Average Width of Sections (m)	Total Length of Sections (m)
Na'our-Dead Sea	20	3.6	44700
Amman-Jarash	22	3.6	45330
Zarqa-Syrian Borders	32	3.7	61000
Total	74		151030

Table 2. Distribution of the Evaluated Pavement Sections that Received Maintenance.

Highway	Number of Sections	Average Width of Sections (m)	Total Length of Sections (m)
Na'our-Dead Sea	6	3.6	16400
Amman-Jarash	10	3.6	27330
Zarqa-Syrian Borders	6	3.6	17600
Total	22		61330

Among the developing countries that tried to switch to maintenance by contract is Jordan. Highways in Jordan have dramatically developed since 1950. The total length of the highway network increased from 895 kilometers in 1950 to 7304 kilometers in 2002 (Ministry of Housing and Public Works, 2003). Jordan applied maintenance by contract for the first time in 2001. The maintenance of three primary highways was carried by local contractors (one year, unit price-based contract); Na'our-Dead Sea highway, Amman-Jarash highway and

Zarqa-Syrian borders highway (two years, unit price-based contract) (Ministry of Housing and Public Works, 2003).

BACKGROUND

Types of Maintenance by Contract

Unit Price Contract: It is the most widely used method for delivery of highway maintenance services, with a clearly defined estimate of quantities, but some

flexibility is allowed for payment of amount of work significantly beyond those estimated originally. In a survey conducted in Belgium, Brazil, France, Kenya, Malaysia, United Kingdom, Algeria, Canada (British Columbia), Chile and Pakistan, it was found that all these countries have procedure to include new items in the contract that are not originally included in it. Payment is based on actual quantities. Overall, the lowest price is the base for the selection of successful bidder (World Bank, 2004).

Table 3. Statistical Characteristics of the Selected Variables for Sections that Received Maintenance and for All Pavement Sections.

Highway	Age (years)		Sub-grade CBR Value (%)		Average Daily Traffic		Number of Trucks	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Na'our-Dead Sea	11.5	10-13	24.2	15-33	4258	3646-4870	1371	1307-1435
Amman-Jarash	10	-	41.4	15-51	52732	14145-91319	264	253-274
Zarqa-Syrian Borders	13.5	-	35.3	28-60	30442	8872-52952	4398	256-20107
All Highways	11.5	10-13.5	35.1	15-60	60426	3646-91319	565	253-20107

Table 4. Results and Statistical Characteristics Obtained for the PSR and Cost for Sections that Received Maintenance and for All Pavement Sections.

Highway	PSRb		PSRa		ΔPSR = PSRa-PSRb		Maintenance Cost (JD/lane-km)	
	Mean	σ	Mean	σ	Mean	σ	Mean	Range
Na'our-Dead Sea	2.93	0.60	2.75	0.47	-0.18	0.91	187.5	0-1281
Amman-Jarash	3.87	0.48	3.37	0.61	-0.50	0.80	261.8	0-1484
Zarqa-Syrian Borders	2.75	0.47	2.64	0.54	-0.11	0.31	161.0	0-1189
All Highways	3.13	0.7	2.89	0.62	-0.24	0.68	198.0	0-1484
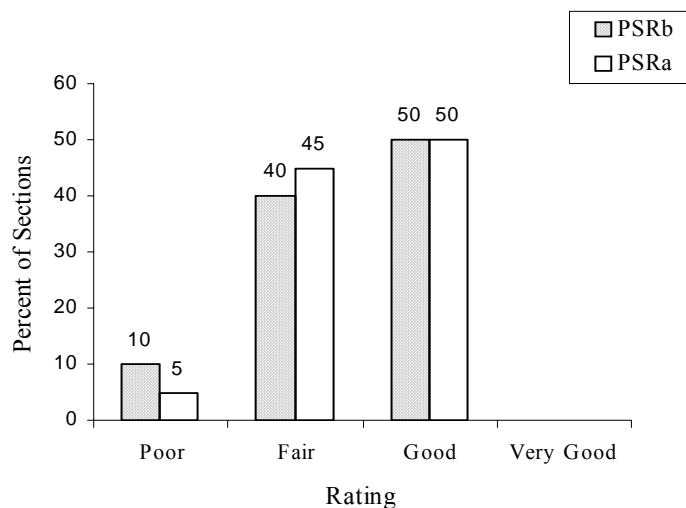
**Figure 1. Distribution of PSRb and PSRa for
Na'our-Dead Sea Highway.**
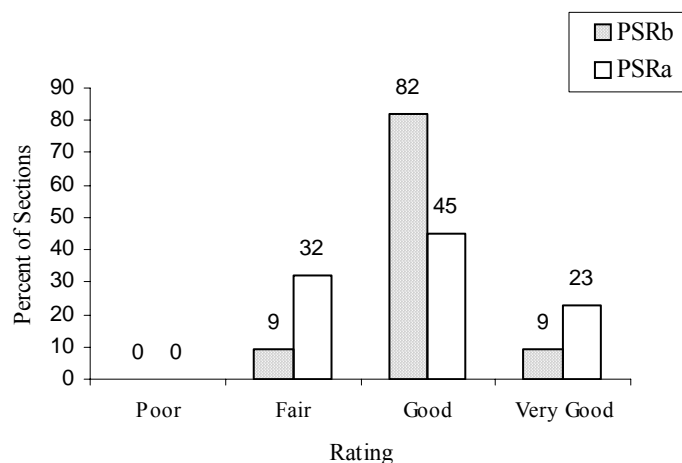
**Figure 2. Distribution of PSRb and PSRa for
Jarash-Amman Highway.**

Lump Sum Contracts (Performance Type): Few countries have adopted long-term performance type or results – based contracts instead of unit price-based short-term maintenance contracts. This approach includes either routine maintenance activities alone, or both the rehabilitation and routine maintenance of highway network included in an integrated contract (Cabana et al., 1999).

Another form of performance-based contracts is the warranty-type contract. It is a total asset management contract while the contractor warranties the work for a long period of time, mostly about 20 years.

Cost Plus Contract: In cost plus contract, the contractor is paid the total cost of the maintenance works plus a stated percentage of profit. It was found out that the countries surveyed have been stopped to use this type of contract (i.e. Brazil) because it doesn't enhance productivity (World Bank, 2004).

The Hybrid Contract: The hybrid contract is a mixture of outcome and output based. The development of this model is considered in New Zealand as the stepping-stone to PSMC model. This model has been let with a 5 years tenure (2+1+1+1), with a performance review target required to be met for annual rollover (Hunter and Kyle, 2004).

Experience of Developed Countries

The contract maintenance activities are increasing in Canada, Great Britain and the United States of America. For example, in Great Britain the governmental maintenance organizations must bid against contractors for maintenance activities. Also, in the last few years the Ontario Ministry of Transportation and Communication in Canada has greatly increased the use of private contractors to provide winter maintenance. This ministry policy is to use maintenance by contract where financial analysis and assessment indicate that costs will be reduced .

Earl (2004) discussed the privatization program of the maintenance of highways and bridges which was announced by the government of British Columbia. The government was responsible for 47024 kilometers of highways, 2645 bridges and 2700 employees. The government offered four options for the employees and they must accept one of them: transfer to the private sector, stay with the government and accept to serve anywhere in any position, retire early or quit the governmental jobs. However, compensation pay was not available under any option.

In 1988, 2280 employees were transferred to the new road and bridge maintenance contractors, about 20 took early retirement, few resigned and only 20 stayed with the government. All of this was at the end of the process for the first round of contracts. Recently, the government

of British Columbia finished the fourth round of contracting a project of five year period with a cost of $1.5 Billion. In this round, 16 contracts were performed by companies owned by people who were employees of the government.

The Portuguese national highway agency model, called Design, Build, Finance and Operate (DBFO), was discussed by Fernandes and Viegas (Fernandes and Viegas, 1999). Six contracts were tendered under DBFO model, the total length of highways maintained was 830 km. The private sector under each contract constructed or upgraded a highway and maintained it for 30 years. In return, the concessionaire would be paid by the agency according to the number of vehicle-kilometers driven on the highway.

The Australian experience in maintenance by contract was described by Frost and Lithgow (Frost and Lithgow, 2004). After the success of the two pilot maintenance by contract projects, the Highway and Traffic Authority of New South Wales contracted the maintenance of a large proportion of the arterial highway network in Sydney, New South Wales. The Performance Specified Maintenance Contract (PSMC) was the type of contract used. The terms of the contract were that the contractor should reach a certain condition standard for a period of ten years in return for a fixed payment stream.

According to a USA study held in 1995 of 120 local governments, the results showed that 37 percent of cities used maintenance by contract for highway maintenance services. It was found that performing the highway maintenance by contract costs half as much as delivering the maintenance by agency personal and equipment (World Bank, 2004).

Experience of Developing Countries

In Ghana, most of the routine maintenance is performed under contract. At the beginning, the contract duration was two months, which created a lot of contracts which confuse the administrator. Therefore, the system changed to one-year contract to carryout all the routine maintenance of a group of highways, and by the beginning of the year the quantity of work is estimated (Parkman et al., 2001).

Harrel (1987) pointed to few successes in founding institution in the developing countries, which have the ability to sustain cost-effective highway maintenance with local resources although the World Bank assisted them. The lack of success is due to the absence of accountability in the maintenance organization (in other words the public sector normally carried out maintenance, also it is responsible for planning, controlling and executing maintenance). The public sector found it difficult to attract high quality staff because of low salaries and lack of pay incentives. Generally, low output occurs because of the lack of available equipments.

METHODOLOGY

In this research, the Pavement Serviceability Rating (PSR) is used to evaluate the pavement performance. This is a subjective method that reflects the comfort of the highway users. The RSR is the mean of individual ratings for a pavement section made by specialized panel of people. It was developed at the AASHTO Road Test (8) and currently used by the Ministry of Public Works and Housing (MPWH) in Jordan.

The three highways, which were maintained by contract in Jordan are Na'our-Dead Sea highway (45km), Amman-Jarash highway (46km), and Zarqa-Syrian borders highway (62 km), they are all primary highways. Each highway was divided into homogenous pavement sections according to the following variables; pavement structure (including materials and thicknesses), traffic volume and pavement age. Table (1) (Shdeifat, 2006) shows the distribution of all the evaluated pavement sections, while Table (2) (Shdeifat, 2006) shows the distribution of the evaluated pavement sections that received maintenance only. Table (3) (Shdeifat, 2006) presents the statistical characteristics of the selected variables for all sections, while Table (4) (Shdeifat, 2006) presents the statistical characteristics of the selected variables for the sections that received maintenance only.

The PSR rating in this study was done by a panel of five persons, each pavement section was evaluated by driving a passenger vehicle at the posted speed limit, then each section was rated by each member of the panel independently on a scale between 0 and 5. The PSR of the pavement section under evaluation is then determined as the mean value of the five ratings. The PSR mean values were used to evaluate the pavement serviceability as follows: failed if $(0 \le PSR \le 1)$, poor if $(1 < PSR \le 2)$, fair if $(2 < PSR \le 3)$, good if $(3 < PSR \le 4)$ and very good if $(4 < PSR \le 5)$. This procedure was performed on sections before maintenance by contract was being performed, and then repeated for sections that had received maintenance. The cost of maintenance in Jordan Dinars (JD) per lane kilometer was also estimated to investigate the effect of cost on pavement serviceability $(1 JD = 1.5 USD)$.

DEVELOPMENT OF MAINTENANCE COST MODELS

Using the curve estimation of Statistical Packages for Social Sciences (SPSS) software, and among different maintenance cost models tried, the cubic and linear models were found the best to fit the investigated highways as follows:

Maintenance Cost Model for Jarash-Amman Highway: For this highway, the best fit model found was the cubic model with R^2 value of 0.43. The developed model is shown in Equation (1).

$$PSRa = 3.576 + 0.0017 \times Cost - 7.303 \times 10^{-6} \times Cost^2 + 4.32 \times 10^{-9} \times Cost^3 \qquad (1)$$

Maintenance Cost Model for Zarqa-Syrian Borders Highway: For this highway, the best fit model found was a linear one with R^2 value of 0.68. The found model is shown in Equation (2).

$$PSRa = 1.971 + 3.248 \times 10^{-4} \times Cost \qquad (2)$$

Maintenance Cost Model for Na'our – Dead Sea Highway: For this highway, the best fit model was also found a linear one with R^2 value of 0.65. The found model is shown in Equation (3).
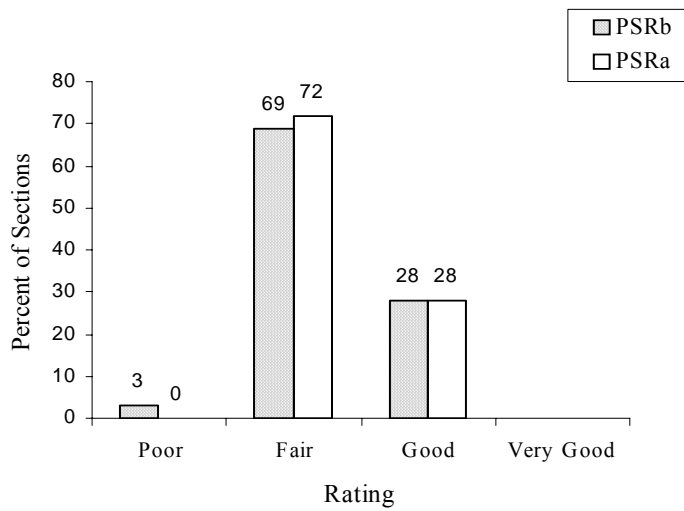
**Figure 3. Distribution of PSRb and PSRa for
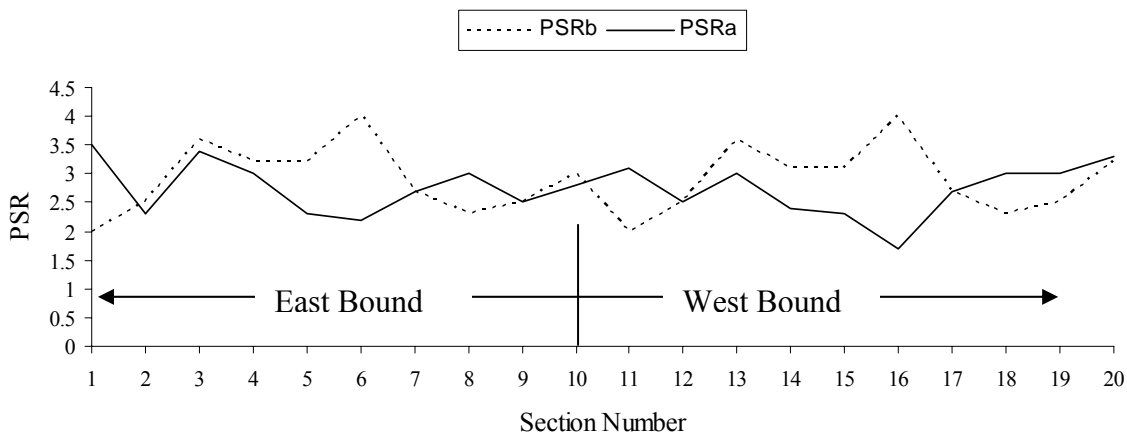Zarqa-Syrian Borders Highway.**

**Figure 4. PSRb and PSRa Versus Section Number for
Na'our-Dead Sea Highway.**

$$PSRa = 3.363 - 4.744 \times 10^{-4} \times Cost \qquad (3)$$

where:

PSRa = Present Serviceability Rating after maintenance
    (0-5).

Cost = Maintenance cost (JD/lane-km).

RESULTS

Results and statistical characteristics obtained for PSR before maintenance (PSRb), PSR after maintenance (PSRa), change in the PSR due to performing maintenance by contract (ΔPSR = PSRa-PSRb) and the cost of maintenance (JD/lane-kilometer) for all sections

are all illustrated in Table (5), while Table (6) shows them for the sections that received maintenance only. The distribution of PSRb and PSRa for Na'our-Dead Sea highway, Amman-Jarash highway, and Zarqa-Syrian Borders highway are shown in Figures (1,2 and 3), respectively. More details on PSRb and PSRa of each pavement section for the three highways are illustrated in Figures (4) through (9). In these figures, sections taken in North, South, East and West bounds are shown. This will clarify the sections that had improved after maintenance, and vice versa. The mean values of maintenance cost is illustrated in Table (5) for all investigated sections and for particular sections that had received maintenance.

Figures (7,8 and 9) illustrate the relationship between the maintenance cost for each individual section – if any - and the change in PSR before and after maintenance of all sections (North, South, West and East bounds) for Na'our-Dead Sea highway, Amman-Jarash highway, and Zarqa-Syrian Borders highway, respectively. These relationships will give a precise idea about the effect of maintenance cost on the serviceability of an individual pavement section.

When maintenance cost models is considered , it is important to mention that the Jarash-Amman highway model was found to be not statically significant, while the Zarqa - Syrian Borders highway, and the Na'our - Dead Sea highway models were found statistically significant at a level of $\alpha = 0.05$. Figure (10) shows a comparison among the developed maintenance cost models for the three investigated highways.

DISCUSSION AND CONCLUSIONS

General

A total 0f 74 pavement sections which varied in length from 800m to 9500m (total length of 151030m) were considered in this research. These sections represent three primary roads in Jordan. Of all the considered sections, around 82% were evaluated as follows; 100% of the sections were taken on Na'our Dead Sea highway, 91% of the sections were taken on Amman-Jarash highway and 62.5% of the sections were taken on Zarqa-Syrian Borders

highway. Sections that had received maintenance (61330m) represent 40.6% of all the considered sections, and around 49.4% of the evaluated sections. Only 27.4% (16800m) of the sections that had received maintenance were evaluated. In the evaluation process, the following variables were considered; PSRb, PSRa, ΔPSR, pavement age in years, Average Daily Traffic (ADT), Number of Trucks (NT), sub-grade CBR values and surface course thickness. The statistical characteristics of all the above mentioned variables (for the three investigated highways) are presented in Tables (3) and (4).

PSRb and PSRa

Figure (1) illustrates the PSR condition for Na'our-Dead Sea highway. It shows that none of the sections was in very good condition, not even after maintenance. 50% of the sections were in good condition before maintenance, this ratio remained the same after maintenance. A slight improvement took place after maintenance on sections that were in poor conditions, they were decreased from 10% before maintenance to only 5% after maintenance. For the fair category sections, a slight increase was noticed, the percentage was increased from 40% before maintenance to 45 % after maintenance.

When Jarash-Amman highway is considered (Figure 2), results showed that sections that were in good condition decreased from 82% before maintenance to only 45%, this is considered a significant decrease. An improvement in sections in the very good condition category took place, the percentage of sections had increased from only 9% before maintenance to 23% after maintenance. A better result was obtained for sections in the fair condition category, the percentage had increased from 9% to 32%.

Finally, for Zarqa-Syrian Borders highway, over and above, similar results were obtained. There were no sections in the very good condition category, not even after maintenance. Sections in the good condition category remained the same, that is 28%. A slight increase was recorded in the percentage of sections in the fair condition category, while sections in the poor condition category decreased from 3% to 0%.
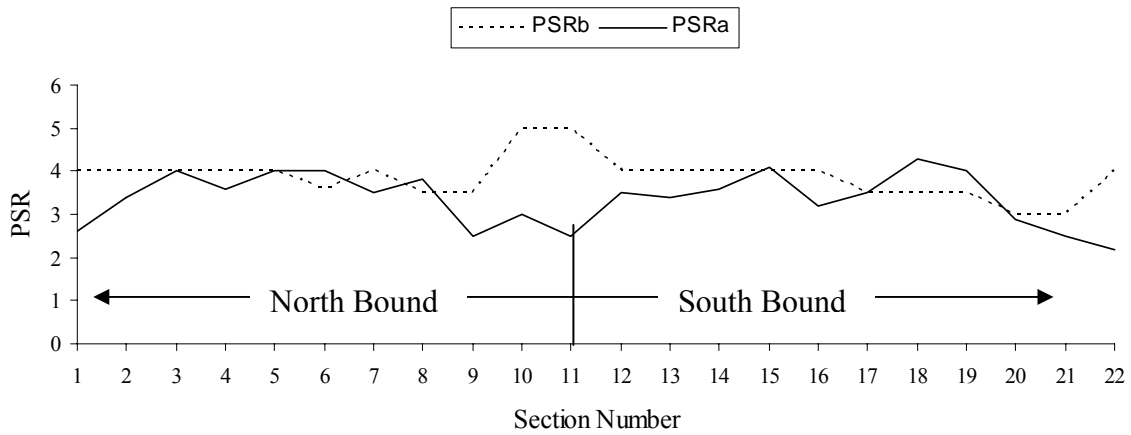
**Figure 5. PSRb and PSRa Versus Section Number for
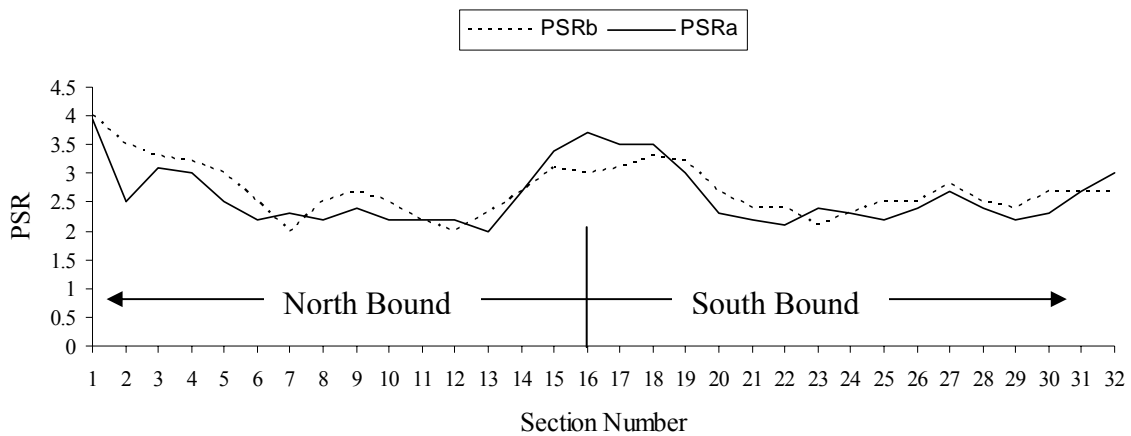Jarash-Amman Highway.**

**Figure 6. PSRb and PSRa Versus Section Number for
Zarqa-Syrian Borders Highway.**

Further discussion of the above results may lead to the following conclusions; a slight improvement took place in sections of poor and fair condition categories. It is believed that sections in poor and fair condition categories were left without maintenance for a very long time until they reached the poor to fair condition, this means that these sections were so much disturbing the users, and they need major maintenance work, thus, any sort of maintenance is better than nothing and may improve its condition regardless whether this maintenance was properly performed or not. It is important to mention that these sections are a minority when compared to sections in the good condition category.

What may be an evidence on the truth of the above conclusion is the situation of the sections in the good condition category which form the majority of all sections. The percentage of the sections in this category

remained the same or decreased after maintenance, or in other words, maintenance did not improve the condition of the pavement sections. Since these sections were in good condition before maintenance, the user was satisfied, and it is believed that any improper application of maintenance may appear and will be noticed by the user which in turn may decrease the condition category of the pavement section.
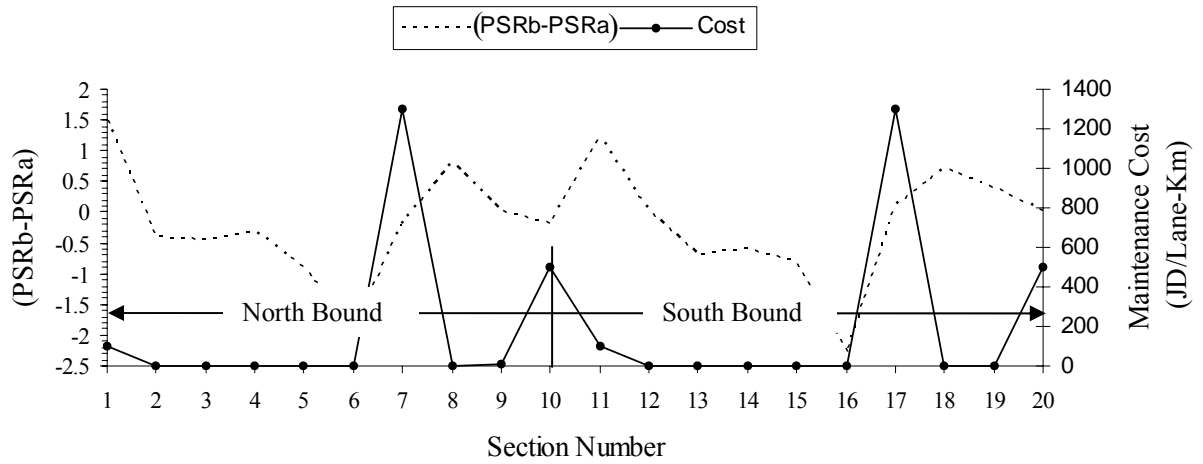

Figure 7. Relationship between Maintenance cost and ΔPSR for Na'our-Dead Sea Highway.

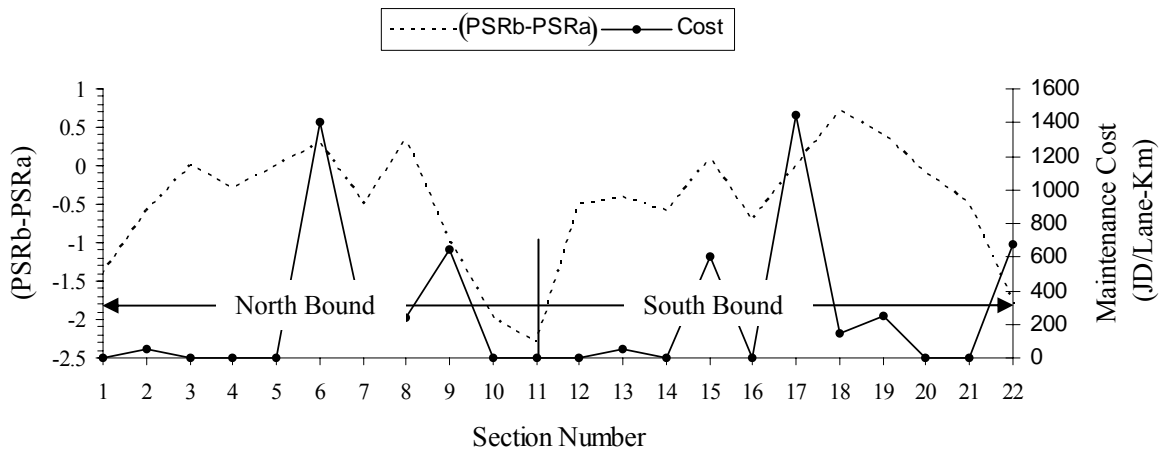

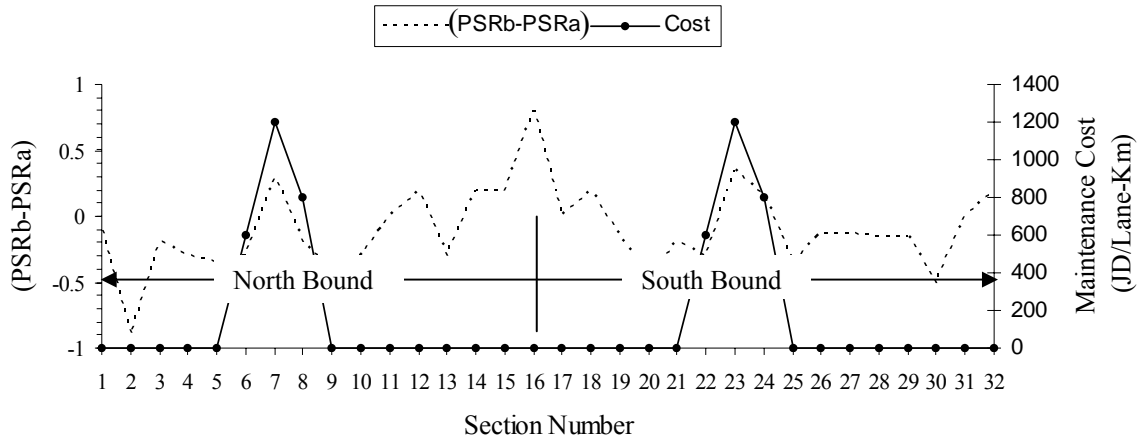**Figure 8. Relationship between Maintenance cost and ΔPSR for Amman-Jarash Highway.**

Figure 9. Relationship between Maintenance cost and ΔPSR for Zarqa-Syrian Borders Highway.

Finally, when sections of very good condition category is under focus, someone may say the following; these sections are in very good condition, and the maintenance work needed is so simple and limited. Because of this, there is no chance that maintenance work could be improperly performed. This will absolutely increase the satisfaction of the users. These sections were a minority in Jarash-Amman highway only, and may not be representative.

Figures (4,5 and 6) illustrate the PSRb and the PSRa for each individual section. It is clear that the PSRa is less than the PSRb for most of the sections. This complies with the above conclusions in term of that sections of good condition category - which form the majority of all the sections - remained the same or decreased. According to these figures, the decrease in the sections of good condition caused the increase in the percentage of sections of fair condition (this is clear for the case of Amman-Jarash Highway); that is the condition of most of sections in the good category was reduced to fair category after maintenance.

Effect of Maintenance Cost on Pavement Serviceability

Figures (7,8 and 9) illustrate the relationship between maintenance cost and ΔPSR. When ΔPSR is positive, it

means that the pavement section condition was adversely affected by maintenance and visa versa. As shown in the figures, many sections that were maintained had a positive ΔPSR, this means that these sections were adversely affected by maintenance. On the other hand, other sections were improved when applying maintenance. The degree of improvement depends on the cost of maintenance. Most of the sections that had received routine maintenance (low cost maintenance) did not improve. This finding supports the above mentioned conclusions.

Maintenance Cost Models

For Jarash-Amman highway, Figure (10) shows the predicted values of present serviceability rating after maintenance at different values of maintenance cost. In this figure, it is obvious that the effect of maintenance by contract on pavement serviceability depends not only on quality of maintenance but also on pavement condition. Routine maintenance is not effective when applied on pavement sections with poor condition because these sections need higher level of maintenance to achieve the required improvement. For Zarqa-Syrian Boarders highway, it is clear that maintenance cost affected pavement serviceability positively (Figure 10).
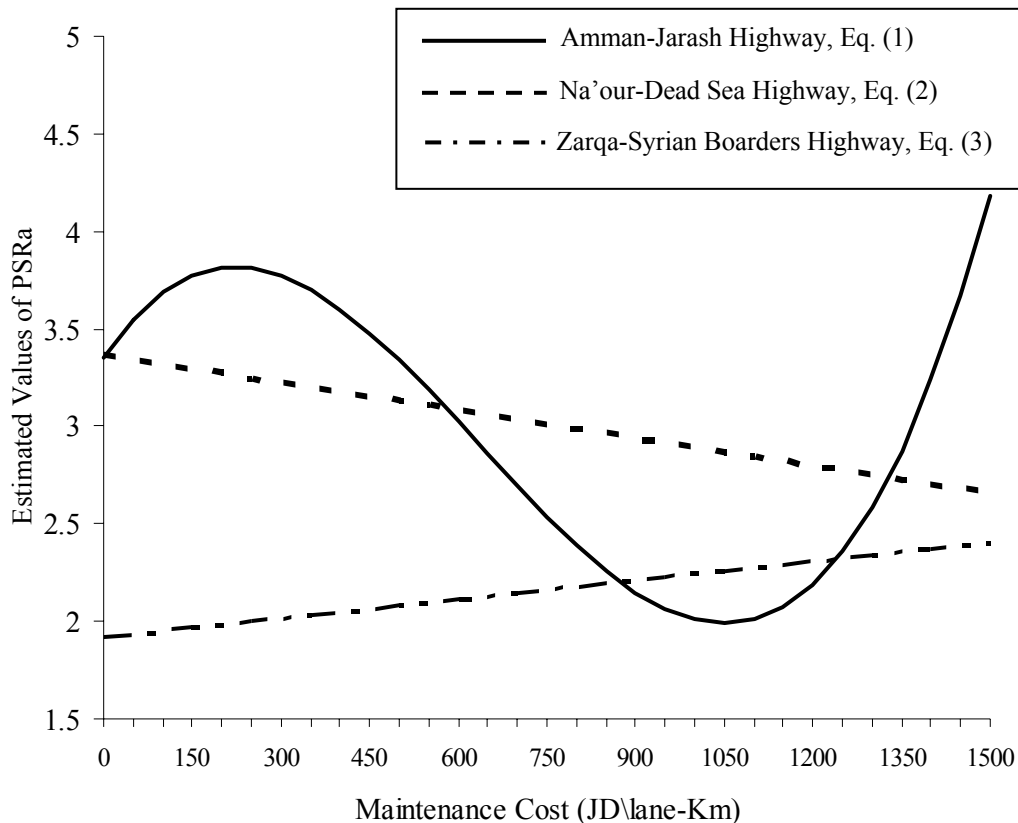
**Figure 10. Estimated Present Serviceability Rating Using
Maintenance Cost Models (Equations 1, 2 and 3).**

This finding may be justified by two reasons. First, the contractor who performed maintenance is qualified, and second, the routine maintenance timing played a major role in improving the pavement serviceability. When Na'our-Dead Sea highway is considered, as shown in Figure (10), maintenance by contract did not improve pavement serviceability. High routine maintenance expenditures did not affect pavement sections with poor conditions. This is due to low performance of the contractor and the improper timing of maintenance.

RECOMMENDATIONS

Based on the above findings, the following may be recommended:

1. In the case of applying maintenance by contract on unit price basis, many terms regarding penalties and incentives should be included in the contract in order to improve the quality of maintenance achieved.
2. Performance standards to be used in monitoring and controlling maintenance by contract in Jordan should be developed.
3. Qualification of contractor plays a major role in the quality of maintenance regardless the cost of maintenance, thus maintenance by contract should be performed only by well qualified contractors.
4. Time of applying maintenance is an important factor in the quality of the obtained results, thus it is

important that routine maintenance should always be performed before any pavement section reaches a poor condition.

5. The evaluation of pavement condition before and after maintenance by contract should be performed

by a team of well experienced engineers.

6. It is recommended to change the type of contract from unit price contract to performance-based contract.

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