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Implementation of Decision Support System (DSS) in Pavement Maintenance Management

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Abstract

Pavement maintenance for the road network in Baghdad does not yet have scientific basis such as monitoring and evaluation. This research describes the possibility of implementing Decision Support System (DSS) in pavement maintenance management for evaluating the Asphalt Concrete pavement surface condition. Common types of Asphalt Concrete distresses including (bleeding of Asphalt, various pavement cracking modes, pot holes, longitudinal and transverse deformation) with their various severity and intensity conditions have been included in the data base of the system, mathematical models for calculating the severity and extent for each distress type was also included. The software was developed in Microsoft Visual basic environment using a logic programming process. The pavement condition rating (PCR) of the roadway sections will be determined by the system. The system suggests the required maintenance action based on expected increase in pavement life and on the cost of maintenance alternatives. The system was examined in evaluating the Asphalt pavement surface condition of the freeway leading to Baghdad international Airport. The traditional visual inspection and manual calculation procedure have also been implemented. The surface of the pavement was divided into sections, and the pavement condition was visually evaluated and rated using specially designed forms, the rating was in the range of (26- 93) % which represents "very poor to very good" conditions for the roadway section based on the rating index provided. Data were fed to the developed decision support system software. The results agrees well with that of the developed software. It was concluded that the developed Decision Support System, could assist planner, or policy maker to support decision making in pavement maintenance.

Keywords

Construction Management, Maintenance, Decision Support System, Pavement, Rating

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1. Introduction

The quality and efficiency of road surface affects the quality of life, the health of the social system and the continuity of economic and business activities. Deterioration and failure of roadway may occur because of aging, overuse, and mismanagement. Therefore, roadway maintenance and preservation should have a great national interest. Pavement maintenance for the road network in Baghdad does not yet have scientific basis such as monitoring and evaluation. In addition, there is no system to determine how and when to investigate the pavements surface distress neither using technical manual in identification, but the whole system depends on Engineers experience. There is a lack in preparing future maintenance plans, while routine maintenance is not applied on scientific bases but it usually applied each five years. The objective of this work was to investigate the possibility of implementing the decision support system (DSS) in pavement maintenance-management process. A Decision Support System in a Pavement Maintenance Management process is a scientific tool for managing the pavements to make the best possible use of resources available or to maximize the benefit for society; it can be used in directing and controlling

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maintenance resources for optimum benefits. A Decision support system is an interactive computer-based decision tool that uses both facts and heuristics to solve difficult decision problems based on knowledge acquired from an expert, (Sarsam, 2008).

2. Methods for Managing Pavement Maintenance

2.1. Implementation of Pavement Maintenance-Management System (PMMS)

(Al-Mansour, 2004) developed a system which was based on data collected for the Pavement Maintenance Management of Riyadh City and performs comprehensive pavement visual survey prior to each maintenance program. In the pavement condition survey, detailed information related to type, severity and density of existing distresses was collected. The collected data was then used to determine the required maintenance activities on the network and a project level. (Guoxiang & Jie, 2010) developed preventive maintenance management system for expressway asphalt pavement, and stated that the functions of maintenance is quality evaluating pavement performance predicting, optimum selecting of preventive maintenance treatment, and post-evaluating could be realized or auxiliary realized. The test results showed that the system could meet the demands of software products register test code. Primary application showed that the system was correct and efficient. (Liu & Zhang, 2011) presented a methodological framework that helps highway agencies quantify the risks to highway networks and revise the highway routine maintenance work plans to minimize the impact of budget fluctuations. The methodology considers the subjective nature of decision makers' assessments, allowing different levels of confidence and different attitudes toward risk to be captured as uncertainty and imprecision are involved in the decision making process. (Al-Zahnoun, 2008) presented a scientific approach for road maintenance management system in Syria to adopt maintenance activities with available budget, and to define the responsibility of each management levels through the study of road maintenance management systems in some countries. The study survey has some questions and problems about routine maintenance; answers to this survey were given by engineers, directors of branches, and contractors to use their notes and experiences in this field in order to correct some points and subjects in routine maintenance system. (AASHTO, 2005) presented guidelines for Maintenance Management Systems that described business tool for improving maintenance efficiency and increasing service levels. The systems were built on the capabilities provided by the legacy systems with more of a focus on performance-based planning and budgeting and customer-service delivery, the analysis of various investment strategies was based on economic analysis and reliable data. (Al-Kheder, 2005) developed Pavement Maintenance Management System for Syrian Roads by using database that helps in making right maintenance decision. The system depends upon establishing the right methodology to collect, input and process data about pavement. It was stated that the data can be used to help decision makers define maintenance requirements according to successive systematic steps that are followed up to develop maintenance management system, taking into account the nature and characteristics of network.

2.2. Introducing the Expert System and Interview Data in (PMMS)

(Sarsam, 2008) developed Pavement Maintenance Management System (PMMS) using an expert system with Visual inspection technique for evaluating the Asphalt Concrete pavement surface condition. The surface of the pavement was divided into sections, and the pavement condition was visually evaluated, data collected were fed to the expert system using the computer, various types of intensity and severity of distress were analyzed by the system, the present condition rating (PCR) of the pavement section was determined. (Mohemed, 2010) carried out the study through interviews, questionnaires and archives from the Public Work Department. Interviews were conducted with the personnel involved in road maintenance management. The questionnaires were distributed to those who are involved in maintenance activities at the Public Work Department. The type of road involved in this study was a Federal Road, under Public Work Department supervision in Malaysia. The data collected were analyzed using an average index method to obtain the result. It was concluded that the most common problem that occurred during the implementation of Road Maintenance Management System was to get the funds for the road maintenance.

2.3. Implementing World Bank's Highway Development and Management System (HDM-4)

(Sandhakar, 2009) stated that various maintenance treatments are being practiced in India for urban roads. The type of treatment is at present selected arbitrarily by the field engineers without any scientific basis. He stated that his present study deals with optimum maintenance treatment identified for the urban roads among the various alternatives recommended in Government of India specifications using a sophisticated and modern scientific tool namely HDM - 4 developed by the World bank. (Hiep and Tsunokawa, 2005) presented a systematic approach to find optimal maintenance strategies for pavement management systems by using the

World Bank's Highway Development and Management System (HDM-4) combined with the gradient methods proposed. The optimal maintenance strategy was defined as the set of optimal maintenance options corresponding to different traffic levels and various initial pavement conditions, which minimizes the sum of agency costs and road user costs in present value or maximizes the net benefit to society over an analysis period. The basic data for the analysis was derived from the Vietnamese conditions and most sensitive parameters in HDM-4 were calibrated into the local conditions for a basic application. It was stated that highway agencies were in better applying the right maintenance work at the right time and thus this resulted in savings with regard to the total transport costs to the society.

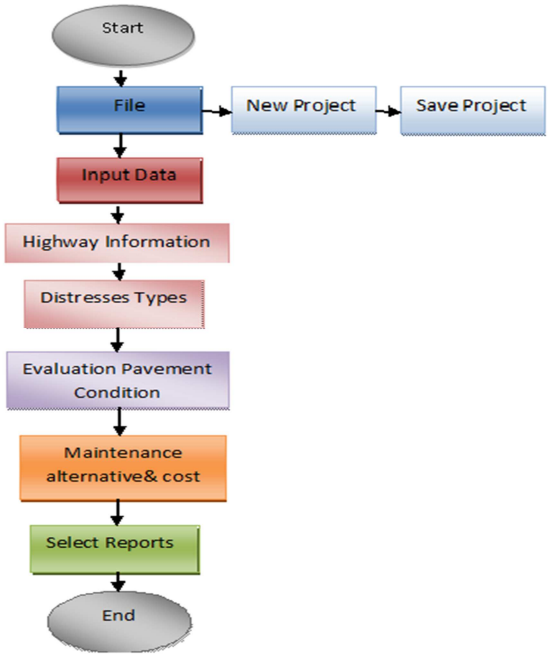


Fig. 1. Application stages of the system.

3. Building DSS for Pavement Maintenance Management

A decision support system (DSS) is a flexible computerized system that supports the process of making decision. It focuses on the process making decision rather than the outcome of the decision or the content of the problem. The building of DSS in this work starts with a systematic procedure that involves a variety of tasks on a periodic basis. It includes defining the roadway network by breaking it into management segments (sections) and creating an inventory for each segment. Fig.1 shows the application stages of the system, while Fig.2. demonstrates the component of the database of the system.

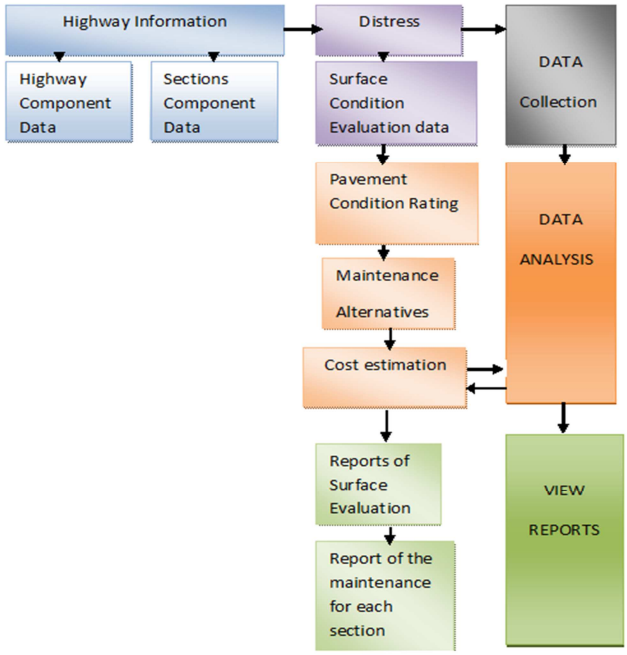


Fig. 2. Database of DSS.

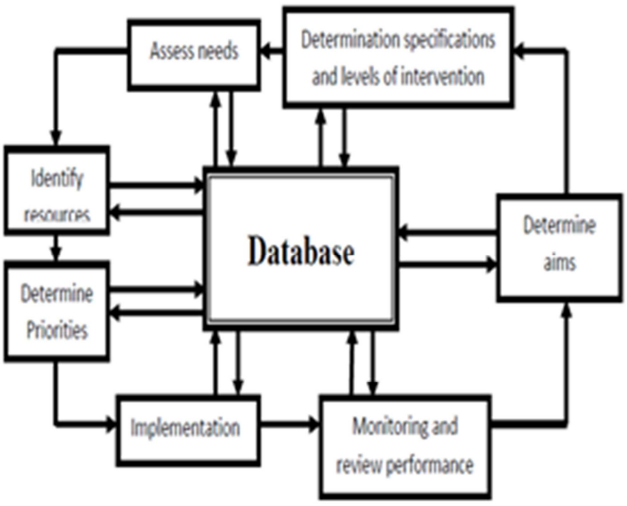


Fig. 3. Systematic planning proposed for the system.

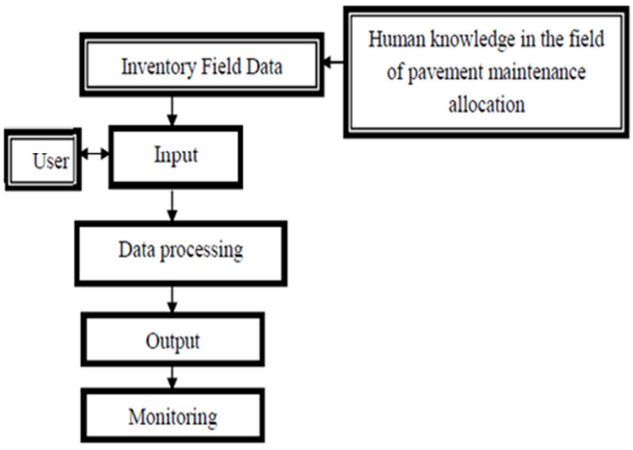


Fig. 4. Framwork of data management system.

The second task was gathering and inspecting the pavement

condition and maintenance data of each segment. The third task was calculating the pavement condition assessment by selecting an evaluation criterion and determining the treatment strategy and cost for each segment based on pavement condition. The fourth task was developing a method of prioritizing segments when funding constraints exist in a pavement maintenance program, and documenting and reporting results. Fig.3 shows the systematic planning proposed, while Fig.4 demonstrates the framework of data management in the system.

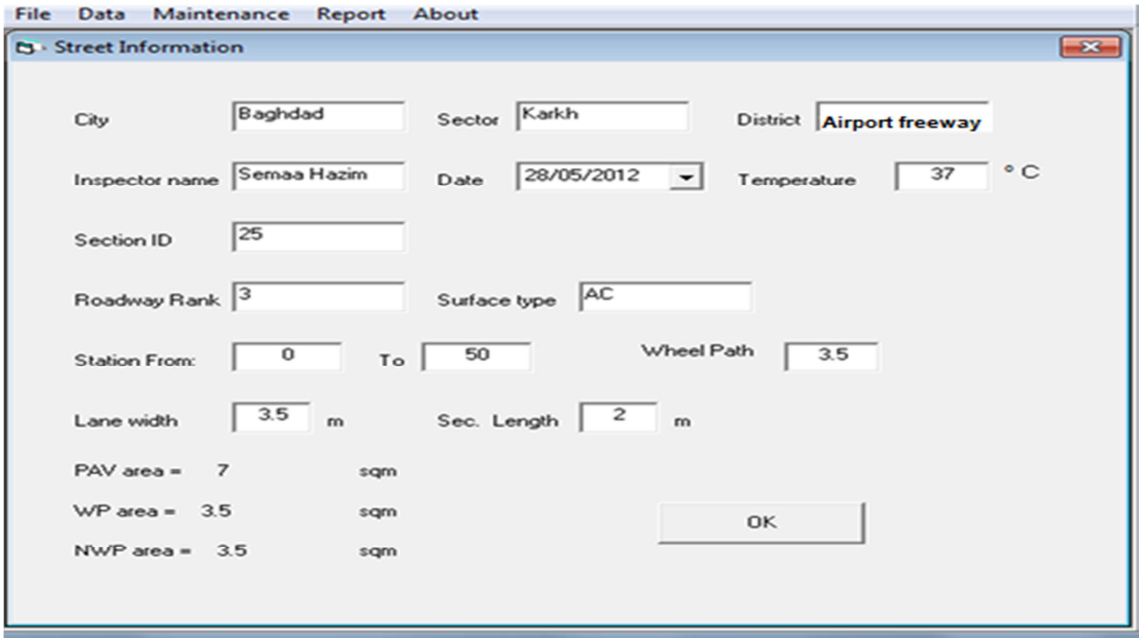


Fig. 5. Main screen of the system.

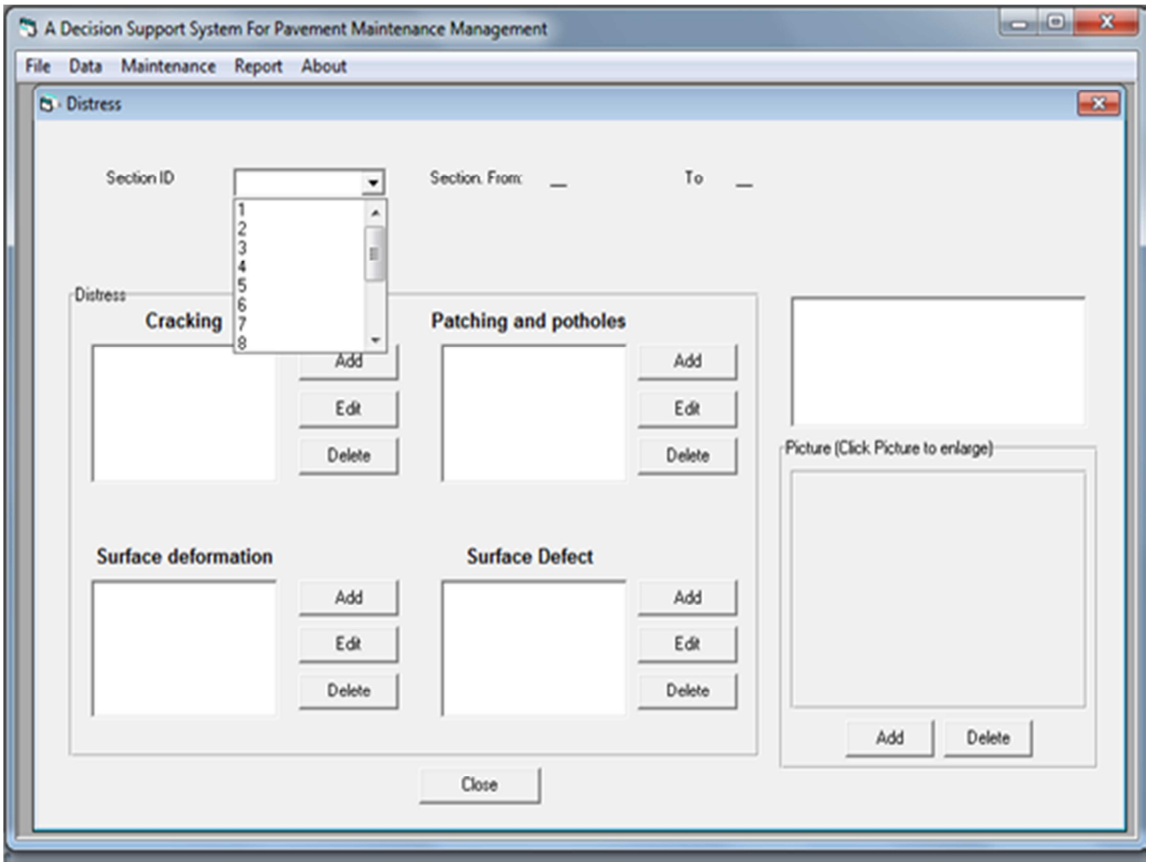


Fig. 6. Second screen of the system.

4. Implementation of the System

When the user operated the system, the main screen will appear, as shown in Fig.5. The toolbar of this screen ask for the data that contain the street information, after the street information are fed, another screen will appear and ask to fed the photograph of the selected section as shown in Fig.6.

There is an option of enlarging the photograph so that all types of distress could be clearly identified, the type of distress will be added manually by the operator based on the distresses appeared in the photo which include the severity and extent of each distress. The following steps were performed by the system to determine the pavement condition rating for the section and the maintenance alternatives. For each different type of distress, a distress severity and density (extent) is calculated by the system for each section, the distress density (extent) and severity of distress limits were obtained from (AASHTO manual, 2005; Sarsam, 2008; Panthi, 2009) which contains definitions and information concerning pavement distresses, the results is tabulated as shown in the screen in Fig.7.

Distress amount in linear meter or square meter per unit area or Unit length of the pavement will be calculated. The deduct value of distress will be obtained for each section as shown in the screen of Fig.8.

Then the deduct value will be corrected using the mathematical models previously fed to the database. The system will tabulate the calculated and the corrected deduct values for the whole sections, then calculate the pavement condition rating PCR value for each section and shows the rating results in a tabular form as demonstrated in Fig.9. The flow chart of pavement rating is shown in Fig.10. On the other hand, Fig.11 demonstrates the flow of data in the DSS. The required maintenance option for each type of distress will be obtained from the database, if there are many types of distress in the section, the system will select more than one maintenance option, which will solve the problem of the whole section. The DSS will finalize the option by optimization process based on the cost and on expected increase in pavement life when implementing that maintenance option.

The cost of pavement maintenance for each type of distress as per the local market condition was fed to the system with the ability of updating. Fig.12 demonstrates the screen for updating the cost of pavement maintenance alternatives.

The system will calculate the cost of each maintenance alternative for the pavement section and tabulate the results as shown in Fig.13. The optimized decision on maintenance alternative, the cost of that alternative, and the expected increase in pavement life if that maintenance alternative will be implemented are presented as an output of the system in the final screen as demonstrated in Fig.14.

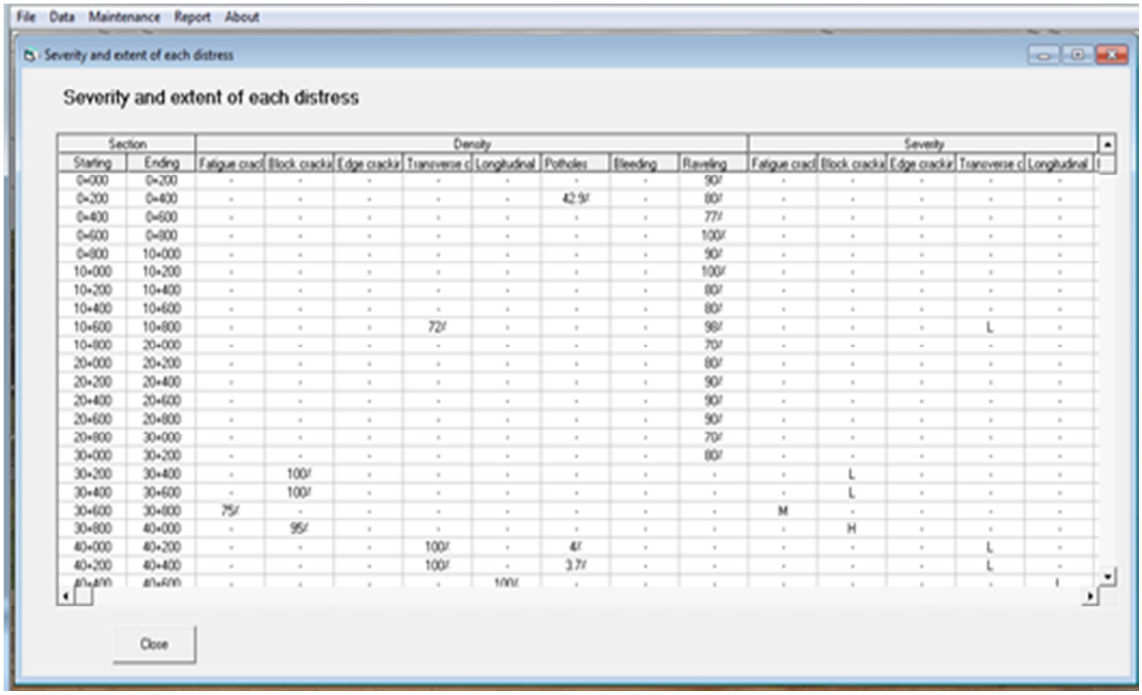


Fig. 7. Tabulating the severity and extent of each type of distress.

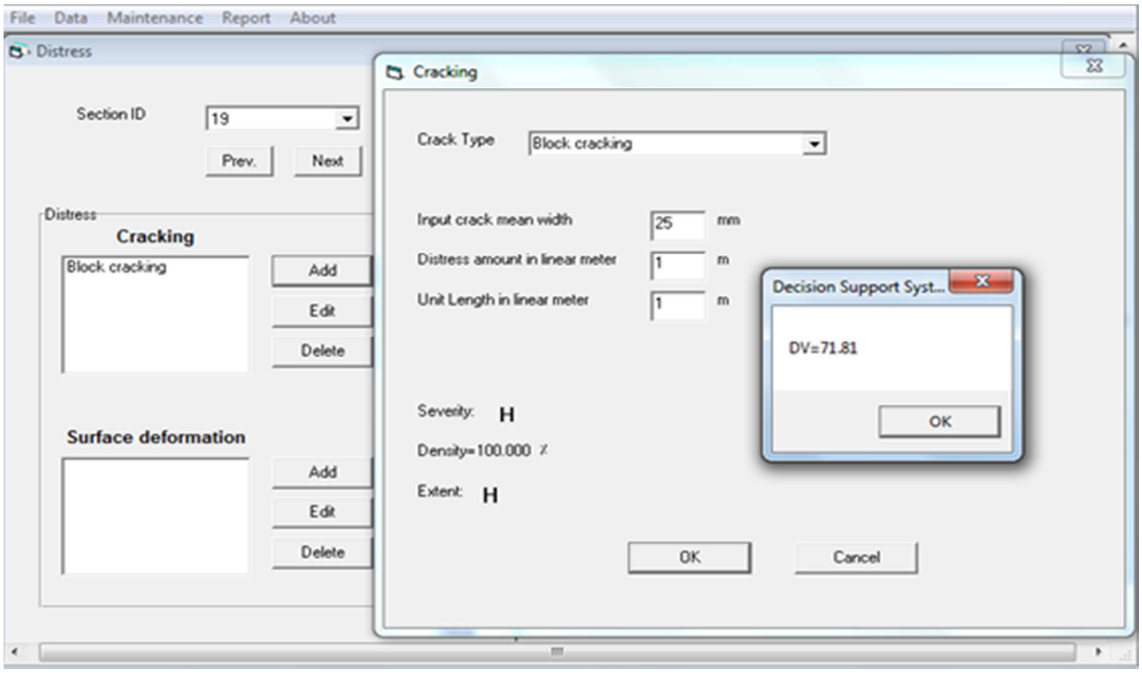


Fig. 8. Determination of deduct value for the section.

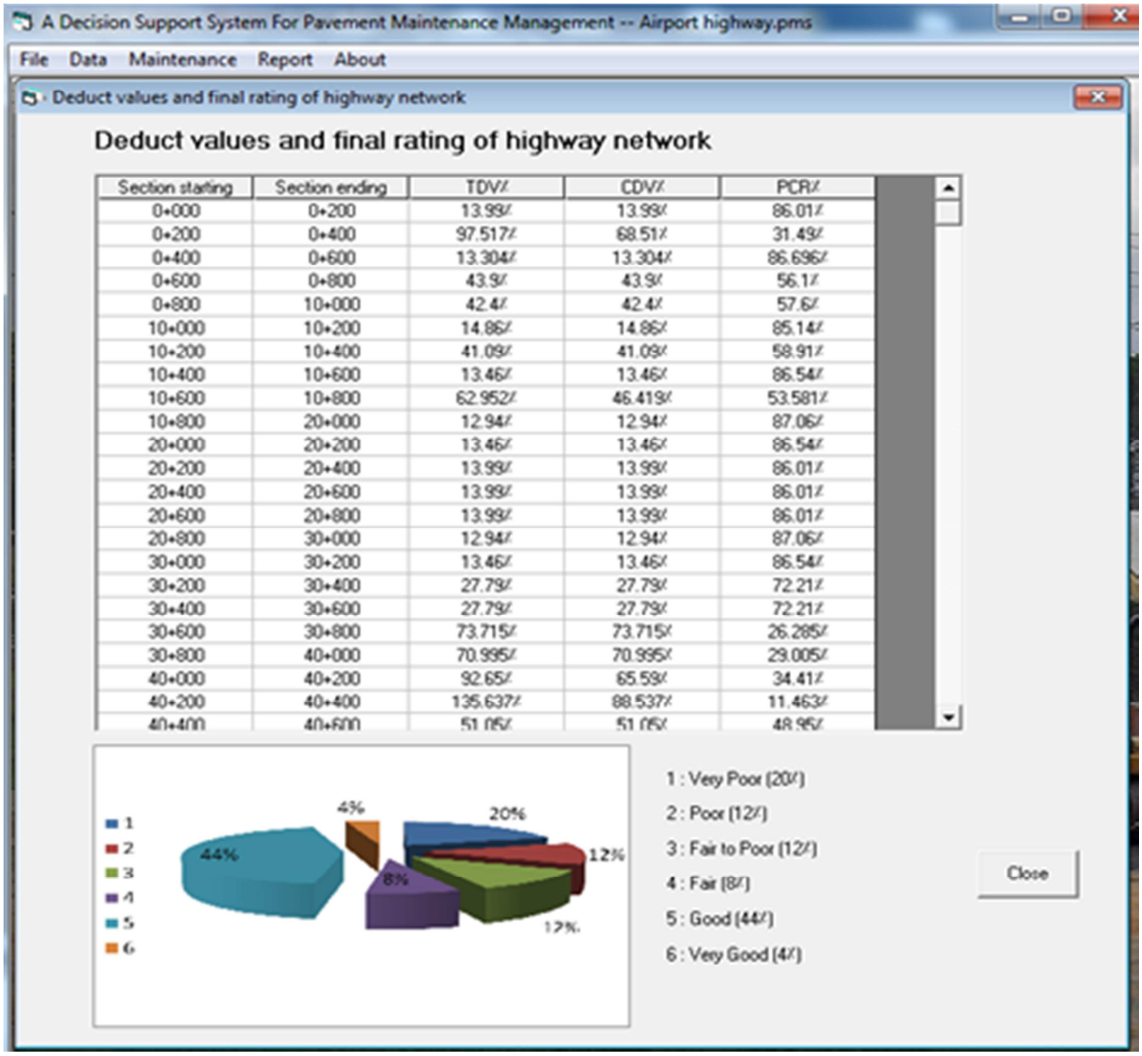


Fig. 9. Tabulation of deduct values and sections rating.

5. Validation of the System

The developed DSS was verified to check its efficiency. A pavement section of 50 meter length and 3.5 meter width (slow lane) on the freeway leading to Baghdad international airport was considered for such purpose. The freeway is six lane, divided roadway. The pavement was divided into subsections (segments) of 5 meters length. Fig. 15 shows google map plot of the site. The flexible pavement was subjected to visual inspection, the (walk through) pavement survey was conducted, and digital photography capture was implemented to identify the various type of distresses. The obtained photographs were fed to the developed software.

5.1. Pavement Condition Assessment Procedure

The procedure involved the identification of type, severity, and extent of the pavement distresses. Common types of Asphalt Concrete distress including (bleeding, patching, block cracking, transverse cracking, edge cracking and transverse cracking, potholes, and longitudinal and transverse deformation) with their various severity and extent have been verified on the software screen as shown in Fig.16. Each type of pavement distresses was identified, and measured in units of (linear meter or square meter). In addition, for each distress, a level of severity was determined Low (L), Medium (M) and High (H), as per the specification limits mentioned by (AASHTO, 2005; Sarsam, 2008). Various types of density (extent) and severity of distresses were analyzed by the system.

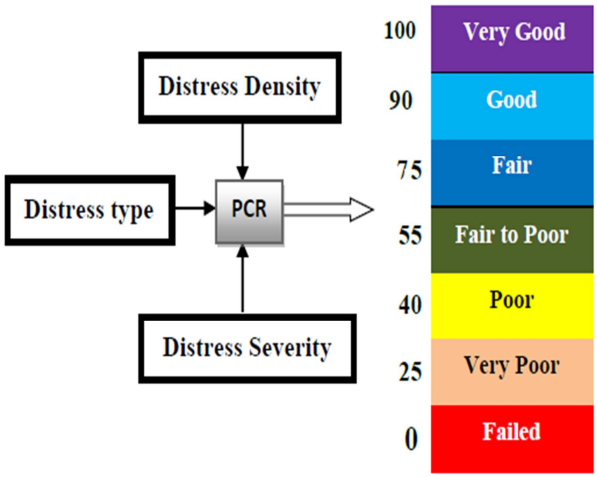


Fig. 10. Flowchart for pavement rating.

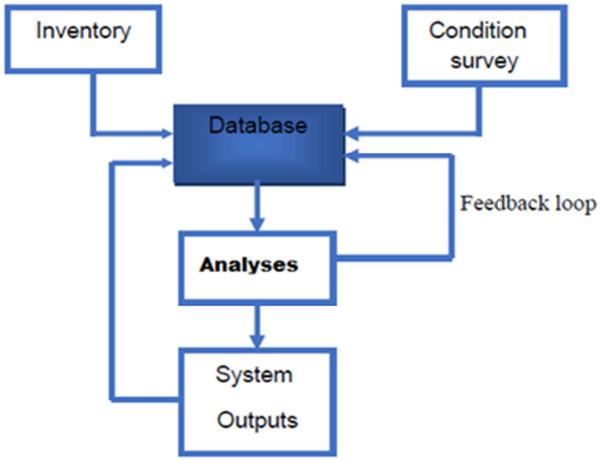


Fig. 11. Data flow in DSS.

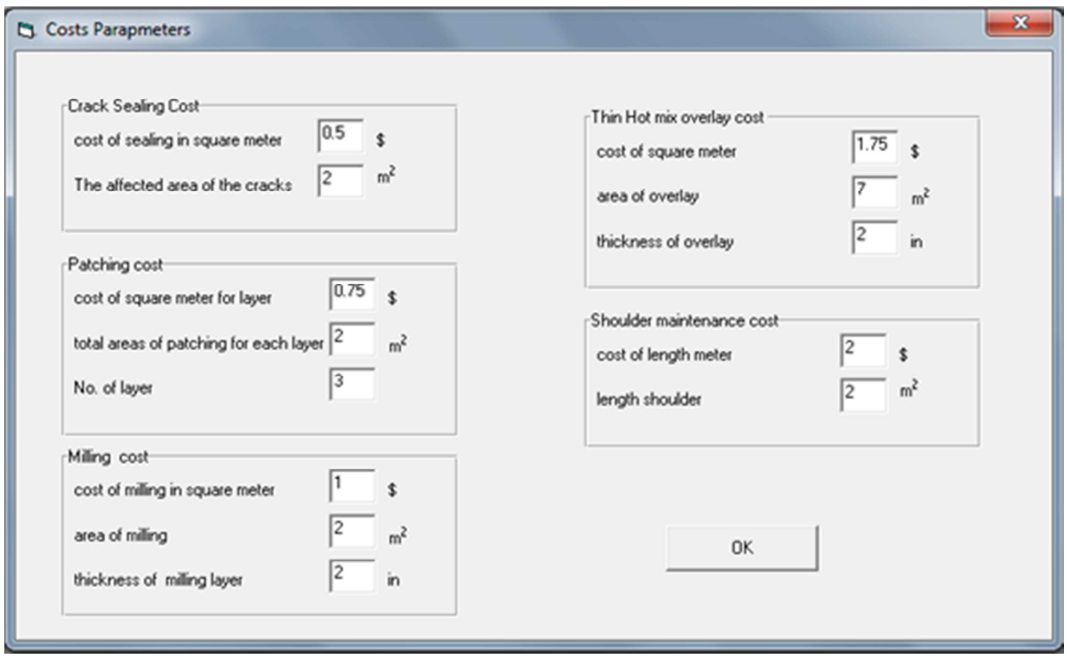
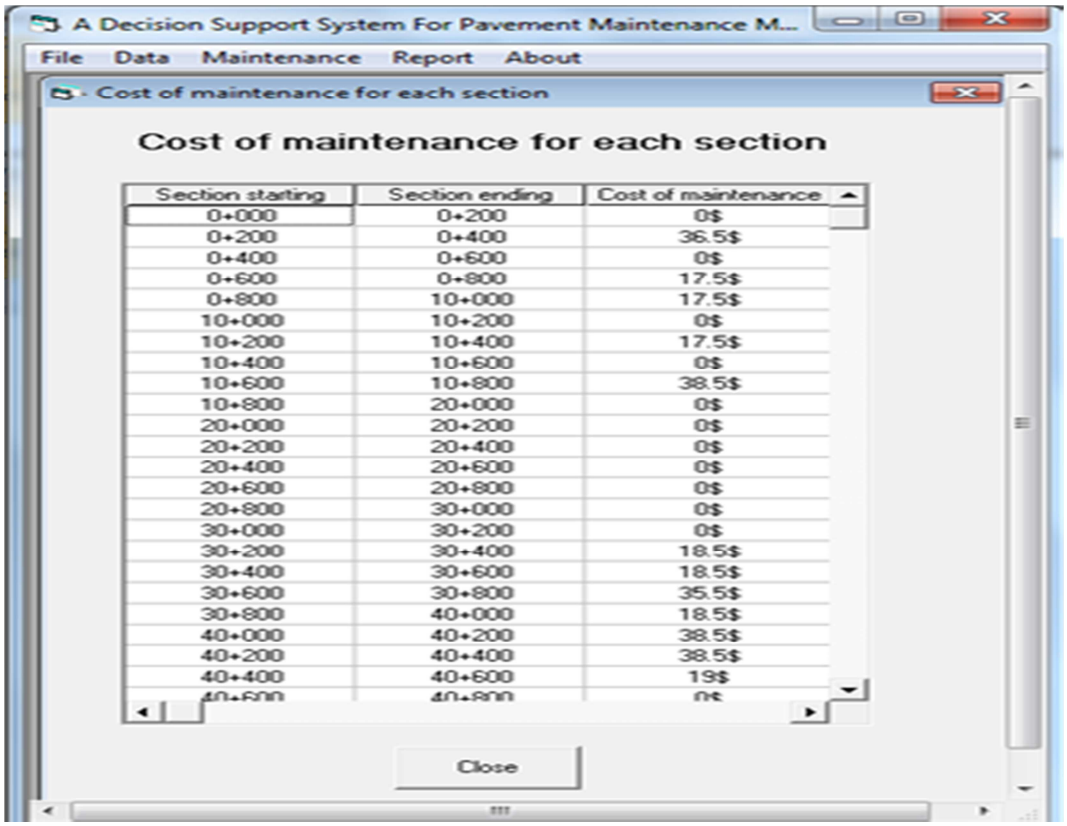


Fig. 12. Updating the cost of maintenance alternatives.



Section starting	Section ending	Cost of maintenance
0+000	0+200	0$
0+200	0+400	36.5$
0+400	0+600	0$
0+600	0+800	17.5$
0+800	10+000	17.5$
10+000	10+200	0$
10+200	10+400	17.5$
10+400	10+600	0$
10+600	10+800	38.5$
10+800	20+000	0$
20+000	20+200	0$
20+200	20+400	0$
20+400	20+600	0$
20+600	20+800	0$
20+800	30+000	0$
30+000	30+200	0$
30+200	30+400	18.5$
30+400	30+600	18.5$
30+600	30+800	35.5$
30+800	40+000	18.5$
40+000	40+200	38.5$
40+200	40+400	38.5$
40+400	40+600	19$

Fig. 13. List of cost of maintenance alternatives

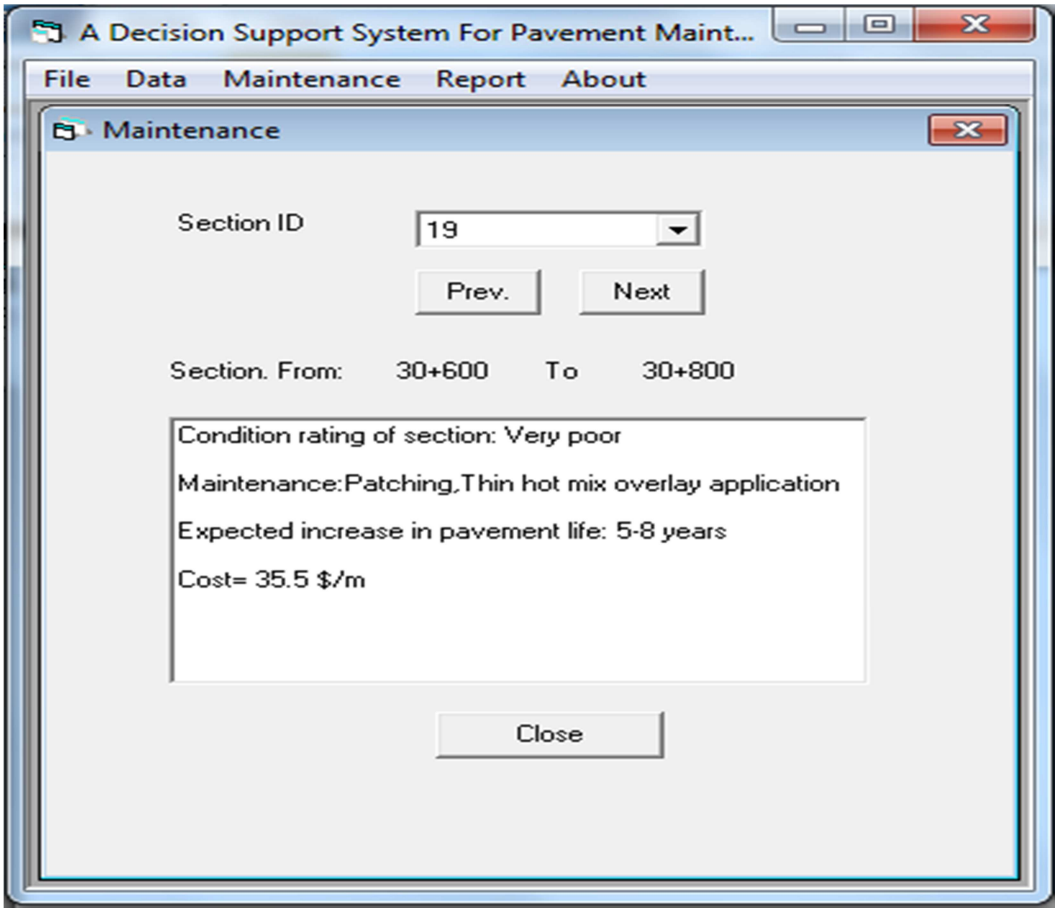


Fig. 14. Output of the DSS.

Fig. 15. Location map of the freeway section.

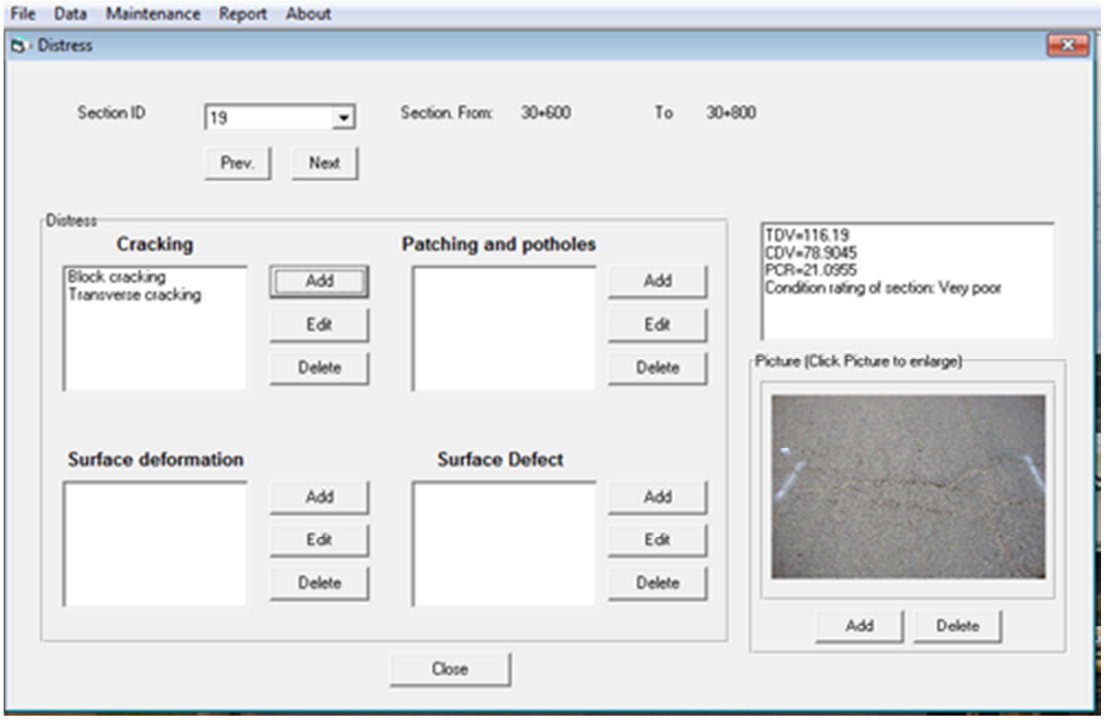


Fig. 16. Feeding the photo of the section for rating.

It has known that Pavement condition can be quantified by the pavement condition rating (PCR) which rates the pavement according to the extent and severity of distress types present (cracking, raveling. bleeding, shoving .etc). (PCR) ranges from 100 to zero (best to worst). A major goal of pavement maintenance management is to keep pavement condition in the upper (PCR) range of (60-90) by limiting surface structural degradation to keep down rehabilitation cost (Panthi K. 2009). The DSS analyses all the sections, and the final decision was given as an output of the system.

5.2. Manual Assessment of Pavement Condition

It was oriented towards analyzing the existing roadway conditions so that a reasonable definition of the special problems and structural needs of the roadway can be made. The assessment was accomplished based on visual assessment of the type, quantity and severity of Pavement distresses and results in the pavement condition rating. The distresses data were recorded on the Inspection Sheet. The severity and extent of each distress type was calculated

manually, the deduct values and the corrected deduct values were determined, and finally the PCR value was determined for each segment.

5.3. Discussion and Comparison of Visual Assessment Results

The data collected in the field, and the results of the calculation made by the system and that made manually were compared. As shown, there were different types of distresses identified during the inspection of the representative area. The levels of severity for the raveling identified in section (30+000 - 30+200) ranged from low severity (L), medium severity (M) and high severity (H). The depth of the pothole in section (0+400) is 20 mm, then the severity is low .The level of severity for bleeding in section (40+800 - 50+000) is of low severity (L) . The mean crack width for the transverse cracking in section (10+600 - 10+800) is 22 mm, then the level of severity is high, while the crack spacing is 9 m, then the level of extent is high. The mean crack width for block cracking in the section (30+200 - 30+400) is 21 mm, then the severity is high and the crack is spread at 100% of section length, then the level of extent is high. The crack means width in section (30+400 - 30+600) for block cracking is 22 mm, then the severity is high and the crack is spread at 100% of section length, then the level of extent is high. The crack means width for the block cracking and transverse cracking in the (30+600 - 30+800) sections are 22 mm, then the level of severity is high, the crack for block cracking covers 100% of section length, then the extent is high and the crack spacing for transverse cracking is 2 m, then the extent is low. For the longitudinal cracking in section (40+000 - 40+200), the crack means width is 16 mm, then the severity is medium. The depth of pothole in section (40+200 – 40+600) is 55 mm, then the severity is high, and the mean width of longitudinal cracking is 20 mm, then the severity is low. The crack mean width for the longitudinal cracking is 16 mm then the severity is medium. The bleeding in section (40+800 – 50+000) shows shining and reflective surface-small area, and then severity is low.

The total amount of “deduct” and the corrected deduct value “CDV” was calculated by the system, and manually. The raveling in section (10+600 -10+800) shows DV of 42%, while for the transverse cracking in same section, the DV is 45% then the total DV of raveling and transverse cracking TDV is 87%, the corrected DV is 62%, then the final rating of this section is 38 % (poor condition). The evaluation of the pavement surface condition by the system was in excellent agreement with that of the manual assessment.

6. Conclusion

1. The original data fed to the software (mathematical models for calculation) was considered as basic element of DSS in pavement maintenance management. It combines all the data required for maintenance decision; it proves to be easy and fast execution, and recommended to be used by road Engineers.
2. The DSS operates when all the required information were fed. The mathematical models stored in database of the system calculated the severity and extent for each distress and calculate pavement condition rating which was in the range between (0-100)%.
3. The DSS proposed the alternatives of maintenance using the information stored in database; then the system determine the expected increase in life of roadway that could be obtained from the implementation of this activity of maintenance and the cost of each maintenance alternative.
4. The implementation of DSS in the evaluation a section of the freeway leading to Baghdad International Airport was compared with traditional assessment (manual), and the variation in rating between the two systems was not significant.

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