T.C.
ISTANBUL GEDİK NIVERSITY
INSTITUTE OF GRADUATE STUDIES

ANALYSIS OF COST AND TIME DEVIATIONS IN ROAD AND BRIDGE MAINTENANCE IN IRAQ WITH EXPERT SYSTEMS

MASTER'S THESIS

Qutaiba Shafeeq Darb AL-AZZAWI

Engineering Management Department

Engineering Management Master in English Program

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İSTANBUL GEDİK ÜNİVERSİTESİ

LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ MÜDÜRLÜĞÜ

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Enstitümüz, Engineering Management Department İngilizce Tezli Yüksek Lisans Programı (201281025) numaralı öğrencisi Qutaiba Shafeeq Darb AL-AZZAWI'nin "Analysis of Cost and Time Deviations in Road and Bridge Maintenance in Iraq with Expert Systems" adlı tez çalışması Enstitümüz Yönetim Kurulunun 06/06/2023 tarihinde oluşturulan jüri tarafından *Oy Birliği* ile Yüksek Lisans tezi olarak *Kabul* edilmiştir.

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DECLARATION

I, Qutaiba Shafeeq Darb AL-AZZAWI, hereby certify that this thesis entitled "Analysis of Cost and Time Deviations in Road and Bridge Maintenance in Iraq with Expert Systems" is my original thesis for the award of Master's Degree in Engineering Management at the Faculty of Engineering Management. I further certify that this thesis or any part thereof has not been submitted and presented for any other degree or research thesis at any other university or institution. (06.06.2023)

Qutaiba Shafeeq Darb AL-AZZAWI

DEDICATION

To my father, my brothers, my sisters, my niece (Tabark), my family and my friends for their efforts. to my professors who were the source of the light that guided me and made me converted to the life of the research and cultivate the love of science and search for information. All of them come after the First person in my life, "my mother"

PREFACE

At the end of my message, I would like to extend my thanks and gratitude to my father and my family for their continuous support. I also thank my friends, their efforts and their constant encouragement. I also apply for every person who contributed to giving information, advice or guidance in any stage of the research. I thank my professors (Asst. Prof. Dr. Bozkurt Nazilli & Asst. Prof. Dr. Abdulrahman Adnan) for supporting me with their valuable advice and continuous directives. I also thank the head of the university, the head of the department and the department, the members of the respectable discussion committee.

June 2023 Qutaiba Shafeeq Darb Al-AZZAWI

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ABBREVIATIONS

AHP	: Analytic Hierarchy Process
BIM	: Building information's Modeling
EPCM	: Evaluation of Pavement Condition Model
GA	: Genetic Algorithm
GRASP	: Greedy Randomized Adaptive Search Procedure
LBL	: Layer by Layer
LP	: Linear Program
LTE	: Long-Term-Effective
M&R	: Maintenance and Rehabilitation
MCA	: Multicriteria Analysis
MFT	: Modification Factor of The time
NH	: Not Happened
PCI	: Pavement Condition Index
PCR	: Pavement Current Rating
PMMS	: Pavement Maintenance Management System
PMS	: Pavement Management System
PTFE	: Polytetrafluoroethylene
RW	: Researcher Work
SHS	: Structural Health Status
SVR	: Support Vector Regression

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ANALYSIS OF COST AND TIME DEVIATIONS IN ROAD AND BRIDGE MAINTENANCE IN IRAQ WITH EXPERT SYSTEMS

ABSTRACT

The roads and bridges field in Iraq is a vital and important field. However, the road and bridge bandits in Iraq suffer from many problems over the past years, where most roads and bridges lack periodic maintenance, which makes these problems subject to development and increasing, and therefore requires high costs, more time for maintenance. In this study, reliance was made on the expert system technique in calculating the time and cost required to repair and maintain each square meter or meter length of road and bridge problems in Iraq. According to the experiences of Experts and Engineers, as well as adding some problems that they noticed in the roads and bridges in Iraq throughout their work periods, in addition to the problems that were obtained through the literature, so that we get most of the problems that the roads and bridges suffer from in Iraq. The results of the open questionnaire were processed by statistical methods to obtain three answers for each problem for the cost and time. After that, a closed questionnaire was conducted on the existing problems and options to obtain the most accurate results. the results of the closed-ended questionnaire were statistically processed to obtain the most accurate results, so that these results would be a database that would be fed into the expert system, and by the programming language of the MATLAB program, a program was designed and programmed to accurately calculate the time and cost for each problem of roads and bridges according to the field questionnaires Results. It is recommended to rely on This program to reduce losses in terms of cost and time, as well as in the field of planning. There are also important measures that should be taken to advance the roads and bridges field, including periodic maintenance of these facilities.

Keywords: *Road and bridges maintenance, Expert system in road maintenance, The time of maintenance roads in Iraq, The cost of maintenance roads in Iraq*

YOL VE KÖPRÜLERDEKİ MALİYET VE ZAMAN SAPMALARININ ANALİZİ: IRAK'TA UZMAN SİSTEMLERLE BAKIM

ÖZET

Irak'taki yollar ve köprüler alanı hayati ve önemli bir alandır. Bununla birlikte, Irak'taki yol ve köprü haydutları son yıllarda birçok sorunla karşı karşıyadır; çoğu yol ve köprü periyodik bakımdan yoksundur, bu da bu sorunların gelişmesine ve artmasına neden olur ve bu nedenle yüksek maliyetler ve bakım için daha fazla zaman gerektirir. Bu çalışmada, Irak'taki yol ve köprü sorunlarının her bir metrekaresinin veya metre uzunluğunun onarımı ve bakımı için gereken zaman ve maliyetin hesaplanmasında uzman sistem tekniğine dayanılmıştır. Uzmanların ve Mühendislerin deneyimlerine göre, literatürden elde edilen sorunlara ek olarak, çalışma dönemleri boyunca Irak'taki yollarda ve köprülerde fark ettikleri bazı sorunları da ekleyerek, Irak'taki yolların ve köprülerin maruz kaldığı sorunların çoğunu elde ettik. Açık anketin sonuçları istatistiksel yöntemlerle işlenerek maliyet ve zaman için her bir soruna yönelik üç cevap elde edilmiştir. Bundan sonra, en doğru sonuçları elde etmek için mevcut sorunlar ve seçenekler üzerine kapalı bir anket yapılmıştır. kapalı uçlu anketin sonuçları, en doğru sonuçları elde etmek için istatistiksel olarak işlenmiştir, böylece bu sonuçlar uzman sisteme beslenecek bir veritabanı olacaktır ve MATLAB programının programlama dili ile, saha anket Sonuçlarına göre yol ve köprülerin her bir sorunu için zaman ve maliyeti doğru bir şekilde hesaplamak için bir program tasarlanmış ve programlanmıştır. Planlama alanında olduğu gibi maliyet ve zaman açısından da kayıpları azaltmak için bu programa güvenilmesi tavsiye edilmektedir. Yollar ve köprüler alanında ilerleme kaydedilmesi için bu tesislerin periyodik bakımları da dahil olmak üzere alınması gereken önemli tedbirler de bulunmaktadır.

Anahtar Kelimeler: *Yol ve köprü bakımı, Yol bakımında uzman sistem, Irak'taki yolların bakım süresi, Irak'taki yolların bakım maliyeti*

1. INTRODUCTION

1.1 General

Failure of a pavement occurs when its usability declines due to the development of defects like cracks and ruts [1]. Some of the things that might lead to flexible pavement distress include an unstable subgrade, an insufficient subbase or base width, a poorly designed asphaltic layer mix, heavy vehicle traffic, excessive axel pressures, and extreme weather. These deteriorations may lessen the use of the sidewalks and cause major automobile damage, which can have devastating effects on local economies and on people's disposable incomes nationwide [2]. Sidewalk upkeep and restoration are costly tasks, and the funding available to handle the current sidewalk infrastructure is restricted. Managers require a priority technique to help them choose the best upkeep choices. Prioritization of maintenance is required to keep paving portions at appropriate service levels within budget and resource limitations [3]. Only through proper combined management planning in a life-cycle complete framework can optimum choices to keep or enhance the dependability and usefulness of buildings and infrastructure systems be made [4]. Maintenance is a collection of actions aimed at maintaining a building in a usable condition throughout its intended life. A road network requires a variety of operations, including identifying flaws and planning, scripting, and arranging for real execution in the field, as well as tracking [5]. Traditional and modern roads alike on the National Road Network need regular maintenance to stay up with standards. The government is obligated to take a more aggressive role in repair management due to the limited availability of the national road network and the diversion of overpopulation. Funding shortages are a common problem for the agency responsible for road maintenance. An optimization model with two goals, maximum irregularity and minimum maintenance cost, is applied to an overflowing road system [6]. Iraq is a middle-income nation where one of the main sources of mortality is traffic accidents. To address the problem of road safety, the Iraqi Ministry of Planning's General Statistical Organization established a data gathering system for traffic incidents, including information on their causes and intensity [7]. To avoid unintended effects, road growth projects must include environmental assessments. Iraqi growth projects lack environmental and social assessments. Project life cycle must be considered in fiscal evaluation. Lack of proven and thorough evaluation methods is the main barrier [8]. Pavement degradation is a significant issue for the road and transportation sectors in almost every country. Bituminous pavement failures are produced by a variety of factors or a mix of factors. Both the lifespan of the maintenance work and the reinforcing coating may be extended by applying repair to the existing surface. In addition to routine maintenance, there are also a variety of pavement preservation measures that may be used to postpone the deterioration of the pavement [9]. roadway management tools and asset management of roadway assets are becoming more popular, so it's essential to improve their upkeep components, especially proactive maintenance. Iraqi roads are not properly maintained until they fail and need repair. Poor maintenance management causes delays and freeway network failures that take odd expenses to fix and sustain. Shortages in upkeep funds force the purchase of new or extra machinery for road building. A planning method for paving upkeep of Iraq's road network and a road failing measure are highly advised [10].

1.2 Research Justification

1. Difficulty controlling projects to repair and maintain roads and bridges problems in Iraq.
2. Difficulty determining the time needed to repair and maintain road and bridge problems in Iraq.
3. The difficulty of estimating the cost required to repair and maintain the problems of roads and bridges in Iraq, according to the number of meters accurately or close to reality.

1.3 Research Hypotheses

The expert system helps to shorten the time and effort to limit the time and cost required to deal with the problems of roads and bridges and their maintenance, which leads to the successful completion of maintenance projects in the shortest way to save time, money, and efforts.

1.4 Research Objectives

Controlling the cost and time of projects to treat and maintain roads and bridges problems, using the expert system. An administrative system was built depending on the expert's technique and through the results that were reached to reach the cost and time of road maintenance with a good estimate using the MATLAB program.

1.5 Research Limitations

This research is limited to the following:

- Spatial Limitation: Maintenance management and problem-solving in the roads and bridges sector in Iraq.
- Temporal Limitation: The research period was during the period 2022-2023.

1.6 Research Methodology

The current research methodology consists of two parts that can be clarified as follows:

1. Theoretical part: This section includes a study on a group of previous research related to the most prominent problems of asphalt roads and bridges in Iraq. The research includes research papers, thesis, books and electronic sites that are within the subject of the investigation.
2. Practical part: The practical part of the following research methodology includes:

a. Several meetings and discussions were held with a number of experts in the field of roads and bridges through which Find the time and cost necessary to maintain each square meter of road problems and bridges that were reached through the investigative study in addition to that some experts proposed a number of realistic problems that did not It is taken in the literature.

b. The use of statistical methods to prepare an open questionnaire to provide the time and cost necessary for maintenance and treatment of the square meter from each of the problems that have been reached.

c. After the open questionnaire is done, we arrange the results obtained by statistical methods and enter the time and the frequent costs in a closed questionnaire for engineers working in the bandits and bridges to reach the most realistic options using statistical methods to reach the time and cost necessary to maintain the square meter, then formula was built for the time amendment of maintenance projects that operate for more than one meter.

d. Discuss the results that have been reached and the appropriate recommendations are made.

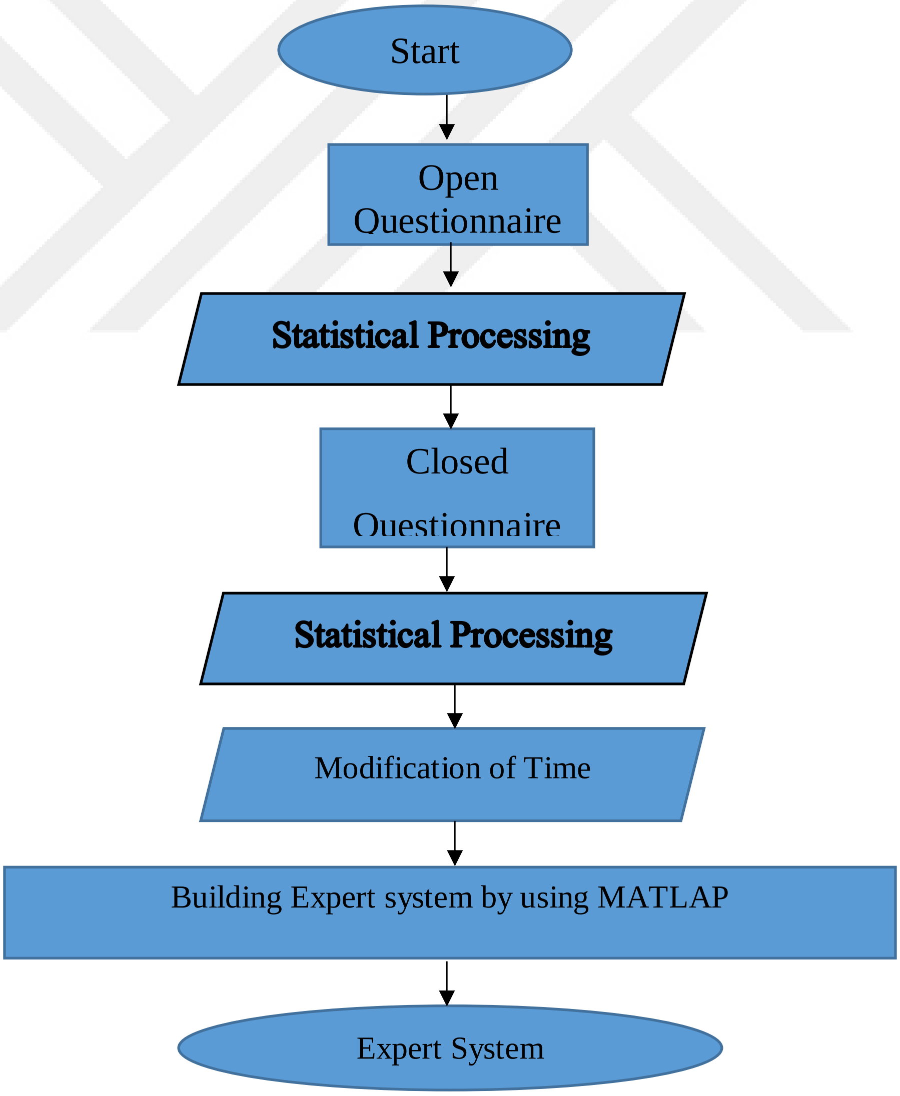

Figure 1.1: The Research Methodology

Source: (R.W.)

1.7 Review of Previous Studies

Studies and research related to the application of expert systems, some problems of roads and bridges, and some solutions related to roads and bridges that reviewed as shown in Table 1.1:

Table 1.1: Review of Previous Studies

Title	Author, Year	Country	The Work
1. Towards A Sustainable Optimization of Pavement Maintenance Programs Under Budgetary Restrictions.	Cristina Torres-Machi, Eugenio Pellicer, Victor Yepes, And Alondra Chamorro. 2017 [11]	Chile	This study offered an optimization method for improving the long-term design of maintenance programs by including environmental factors in the decision-making process. The application of the suggested technology to a real-world case study of an urban pavement network in Chile yields a number of scholarly contributions as well as practical suggestions. The findings of this research show that integrating environmental implications with conventionally studied variables (technical and economic) allows for a more sustainable allocation of maintenance resources.
2. Multicriteria Analysis Method for Pavement Maintenance Management	Salvatore Cafiso, Alessandro Di Graziano, Henry R. Kerali, and J. B. Odoki 2002 [12]	Italy, United Kingdom	MCA (multicriteria analysis) is a framework for dissecting an issue into its basic elements. In the face of competing priorities, MCA allows you to examine a variety of solutions. By framing an issue inside the MCA framework, solutions may be prioritized based on predetermined preferences in order to meet set goals. It is detailed an approach for providing an MCA framework inside the Highway Development and Management Tools, Version 4 (HDM-4). Many Factors, including the strategic relevance of roads, have been integrated inside a unified decision-making framework. Because it reduces the analysis of Conflicting aims to a series of basic comparisons between component pieces, the analytic hierarchy process technique was chosen for HDM-4.

Table 1.1: (Cont). Review of Previous Studies

Title	Author, Year	Country	The Work
3. A multi-year pavement maintenance program using a stochastic simulation-based genetic algorithm approach.	Piya Chootinan, Anthony Chen, Matthew R. Horrocks and Doyt Bolling. 2005 [13]	USA, Utah State University	This research aims to provide an annual pavement repair planning system that takes into[13] account pavement degrading uncertainty. This is accomplished by using a genetic algorithm (GA) approach in a simulated environment that can schedule maintenance activities over a period of years. Using the calibrated degradation model as a basis, a stochastic simulation is used to simulate the unpredictability of future pavement conditions, and a genetic algorithm (GA) is used to handle the combinatorial aspect of programming pavement maintenance for a network. Using a case study, we examine how uncertainty about pavement deterioration affects the maintenance plan. The results indicate that forecasting pavement network performance based only on predicted pavement conditions is risky and may lead to underestimating the budget for necessary repair activities.
4. Network-level optimization of pavement maintenance renewal strategies.	Jesus M. de la Garza, Sercan Akyildiz, Doug R. Bish, Denise A. Krueger. 2011 [14]	United States	In order to achieve the agencies' pavement performance objectives in terms of total lane-miles in each pavement condition state while staying within budgetary limits, this study presents a simplified but still effective network-level pavement maintenance optimization model, a Linear Program (LP). A useful tool for selecting choices is the Risk Solver Platform for Excel, developed by Frontline Systems. This program determines how much money should be spent on various types of pavement maintenance over the course of a certain loan period. State Department of Transportation District pavement condition data is used to evaluate the model. Within this framework, nine treatment alternatives and their corresponding dollar values per lane mile, pavement deterioration rates, network-level pavement

Table 1.1: (Cont). Review of Previous Studies

Title	Author, Year	Country	The Work
			performance goals, and annual maintenance budgets are defined over a 15-year planning horizon. The results show how to allocate a yearly highway maintenance budget to meet the district's value offer under various conditions.
5. Optimal pavement maintenance programs based on a hybrid Greedy Randomized Adaptive Search Procedure Algorithm.	Víctor Yepes, Cristina Torres-Machi, Alondra Chamorro & Eugenio Pellicer 2016[15]	Chile	This study provides a technique for optimization that makes use of a modified version of the Greedy Randomized Adaptive Search Procedure (GRASP). By analyzing how different budgetary scenarios will affect the health of the network as a whole, this tool helps with the development of feasible maintenance plans within the context of limited resources and existing infrastructure. A case study is presented to show how the optimization tool performs when applied to real-world data. It has been shown that optimized maintenance schedules deliver 40% more LTE than conventional reactive maintenance programs. To generalize the results of this case study, a set of hypothetical situations based on the observed range of values is also optimized. Based on the results of this study, using this optimization method to allocate maintenance funds is preferable than using a more traditional, reactive strategy. The sensitivity analysis of several budgetary situations reveals that the LTE of suitable maintenance plans is significantly influenced by the initial money level.

Table 1.1: (Cont). Review of Previous Studies

Title	Author, Year	Country	The Work
6. Establishing optimal project-level strategies for pavement maintenance and rehabilitation – A framework and case study	Muhammad Irfana, Muhammad Bilal Khurshidb, Qiang Baic, Samuel Labic* and Thomas L. Morind 2011[16]	Pakistan	This article presents a technique for identifying the optimal pavement maintenance and rehabilitation (M&R) strategy using a mixed-integer nonlinear programming model, and it provides an illustrative example. Cost-effectiveness, defined as the ratio of efficiency to expense, is the target performance indicator. The optimization issue has constraints associated with three variables: performance, cost, and freedom of action. Cost is presented in terms of agency and user costs throughout the life cycle, and two different formulations of effectiveness are generated using treatment-specific performance models for each therapy that makes up the strategy. A case study is presented to illustrate the methodology. Developing probability distributions for the optimization input variables and running Monte Carlo simulations yields the optimal solution. M&R strategy contours are created using the findings of these simulations as a unique tool to assist pavement managers in rapidly identifying the appropriate M&R approach for a specific pavement segment.
7. Genetic Algorithm Applied for Optimization of Pavement Maintenance under Overload Traffic: Case Study Indonesia National Highway	ANDRI I. Rifai, SIGIT P. Hadiwardoyo, A. GOMES Correia and PAULO Pereira 2016 [17]	Indonesia [table13]	In this research, routine and periodic maintenance are selected. Based on Genetic Algorithms, a multi-objective optimization model was created. The created model has two restrictions: budget limits and overloading. The Pareto optimum solutions of the two objective functions are found based on the R-Tools finding. An agency may more readily receive maintenance planning information from the ideal options indicated by the roughness index and cost. The created model's results have been applied through the choosing of repair situations on the road network with varying degrees of congestion.

Table 1.1: (Cont). Review of Previous Studies

Title	Author, Year	Country	The Work
8. Integrated Fuzzy Analytic Hierarchy Process and VIKOR Method in the Prioritization of Pavement Maintenance Activities	Peyman Babashamsi, Amin Golzadfar, Nur Izzi Md Yusoff, Halil Ceylan, and Nor Ghani Md Nor 2016 [18]	Iran	This research employs the fuzzy analytic hierarchy process (AHP) in conjunction with the VIKOR approach for multi-criteria decision analysis (MCDA) to assess potential pavement repair strategies in light of a variety of network metrics. Among the selected indicators are the pavement condition index (PCI), the frequency of traffic jams, the width of sidewalks, the cost of new construction and maintenance, and the time required to complete a race. The imprecise AHP is used to find the weights of the indices. Following that, the objectives of the options are ordered based on the metrics weighted with the VIKOR model.
9. Optimum analysis of pavement maintenance using multi-objective genetic algorithms	Amr A. Elhadidy, Emad E. Elbeltagi, and Mohammad A. Ammar 2014 [19]	Egypt	This article presents a network-scale multi-objective optimization problem for the maintenance and repair of sidewalks. Minimal action costs and the best possible road network state are both considered in a dual-objective optimization model. Markov-chain models are used in the suggested method to forecast the performance of road paving and compute the predicted decrease over time. The multi-objective optimization issue is solved using a genetic algorithm-based method. The program looked for the best repair steps to take at the right moment on the right surface. Based on the results of the calculations, the Pareto optimal solutions of the two-objective optimization functions are determined. Using the best alternatives suggested by cost and condition, a decision maker may easily acquire information on maintenance and repair plans with low action costs and optimal condition.

Table 1.1: (Cont). Review of Previous Studies

Title	Author, Year	Country	The Work
10. multi-objective optimization for pavement maintenance and rehabilitation decision-making: A critical review and future directions	Wang Chen and Mulian Zheng 2021 [20]	China	This review provides the state-of-the-art in the development and application of MOO methods for the PMMS decision-making module, which is the first review in the field of pavement maintenance decision-making, with a focus on decision-making model construction methods, uncertain decision-making representation methods, application of new decision-making algorithms, MODAT for PMMS, and novel decision-making models. As various study topics were rigorously analyzed, present shortcomings and future directions in the use of MOO in pavement research were identified.
11. Prediction of Optimal Maintenance Alternative for Iraqi Pavement Management Based on Multi-Objective Optimization Technique and Constraint Genetic Algorithm.	Dr. Namir G. Ahmed Dr. Ali J. Kadhim and Amani A. Ferman 2017 [21]	Iraq	The fundamental purpose of this research is to develop a multi-objective optimization model to enhance the decision-making process of the Iraqi sidewalk repair management system over a span of years. Optimal targets include both lowering maintenance costs and improving the surface's current state.
12.Development of Pavement Maintenance Management System Using Visual Evaluation of Asphalt Concrete Surface Condition and Expert System	Saad Issa Sarsam 2008 [22]	Iraq	This study covers the creation of a PMMS for assessing the Asphalt Concrete pavement surface quality utilizing an expert system and a visual inspection approach. Asphalt Concrete distress conditions have been included in the system as data bases. The data is then sent into the expert system via computer, the system analyzes different forms of intensity and degree of distress, the current condition rating (PCR) of the pavement section is calculated, and the system advises the necessary maintenance action.

Table 1.1: (Cont). Review of Previous Studies

13.Network-level optimization of pavement maintenance renewal strategies	Jesus M. de la Garza, Sercan Akyildiz, Doug R. Bish, Denise A. Krueger 2011 [23]	USA	This study describes the creation and application of a simpler, yet useful, network-level pavement maintenance optimization model, which is a Linear Program (LP) subject to budget constraints and the agencies' pavement performance goals in terms of total lane-miles in each pavement condition state. Frontline Systems' Risk Solver Platform add-in for Microsoft Office Excel is used to create a decision-making tool. The appropriate amount of expenditure for each pavement treatment type in a particular financing period may be calculated using this decision-making tool.
14.An Iterative Approach for the Optimization of Pavement Maintenance Management at the Network Level	Cristina Torres-Machí, Alondra Chamorro, Carlos Videla, Eugenio Pellicer, and Víctor Yepes 2014 [24]	Chile	In this research, two methods to network maintenance program design are identified: holistic and sequential approaches. The former addresses the issue as a whole, before any individual sections or treatments are identified, and deals with potential remedies. The sequential method approaches the issue in two steps. It begins by optimizing the section-level maintenance approach. The budget is then distributed throughout the network's different components. This procedure reduces the issue to choices.
15.Network-Level Road Pavement Maintenance and Rehabilitation Scheduling for Optimal Performance Improvement and Budget Utilization	Lu Gao, Chi Xie & Zhanmin Zhang 2012[25]	USA	In this work, a parametric solution for solving the bi-objective pavement maintenance and rehabilitation scheduling issue is proposed. The efficacy and efficiency of the parametric technique are studied and proved in a case study utilizing real-world data from the Dallas District's Pavement Management Information System.

2. LITERATURE REVIEW

2.1 General

Management is one of the most important ingredients and elements of success in road and bridge maintenance projects. The most important elements of management are time and cost control. In this chapter, the literature is reviewed about the problems of roads and bridges, their types and causes, especially those problems that exist in Iraq, to study how to control time and cost in addressing and repairing these problems.

2.2 The Roads and Bridges Maintenance

Transportation infrastructure is one of a country's most valuable assets since it helps to economic and social growth. As a result, adopting appropriate maintenance standards must be one of the goals of public bodies; they include time-bound techniques such as preservation, maintenance, and rehabilitation therapies [26].

An institutional arrangement has been proposed on the basis of three types of maintenance- routine, periodic, and emergency. Many concerns must be solved before a rural road maintenance system can be successfully implemented. Some of the major ones have been highlighted, such as the classification of rural roads and their management under a single administration; the development of manuals for road maintenance ...etc. It has been recommended that maintenance be included as part of the entire road asset management system. Given the complexity of the procedure, it has been suggested that a step-by-step method be used [27].

Maintenance of a road network entails a variety of actions, such as identifying pavement faults, work planning, programming, and scheduling for existing field operations, as well as regulating and monitoring. The primary goal should be to keep the road surface in pristine condition while also preserving the age of the highway to its anticipated service life (or extending the projected service life). In general, maintenance operations include identifying problems and their causes, determining appropriate repair work, carrying out these tasks in the field, and comparing the outcomes to the plan[28].

Pavement maintenance methods should include important functional demands that protect the present highway network's quality while new enhancement activities are underway. As a result, there is a need to modify and improve the operational requirements, ensuring that financial features and enough preparation are obtained in order to carry out the required and adequate repair. This endeavor to explain the realistic needs at the operational level is significant in order to provide adequate highway maintenance activities.

Roads quickly become uncomfortable or unsuitable for traffic. The rate of degradation in general is determined by the quality of the surface materials as well as the early phase of highway construction, drainage efficacy, weather conditions, and traffic volume [22],[29].

The maintenance trends of several emerging nations suggest that adequate maintenance and rehabilitation practices are required. The primary reasons of road degradation and the ineffectiveness of various maintenance techniques sometimes go unnoticed due to the lack of a current data base required for the analysis of various operations such as planning, design, structural works, rehabilitation, and so on. As a result, the gap between budgetary allocation and requirements has grown over time[30].

Most African states have established road budgets and organizations and achieved significant road maintenance accomplishments. All African governments have increased road maintenance spending, but it is still insufficient. Poorly maintained roads increase accident rates, increase car operating costs, rural isolation, poverty, poor health, illiteracy, and increase heavy vehicle running costs [31].

The field of roads and bridges suffers in Iraq, as there is no periodic maintenance for roads and bridges, and there is no preventive maintenance. There is only emergency maintenance when problems develop, so they need more time and cost. even if the problems repaired be completed. The problems will develop in another place.

2.3 Methods and Techniques for Detecting Road and Bridge Problems

Uses automated optical image analysis to solve the issue of fracture identification on the surface of French national highways. The first addition is a state-of-the-art image-processing instrument for structural engineering. The second addition is about detecting tiny defects in concrete surfaces. The method relies on multi-scale extraction and Markovian segmentation. Third, an assessment and comparative procedure for assessing this challenging task—road concrete fracture detection—is presented. Finally, the suggested technique is verified, analyzed, and compared to a structural identification methodology [32].

Surface flaws and breakdowns can be detected using existing techniques for tracking the structural health status (SHS) of road surfaces. the goal of this research is to develop a guided machine learning (ML)-based technique for identifying and classifying the SHS of a differently fractured road surface based on its vibro-acoustic characteristic. The technique seeks to gather these signals (via curb side sound monitors) and identify the SHS of the sidewalk using ML models. Various ML models [33].

Ground Penetrating Radar (GPR) was used to evaluate its capacity on finding fractures of various sizes due to its usefulness for road maintenance and high precision. The findings revealed that the potential of detecting a fracture is primarily determined by the difference of the strata encircling the split. A computer calculation was also run, which verified the results [34].

This analysis concludes that, with the exception of the low severity case, all of the technologies under consideration are capable of reliably identifying the various types of damage seen in the racking group (fatigue cracking, block cracking, edge cracking, longitudinal and transverse cracking, joint reflection cracking, and slippage cracking). Because the necessary data varies in height, the laser scanner is ideally suited for detecting the distresses associated with the viscoelastic deformation group (bumps and sags, rutting, corrugation, depressions, potholes, swell, lane/shoulder drop off, and showing), and good results are also obtained when using laser triangulation. When it comes to spotting surface flaws (such as bleeding, polished aggregate, and raveling), camera, line scan, and laser triangulation technologies all achieve sufficient accuracy; The problems of the last group are picked up by all the technological solutions discussed in this study. (Railroad crossing, patching, and manhole). Starting with the data needed by the PMS, this framework might include all aspects of survey design and planning [35].

The researcher provides a technique for pavement crack recognition, segmentation, and geometric parameter computation based on a deep convolutional neural network fusion model [36].

Suggested a method for complained the GIS-enhanced PMS with life-cycle assessment and recommended to improve pavement preservation plans and decision-making processes. The proposed system includes a framework and technique for integrating life-cycle and environmental parameters in order to create an accurate pavement degradation prediction model that can be utilized for maintenance prioritization and life-cycle cost analysis [37].

When road damage is detected quickly and accurately, organizations responsible for road maintenance may make immediate improvements to road surfaces, maintaining optimal road conditions, increasing transportation safety while decreasing transportation costs. Eight methods for detecting road damage using deep learning were evaluated in depth for this study. A total of 9493 images were used to train each model. The 16165 instances of road damage seen in these images were categorized into five distinct types: longitudinal fracture, horizontal crack, alligator damage, cracks caused by potholes, and line distortion[38].

2.4 Problems of Roads and Bridges

This piece depicts the condition of roadways in the Republic of Iraq and investigates the feasibility of using cold renewal technology of asphalt concrete as the pavement's foundation. Furthermore, it demonstrates the economic effectiveness of using cold renewal of asphalt concrete technology in asphalt factories and roadways, including granulate pulverizing, cement, and a watery solution of a lubricant. When compared to conventional heated asphalt pavement techniques, the use of cool technology for reusing asphalt concrete in (Iraq and the Russian Federation) provides significant fiscal and environmental benefits [39].

A review of the state of upkeep techniques for road sidewalks in Iraq, open and closed surveys were distributed in Baghdad to assess the state of road surface upkeep in Iraq. to determine the degree of upkeep and methods used to manage asphalt roads in Iraq. Results: According to the conversations conducted, upkeep in Iraq is of minor significance, with no specific funding allotted for such essential works. Furthermore, the upkeep methods and techniques used do not correspond to advancements and contemporary techniques[10].

Summarizes the most recent research on the problems with flexible pavement and the maintenance of flexible pavement. A poorly designed pavement may be destroyed by water penetration in as little as one season. Flexible pavement defects exist in several dimensions. The issue of flexible pavements has been made more difficult by the exponential rise in vehicle traffic (measured in terms of the number of axle loadings of commercial vehicles), the rapid expansion of the road network, the absence of suitable technology, materials, equipment, skilled labor, and poor allocation of funds[5].

Sought to discover factors that degrade newly constructed roads in Khartoum state the common road defects, and their causes. This study selected three major road projects with different degradation reasons. In such initiatives, field surveys and laboratory tests assessed pavement problems. Cracks, potholes, and wheel path rutting plagued the roads examined [40].

The purpose of this research, is to lay out a technique for assessing environmental, social, and economic (ESE) factors during the pre-construction phases. The Al-Nebai-Baghdad Highway Rehabilitation and Improvement Project has been chosen for this research. The ESE markers are chosen based on the data and methods accessible. The necessary data, such as traffic flow, surface state, and geometry design features, are gathered in order to process the engineering and ESE evaluation by combining several methods and analysing the findings using the cost-effectiveness technique [41].

an analysis of A local road in Abo-Ghreeb city, Baghdad (the capital of Iraq), measuring (1.45) km in length and (8.0) m in width was analysed using the EPCM tool. The treatment necessitated an asphalt overlay for the road. Resurfacing is a common method of maintenance in Iraq, and the municipality of Abo-Ghreeb deemed it necessary to do so in order to fix the road. Because there aren't any hard and fast rules for picking a maintenance method [42].

Most Basra roads have substantial failures in their layers and bases, which manifest as cracking, crushing, landing, and enormous holes. Geotechnical variables have been explored in relation to the performance of Basra roads. This necessitates performing geotechnical studies of the road's course before to construction to assess the type of the foundation soils and the existence of soils with issues that must be fixed and remedied prior to construction [43].

This research, intends to use a field assessment to collect a number of samples from various sections of the Baghdad-Baquba expressway in order to analyse the structural characteristics of the sidewalks using laboratory testing. The findings of the experiments were used to assess the pavement's capacity using the AASHTO 1993 technique. The findings showed that the projected applicable traffic load was more than 12 times greater than the computed permissible traffic load, indicating a catastrophic scenario. As a result, the research suggested that the sidewalks be rehabilitated through rebuilding. According to the research, all strata must be of exceptional quality and have a high elastic elasticity in order to withstand the predicted traffic burden [2].

Roadways made of bituminous material eventually wear down and lose their effectiveness after years of usage. As bitumen ages, it becomes more brittle, weakening pavement and shortening its useful life [44].

There are three different kinds of pavement failure: those in the sub-grade, sub-base, or base courses, and the wearing courses. Climatic fluctuations, increasing multi-axle vehicles, and excessive traffic are only few of the causes of pavement deterioration. The most typical types of damage to flexible pavement are also shown. Some common failure modes include the following: alligator cracking, transverse cracking, edge cracking, longitudinal cracking, block cracking, corrugation ravelling, and pushing, potholes, patching, polished aggregate, bleeding, and depression [45].

The swelling behaviour of some soils, particularly those with a high clay concentration, has a significant effect on woodland roadways. Moisture fluctuation causes volume shift in expanding soils. If the earth cannot expand easily, it will exert weight on nearby buildings, potentially causing harm or total ruin. As a result, it is critical to evaluate the growth capacity of foundation sediments and take suitable steps to address this issue [46].

Rutting in a pavement is negative effects for various reasons. Rutting causes issues for users by increasing fuel consumption and the danger of sliding (on water or ice). It also causes problems for owners since ruts enable water to seep into the pavement rather than draining off the surface, resulting in fast pavement degradation [47].

This study set out to investigate the factors that contribute to the increasing incidence of ravelling in asphalt pavements that are already in use, and how this phenomenon affects the performance of these pavements in dry climates. This study contributes to the larger effort to identify the best method for addressing the premature ravelling problem in Kuwait's arid climate [48].

Damage to pavement includes things like cracks, surface problems, and disintegration, all of which reduce its use and lead to degradation. The most obvious surface defects that cause locals to worry are potholes. The purpose of this study was to investigate what factors contribute to the development of potholes on Chandigarh's roads [49].

This study, examines how higher Iraqi temperatures improve tarmac self-repair. Rest times were used to reverse ageing and allow asphalt to move and disperse. High temperature reduces asphalt viscosity, allowing bitumen to flow and increasing asphalt wettability. As the study focused on Iraqi summer temperatures, samples were aged in the lab and temperature was given in the field. This study found that adding only warmth to old asphalt reduced viscosity and improved bitumen flow[50].

The study consisted of two parts: the first examined the visual assessment of current pavement issues, and the second investigated the root causes of these failures. Khartoum's Obeid Khatim Street was selected as a case study. Extensive field investigation was done to determine the current pavement condition of this route. Cracking and rutting were found to be severe problems in the majority of the impacted pavement sections. It's possible that the constant stress of heavily loaded truck-trailers on the pavement led to these failures. The damage might have been brought on by improper drainage, inadequate planning, or the use of unsuitable paving materials [51].

Road surface care is critical for preventing significant degradation and lowering mishap rates. The identification and categorization of various kinds of fractures on roadways is typically addressed in this job. However, in most instances, these duties are not completely automatic, and fix choices must be overseen by an expert. The emphasis of this study is on the automated categorization of the three most prevalent kinds of fractures: longitudinal cracks, transverse cracks, and alligator cracks [52].

2.5. An Inventory of the Most Prominent Problems of Roads and Bridges in Iraq

1-Cracks

a-Alligator Cracks This problem appears due to the instability and subsidence of the basic layers or what is under the foundation as a result of saturation of the layers with water, in addition to the passage of loads that are more than the design weight of the road. Figure 2.1 shows Alligator Cracks.

Figure 2.1: Alligator Cracks

Source: (www.noor-book.com, 03.02.2023)

b. Longitudinal & Transverse Cracks The reasons that lead to the occurrence of the problem are the movement of earth materials (Earthen Filling) or the movement of materials in the base layer or under the foundation, shrinkage or shrinkage of the paving layer, swelling in the fillings or foundation materials or what is under the foundation or shrinkage of earth materials in addition to the lack of traffic on the road. Figure 2.2 shows Longitudinal & Transverse Cracks.

Figure 2.2: Longitudinal & Transverse Cracks

Source: (www.noor-book.com, 03.02.2023)

c. Block Cracks This type of failure is the least common problem in Iraq and its causes are low temperature and when the bitumen is hard or stiff, i.e., when the permeability of the bitumen is low, it is in the direction of hardness. Figure 2.3 shows Block Cracks.

Figure 2.3: Block Cracks

Source: (www.noor-book.com, 03.02.2023)

d. Edge Cracks: The reasons for the occurrence of this problem are the lack or loss of the lateral support from the shoulders, poor water drainage, subsidence and looseness of the materials under the cracks area, swelling of the materials due to freezing, shrinking of the materials due to drought, the large number of trees and shrubs adjacent to the tiling, and the main reason is the possibility that the width of the tiling is more than one width. Layer under the foundation. Figure 2.4 shows edge Cracks.

Figure 2.4: Edge Cracks

Source: (www.noor-book.com, 03.02.2023)

e. Reflection Cracks: The reasons that lead to the occurrence of the problem are the vertical or horizontal movement of the asphalt layer (may be concrete) under the new paving layer, as well as due to the change in temperature and humidity and the failure to repair cracks in the old layer. Figure 2.5 shows Reflection Cracks.

Figure 2.5: Reflection Cracks

Source: (www.noor-book.com, 03.02.2023)

f. Slippage Cracks: The reasons for the appearance of this problem are poor bonding between the tiling layers due to not cleaning from dust before applying the final layer or not spraying the take-coat material, or it may be because the mixture contains a high percentage of sand, or the quality of the sand used in the mixture is not good and it may be due to a lack of compacting or cooling the mixture for the last layer. Figure 2.6 shows slippage Cracks.

Figure 2.6: Slippage Cracks

Source: (www.noor-book.com, 03.02.2023)

2. Patching: Patching is considered one of the most widespread maintenance methods for asphalt pavement. All roads need to be patched during their lifespan, either to treat potholes that occur in the road due to any natural phenomena, or to fill in the trenches necessary to extend public services under the roads. Also, the patching process requires accuracy, experience, and complete and direct supervision so that there are no dents in the road, and thus water reaches the lower layers, which in turn will lead to complete damage to the road. Figure 2.7 shows Patching.

Figure 2.7: Patching Problem

Source: (www.noor-book.com, 03.02.2023)

3.Potholes : The causes of this problem are due to the cessation of water over the surface of the paving and it begins to dismantle the rubble from the bitumen and with the passage of vehicles it begins to expand. Figure 2.8 shows potholes problem.

Figure 2.8: Potholes Problem

Source: (www.noor-book.com, 03.02.2023)

4.Shoving: The reasons for the appearance of this problem are the poor bonding between the paving layers, as well as the poor design of the asphalt mixture. Figure 2.9 shows shoving problem.

Figure 2.9: Shoving Problem

Source: (www.noor-book.com, 03.02.2023)

5. Depression: The reasons for the emergence of this problem are the passage of more than the design load on the road, the weakness in the implementation of a specific area due to compacting weakness, or lack of attention to the level. Figure 2.10 shows depression problem.

Figure 2.10: Depression Problem

Source: (www.noor-book.com, 03.02.2023)

6. Rutting: The reasons for the appearance of this problem are the lateral movement of the foundation layers or what is under the foundation under the wheels, or the crawling of the paving itself for the new layers that were not well resolved during implementation, or the weakness in the strength of the asphalt layers over time. Figure 2.11 shows rutting problem.

Figure 2.11: Rutting Problem

Source: (www.noor-book.com, 03.02.2023)

7. Bleeding: The reasons for the occurrence of bleeding in the asphalt are either that the air spaces are few or the percentage of asphalt is high. Figure 2.12 shows bleeding problem.

Figure 2.12: Bleeding Problem

Source: (www.noor-book.com, 03.02.2023)

8. Raveling & Weathering: It is the problem of separation of the aggregates from the asphalt mixture, which results in erosion of the pavement layer. The reasons for this problem

1-Weak adhesion strength between aggregate and asphalt particles.

2-Lack of asphalt resistance to heat (the degree of ductility of asphalt).

3-Structural factors (unfavorable slope, opening the road immediately after its construction).

4-Environmental factors (surface temperature, the effect of vehicle loads in the presence of water).

Figure 2.13 shows Raveling & Weathering problem.

Figure 2.13: Raveling & Weathering Problem

Source: (www.noor-book.com, 03.02.2023)

9. Polished Aggregate: The reasons for the emergence of this problem are:

1.The Texture of the grave is very fine.

2.The viscosity of asphalt is weak. Figure 2.14 shows polished aggregate problem.

Figure 2.14: Polished Aggregate Problem

Source: (www.noor-book.com, 03.02.2023)

10.Sags & Bumps: The main reason for the appearance of this problem is poor mixture design, in addition to poor construction. Figure 2.15 shows sags & bumps problem.

Figure 2.15: Sags &Bumps Problem

Source: (www.noor-book.com, 03.02.2023)

11. Corrugation: The reasons for the emergence of this problem are the lack of stability of the asphalt layers, the presence of a high percentage of asphalt in the Bitumen mixture or a high percentage of soft materials, and the mixture containing a high percentage of moisture or the creep of the upper layers, which results in poor adhesion with the layers below it, especially on slopes.
Figure 2.16 shows corrugation problem.

Figure 2.16: Corrugation Problem

Source: (www.noor-book.com, 03.02.2023)

12. Lane Shoulders Drop: The reasons for the occurrence of this problem are weakness in the compaction process or the quality of the materials is not appropriate. Figure 2.17 shows lane shoulders drop problem.

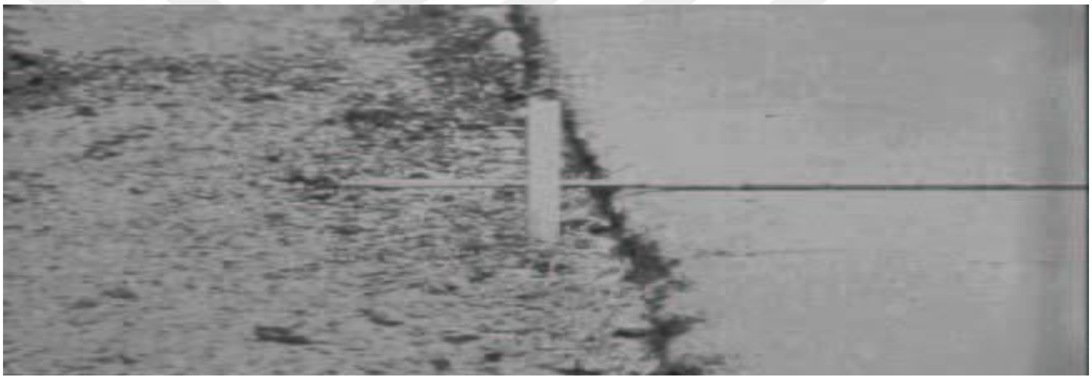

Figure 2.17: Lane Shoulder Drop Problem

Source: (www.noor-book.com, 03.02.2023)

13. Swelling: The reasons for the occurrence of this problem are due to the muddy or organic soil because the burial work is not correct. Figure 2.18 shows swelling problem.

Figure 2.18: Swelling Problem

Source: (www.noor-book.com, 03.02.2023)

14.Railroad Crossing: The shoulders of the railways during the road must be made of reinforced concrete, after that the asphalt joint with concrete, and since most of the roads in Iraq work the shoulders of the railways from asphalt, the problems of the railroad crossing occur. Figure 2.19 shows railroad crossing problem.

Figure 2.19: Railroad Crossing Problem

Source: (R.W.)

15.Utility Cut Patch: This problem appears after road maintenance or as a result of negligence and lack of care for the roads. Figure 2.20 shows utility cut patch problem.

Figure 2.20: Utility Cut Patch Problem

Source: (www.noor-book.com, 03.02.2023)

16.Joints: The joints of bridges are made of plastic, that means most of the materials are plastic, so delaying periodic maintenance and cleaning them, and poor follow-up leads to problems that cause damage to these joints. Figure 2.21 shows joints problem.

Figure 2.21: Joint Problem

Source: [R.W.]

2.6 Expert System

An expert system represents a human expert's domain-specific knowledge and ability, which has been gained and honed over years of experience. A variety of diagnostic and engineering issues can be solved using went expert-system methods. This document lists the major components of such issues as well as the measures made to solve them [54].

This paper[55], describes a paradigm for building expert systems that attempts to identify tacit knowledge, provides means for capturing it in expert system knowledge bases, and applies it to more perceptive machine-generated explanations and more consistent and maintainable system organization.

this piece looks at how a parametric forecasting approach might be applied to road construction projects in Texas using a database of project characteristics. The early quantity prediction for geometry-related work activities such as earthwork, paving, and traffic management was modelled using generalized linear models for use in tracking project costs through time. As additional data becomes available, this method may be expanded from its initial stage of producing early parametric cost forecasts to full-fledged comprehensive cost management. While it is common practice to calculate a total cost per lane length during the project's preliminary planning stages, the proposed method, when used in conjunction with the developed expert system, provides a more solid basis and efficient means of tracking the effects of changes throughout the project's lifetime [56].

The goal of this article [57], is to provide a concise summary of current research on the topic of building transit applications, developing an expert system, and then evaluating it. In addition, the results of this research might provide new insights on the subject. Experts in the field of performance are able to use the expert system to evaluate, decide, and customize data in order to aid relevant stakeholders in making decisions. It's also thought that more complicated models with the most potential might be built by combining advances in different ways.

In Sweden, an expert system performs the categorization using weather data from the Swedish Road Weather Information System. The road state is categorized as excellent or one of ten distinct kinds of road slipperiness. The road conditions are examined during three distinct winter seasons. The findings indicate that changes in temperature cause significant differences in yearly road state traits.

The expert system's classification of road slipperiness output is compared to previously documented winter road repair data. When road conditions were categorized as slick, 49% of the time, maintenance action was taken [73].

It offers decision-makers with a simple and straightforward approach for selecting the best answer based on environmental factors. The suggested method is demonstrated using a case study from France. Following that, various methods representing the decision-maker's views toward economic and environmental goals are examined. This program yields conclusions and suggestions for future enhancements [58].

The major components of the automated decision support system being created for roadway repair management applications in Greece are as follows:

• A module for predicting pavement performance over time using Markov analysis;

• A module for allocating optimal budgets based on maintenance needs;

• A module for managing maintenance projects; and

• A user interface with appropriate input/output forms and data representation on a digital map (GIS) [59].

The goal of this article [60], is to summarize the most recent findings from studies on the process of designing, creating, and applying an expert strategy for adaptable concrete construction. Furthermore, the study demonstrates the importance of developing an expert system to aid in damage management in humid areas. The adaptable sidewalks on the equatorial region's highways are founded on the expertise of specialists who have studied and managed highway pavements. This system allows performance experts to analyse, decide, and personalize data to assist pertinent stakeholders in decision-making processes. The Figure 2.22 attached show Expert Systems for Flexible Pavement maintenance.

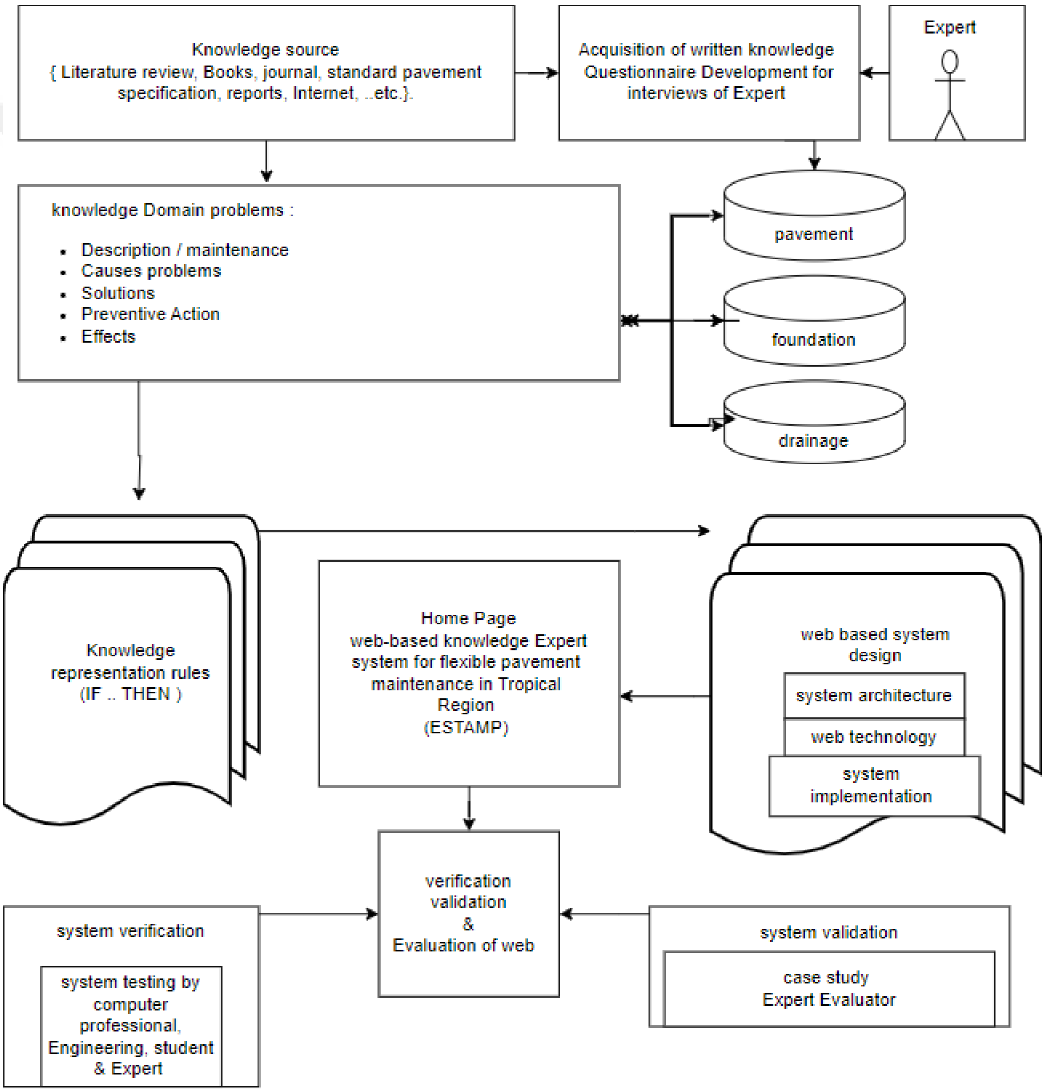

Figure 2.22: Expert Systems for Flexible Pavement Maintenance

Source: (J. Teknologi *et al.*, 2016).

Expert systems, a novel information technology drawn from artificial intelligence study, have been developed in the field of sidewalk administration for several decades. It was created in order to mimic or replicate clever problem-solving behavior in a computer software. Because of reductions in paving funding, the use of expert systems in this field is quickly increasing. Because the majority of current expert system uses are for roadway networks, this study is concerned with the possible creation of such knowledge-based or expert systems for airport tarmac repair methods[61].

With data provided by the General Administration of Operation and Maintenance in Riyadh, Saudi Arabia, an expert system was developed utilizing performance models for sidewalks. For the first time, eight regression models were constructed to take into consideration the four M&R techniques for maintenance and rehabilitation. (No maintenance, regular maintenance, overlay, and rebuilding for low and heavy traffic). Then, an actionable expert system was created to help experts in the sidewalk maintenance industry choose the best M&R strategies and schedules[62]. Expert Systems mentioned for Pavement Maintenance are shown in the accompanying Figure 2.23.

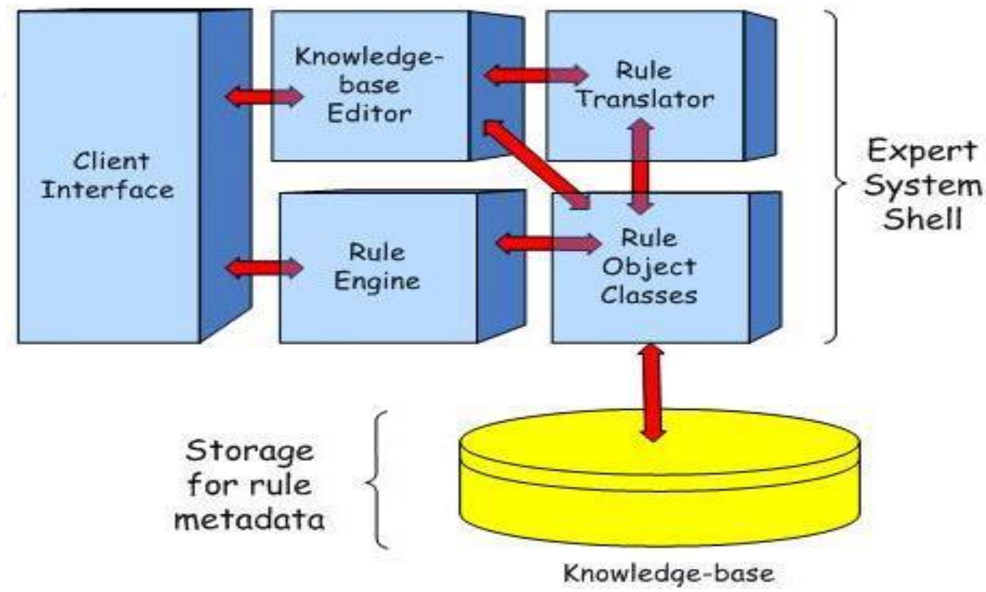

Figure 2.23: Expert Systems of Pavement Maintenance

Source: (A. Al-Mansour, *et al;* May 2022)

For the classification of distresses, a technique based on fuzzy logic has been devised. In C, an expert system with fuzzy logic thinking was created. The created methodology's goal was to use automated methods for fast, efficient, and consistent categorization of flexible sidewalk distresses based on data from the automated distress monitoring system. The expert system created was intended to be used as an element within a sidewalk control system. This will aid in fully automating sidewalk state assessment and plan creation for pavement upkeep and repair, removing bias and irregularity from the process. The discrepancies between real observed data and findings from fuzzy logic expert system methods, according to the specialists, were well within permissible limits [63]. This research details how an expert system with visual evaluation was developed into PMMS for assessing the condition of asphalt concrete sidewalks. Asphalt concrete damage such as patching, bleeding, edge cracking, block cracking, longitudinal and transverse cracking, pot holes, and longitudinal and transverse deformation are all stored in the system's database. Pavement will be divided into sections and visually evaluated using specialized forms; this information will be fed into a computerized expert system, which will then analyze the data to rank the pavement sections according to their current condition (PCR) and recommend necessary repairs [64], [65].

A prototype web-based expert knowledge system for tropical moveable sidewalk maintenance is shown in the research. This notion benefits from the use of web-based expert system technologies. The most serious problem in Malaysia is bitumen surface layer deterioration, which requires maintenance to maintain roads open and transit services consistent, timely, and safe. Therefore, the system improves engineers' ability to assess, interpret, and customize data connected to projects, increasing the likelihood that they will choose the best alternative and provide the most effective treatment at the right moment [22].

2.7 The Impact of Cost and Time on Road and Bridge Maintenance Projects

So far, most research has focused on determining the reasons of cost and time overruns. First, the variables that impede both time and cost management during building projects were identified. The goal of project control in the construction business is to guarantee that projects are completed on schedule, within budget, and meet other project goals. A questionnaire survey and in-depth interviews were utilized to give relevant information about project control challenges in practice in the UK. Issues such as the extent to which project controls are employed, as well as the most widely used time and cost estimates [66].

The goal of the study, is to explicitly declare the scope of the study by considering only the scope, time, cost, and quality as process success parameters and how specifically the cost element would influence project success when all other elements or factors other than cost are represented in terms of cost factor along with the contract conditions as basic rules or constraints that drive the strategic cost based on applying the CRASP methodology concept [67].

This research [68], creates models that separate project cost and schedule into four distinct performance groups. The research then looks at the practices that discriminate against these four groups. Pre-project planning, project change management, and design/information technology practice are critical practices with a significant influence on both cost and schedule performance. The major goal of this study [69], is to provide a project cost planning and control model for construction firms. This model seeks to aid in the creation of production management systems in which cost management and production planning and control may be progressively linked in order to overcome the limits of cost accounting systems.

The cost estimate is an experience-based process that requires evaluating unknown conditions and intricate interactions between cost-influencing components. This study [70], shows how to create a cost estimation model using artificial neural networks and a back-propagation technique. Building project cost determinants were identified, and data from the BCIS database was retrieved.

The purpose of this research [71], was to investigate the cost-cutting strategies employed by contractors on ongoing projects and to recommend steps that would allow projects to be finished within budget. Schedules, budgets, inspections, meetings, reports, records, monitoring, and evaluations were identified as seven widely utilized cost control approaches in the study.

This paper [72], attempts to identify the cost control methods and procedures that Malaysian construction practitioners are currently employing and seeks feedback from respondents on whether the current approach and techniques are adequate or whether a new approach to cost control as an alternative to the conventional corrective technique is truly required. Face-to-face interviews with respondents were conducted for this study, and the approach was entirely qualitative. The study's findings indicated that efficient cost-cutting methods, practices, and techniques are severely missing, and they are similar to those in other nations.

The necessary funding is directly influenced by the sidewalk upkeep and repair (M&R) strategy for keeping adequate surface quality. Because deterministic budgeting is a false premise, this research develops a two-stage stochastic model using integer programming to handle budget ambiguity. Another goal of this research is to create an executive model that takes into account a wide variety of factors when planning network upkeep and restoration. the evolved model includes several M&R designs that are budget-compatible [73].

This study [74], attempted to identify the major reasons of cost overruns in construction projects and sought to explore cost control approaches. This study conducted a literature review, which aided in determining the main causes of cost overruns on construction projects. An accurate cost estimate, as well as efficient cost monitoring and management, are critical components of construction project success.

This study focuses on the Building Information Modeling Strategy in Mitigating Variation Orders in Roads Project. Its contribution to this area is BIM Design: an applied technique for reducing the sequence of change in road projects. The research suggests that this technique be utilized to handle construction industry difficulties in Jordan, given that BIM has supported its potential to solve construction challenges all over the globe as BIM-related services[75].

This study[76], presents a complete cost-estimating and monitoring approach. The model is coupled with BIM to allow the user to see real costs invested in various architectural parts and compare them to those budgeted at different time intervals. The relevance of integrating project cost estimation, cost monitoring/control approaches, and BIM platforms is emphasized.

The purpose of this study [77], was to discover the elements that influence the construction cost of building projects, a questionnaire survey was undertaken in the three largest construction sectors, namely Japan, the United Kingdom, and the United States. Based on the practices of contractors in the three nations, a construction cost model was constructed that identified the most important elements found to impact contractor cost performance and highlighted potential areas for improvement.

The majority of the study [78], effort focuses on the causes of cost increases and the different strategies used to manage this growth. Questionnaires were created and sent to specialists in the construction business, and the data was examined to draw many conclusions. The conclusion result demonstrates that project cost control planning is critical since it will assist experts in the construction area to optimize funds and utilize them efficiently throughout project execution.

In this study, questionnaires were conducted, expert opinions were collected, and a field survey was conducted to determine the time and cost required for road and bridge problem repair and maintenance in Iraq using the expert system. A program was created using the MATLAB programming language to calculate the cost and time directly according to the number of meters for each problem.

3. FIELD STUDY

3.1 General

It began to extract the most realistic problems of roads and bridges in Iraq. It was collected by looking at previous studies, literature, and an open questionnaire to engineers and experts in this field. In which the most prominent problems in Iraq were extracted and preliminary results were obtained for the time and cost required to repair and maintain each square meter of these problems. The results were processed by statistical methods to obtain answers covering all experts' opinions in the open questionnaire. the results of the open questionnaire were put as options for the same problems in a closed questionnaire in Google form. After that, an equation was found to achieve the time needed to repair and maintain more than one square meter. Because the time is cumulative, the first square meter takes more time because it includes the time for preparing to the work. It was necessary to conduct an open and closed questionnaire to achieve the research objectives.

3.2 Open Questionnaire

The open questionnaire aims to conduct direct interviews with 42 experts and engineers with sufficient experience to obtain answers to questions prepared in advance through the literature or that are added or updated during meetings and dialogues so that more information and correct ideas are added to the research. During this stage, many direct interviews were conducted with experts, consultants or expert engineers in the roads and bridges sectors to obtain sufficient information about the most prominent problems of roads and bridges in Iraq. Problems of roads and bridges in Iraq, as well as other problems are added if they are not addressed in the literature and exist in reality with the time and cost required to maintain each square meter of them to enter all these results and outputs into the closed questionnaire after processing them by statistical methods.

3.2.1 Most of problems in roads in Iraq

According to the previous studies, literature, and the opinions of expert engineers with great experience in the field of roads and bridges. Most of the problems that the road and bridge bandits suffer from in Iraq have been listed, whether they are in District roads, international roads and bridges, and they were as follows:

1.Cracks

a. Alligator Cracks
b. Longitudinal & Transverse Cracks
c. Block Cracks
d. Edge Cracks
e. Reflection Cracks
f. Slippage Cracks

2.Patching
3.Potholes
4.Shoving
5.Depression
6.Rutting
7.Bleeding
8.Raveling & Weathering
9.Polished Aggregate
10.Sags & Bumps
11.Corrugation
12.Lane Shoulders drop
13.Swelling
14.Railroad Crossing
15.Utility Cut Patch
16.Joints.

3.2.2 Statistical treatment of the results of the questionnaire

After the open questionnaire was done, there were differences in time and cost in Experts opinions. The arithmetic average of the most frequent values was chosen to cover all the answers and entered into the closed questionnaire.

3.2.2.1 The time in the open questionnaire

The opinions of most experts centered around (1 day, 2 days, and 3 days) According to many reasons, including the type of road, size of the problem, location, environmental conditions, and administrative approvals. This times not only mean the time required for repair and maintenance, but also includes preparation for starting work, assembling cadres and mechanisms, identifying problems accurately, and completing administrative transactions, which means that this time is required to repair only first one square meter. As for the maintenance of more than one square meter, an equation is used in which we use an adjustment factor that represents the percentage of the cumulative time required to repair more than one square meter, that's clarified later. After getting the results of the closed questionnaire for the time, it is recommended to enter 1 day, 2 days, and 3 days in the closed questionnaire to obtain accurate results within these options that are adopted for the repair of one square meter in the time equation (1 day, 2 days, and 3 days).

3.2.2.2 The cost in the open questionnaire

As for the cost, the costs required to repair and maintain each square meter of each problem were analyzed. It is worth noting that the final cost required to repair one square meter is multiplied by the number of square meters required, so the cost per square meter is multiplied by the number of square meters for each problem to get the total cost. Since the repair of each problem has a special cost according to the severity of the problem, the type of road, the location, the type of maintenance and its requirements, and the implementing agency. The costs required to repair and maintain the problems were analyzed based on the opinions of experts to determine the cost rates that are entered into the closed-ended questionnaire to obtain the final cost rate. The cost analysis for each problem was for Iraq:

1. Cracks:

a. Alligator Cracks: The cost of maintenance was analysed in the open questionnaire and according to the field studies and the field survey as example for (100 m^2) as shown in Table 3.1.

Table 3.1: Analysis of Cost for Alligator Cracks Maintenance.

The Works	Cost
1-Cutting and removing the paving layers, the base, the under-base, and a section of the earthwork to the required depth until we reach a strong, non-moistened area, provided that the excavation extends to the edges of the area surrounding the failure with 30 cm of non-cracked areas, and the excavation is vertical in the form of a square or rectangle.	200$
2-Good drainage work, such as deepening the canals, laying off the shoulders, and making channels to prevent water from reaching the area.	100$
3-Spraying a layer of Tack Coat on the vertical faces only without the base in case the hole is filled with asphalt only.	100$
4-Filling the entire excavation with concrete asphalt, which shall be spread in layers, the thickness of which does not exceed 15 cm.	1000$
5-Compacting the layers well with a vibrating hand roller or regular roller	200$
6-In the case of using layers under the base, prime coat must be sprayed on the final layer before the base layer. The final level of the excavation must be equal to the level of the paving from the sides, using long wooden rulers to adjust the final level.	100$
The Total Cost	1700$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1700$ / 100 m² = 17 $/m²

This value is subjected to change according to the type of road, the severity of the problem, the location of the problem, and the area within which it is located, as well as environmental conditions such as temperature. And other factors. According to experts' opinions, it was recommended to test the values ($10, $20, and $30) in the closed questionnaire to cover all cases and obtain an average of the selected values according to the number of voters. This observation applies to all problems except joints.

b. Transverse& Longitudinal Cracks: For (100 m²) as shown in Table 3.2.

Table 3.2: Analysis of Cost for Transverse& Longitudinal Cracks Maintenance

The Works	Cost
1- Cleaning the cracks well.	100$
2- It can be repaired by filling the cracks with asphalt liquid mixed with sand	1300$
3- Then the area is covered with a thin layer of tar mixture with a thickness of 2.5 cm.	200$
The Total Cost	1600$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per $1m^2$ = The total cost / No. of m^2 =1600$ / 100 m^2 = 16 $/$m^2$

c. Block Cracks: For (100 m^2) as shown in Table 3.3.

Table 3.3: Analysis of Cost for Block Cracks Maintenance.

The Works	Cost
1-Cleaning: It means cleaning the cracks with air	100$
2-Putting a mixture consisting of bitumen and sand called (sand Mix) on the Cracks, the mixture must be hot	1500$
3-Sprinkle sand over the entire road surface	100$
4-The sand is removed from the surface of the road, and only the sand that is combined with the bitumen binds together	50$
The Total Cost	1750$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per $1m^2$ = The total cost / No. of m^2 =1750$ / 100 m^2 = 17.5 $/$m^2$

d. Edge Cracks: For (100 m^2) as shown in Table 3.4.

Table 3.4: Analysis of Cost for Edge Cracks Maintenance.

The Works	Cost
1-Cutting and removing the cracked area, provided that the cut extends to the edges with a distance of 30 cm and is cut in a rectangular or square geometric shape with vertical flat edges	200$
2-The excavated area shall be cleaned of dust or any other suspended material with a pressure brush	100$
3-Spraying a layer of adhesive (Tack Coat) at the bottom of the place and on the sides, then spread the gravelly mixture well, noting that the course materials in the mixture do not separate from the fine ones at the same level as the adjacent area and compacted well.	150$
4-The level is checked with a wooden ruler, and it can be compacted with a manual, vibrating, or rubber compactor.	100$
5-But if the cause is from a layer under the foundation, the area must be extracted and re-established well. (subbase=200$) + (asphalt=1500$)	1700$
The total cost	2250$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per $1m^2$ = The total cost / No. of m^2 =2250$ / 100 m^2 = 22.5 $/$m^2$

e-Reflection Cracks: For (100 m^2) as shown in Table 3.5.

Table 3.5: Analysis of Cost for Reflection Cracks Maintenance

The Works	Cost
1-Cleaning the incision well by brushing it with an air compressor	100$
2-Filling the crack with asphalt liquid mixed with sand	1500$
3-Waxed with asphalt liquid	100$
4-Sprinkleing the area with dry sand	100$
The Total Cost	1800$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per $1m^2$ = The total cost / No. of m^2 =1800$ / 100 m^2 = 18 $/$m^2$

f- Slippage Cracks: For (100 m^2) as shown in Table 3.6.

Table 3.6: Analysis of Cost for Slippage Cracks Maintenance.

The Works	Cost
1-Cutting and removing the cracked area, provided that the cut extends to the edges with a distance of 30 cm. It is cut in a rectangular or square geometric shape with vertical flat edges.	200$
2-Cleaning the excavated area of dust or any other suspended matter by brushing and compacting	100$
3-Spraying a layer of tac-coat at the bottom of the place and on the sides, then spread the bituminous mixture well, noting that the course materials in the mixture do not separate from the soft ones at the same level as the adjacent area and compacted well.	1500$
The Total Cost	1800$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per $1m^2$ = The total cost / No. of m^2 =1800$ / 100 m^2 = 18 $/$m^2$

2. Patching: For (100 m^2) as shown in Table 3.7.

Table 3.7: Analysis of Cost for Patching Maintenance

The Works	Cost
1-Cutting and removing the cracked area, provided that the cut extends to the edges with a distance of 30 cm. It is cut in a rectangular or square geometric shape with clean it well.	200$
2-The excavation and its sides shall be sprinkled with a layer of diluted asphalt that matures rapidly if the excavation is shallow and does not reach the soil layer. Or it is sprinkled with diluted asphalt of medium maturity if the excavation is deep and reaches the earthen layer.	100$
3-The asphalt layer is well laid and compacted	1500$
The Total Cost	1800$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1800$ / 100 m² = 18 $/m²

3.Potholes: For (100 m²) as shown in Table 3.8.

Table 3.8: Analysis of Cost for Potholes Maintenance.

The Works	Costs
1- The holes are cut from the Pavement in the form of a rectangle and the suspended materials are removed	200$
2- The floor under the Pavement is compacting well	200$
3- Bituminous liquid is pumped over the edges	100$
4- Spreading a layer of prime-coat on the floor and sprinkle on the edges (After 24 hours, the asphalt is Compacting)	100$
5- Spreading and compacting the asphalt, noting that the laying is done at a higher level than the original Pavement level so that it is equal to the tiling after Compacting at a temperature of more than 120 degrees.	1500$
The Total cost	2100$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² = 2100$ / 100 m² = 21 $/m²

4.Shoving: For (100 m²) as shown in Table 3.9.

Table 3.9: Analysis of Cost for Shoving Maintenance

The Works	Costs
1- The damaged tiling layer is completely removed.	200$
2- Distribution and compacting of the new asphalt layer.	1300$
The Total Cost	1500$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1500$ / 100 m² = 15 $/m²

5.Depression: For (100 m²) as shown in Table 3.10.

Table 3.10: Analysis of Cost for Depression Maintenance

The Works	Cost
1-Determine the amount of depression by means of a wooden ruler, and the area is marked, and the area can be milled to obtain vertical faces, if machines are available for that. The area is cleaned well, at a distance of 30 cm from each additional side.	200$
2-Spraying the take-coat material at a rate of 0.2-0.7 liter/m2, then spread the bituminous mixture and level it to obtain the required level after the good compacting.	1500$
3-The area can be sprayed with liquid asphalt to prevent water from leaking into the mixture, and fine sand can be sprinkled over it to prevent its extraction.	200$
The Total Cost	1900$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1900$ / 100 m² = 19 $/m², this value

6.Rutting: For (100 m²) as shown in Table 3.11.

Table 3.11: Analysis of Cost for Rutting Maintenance

The Works	Costs
1-In the event that the creep is a little (i.e., less than 1.5 m), after determining it with a wooden ruler of length 3-4, the area should be cleaned well, then the tac-coat should be sprayed at a rate of 0.2-0.7 liters / m2.	300$
2-Spread a thin layer of the bitumen mixture to fill the grooves, making sure that the edges are well-filled.	1300$
3-Compacting is done with a rubber road roller, provided that the final level is equal to the road level.	200$
The Total Cost	1800$
- (i.e., more than 1.5 m) 1-The grooves must first be excised by an asphalt cutter to get rid of the large height of the grooves,	200$
2- Then the area is cleaned using an air compressor,	100$
3- A layer of tac-coat is spread	100$
4- Then the concrete asphalt is leveled, and it is well compacted, with the necessity of observing the level.	1500$
The Total Cost	1900$

This means that calculation the cost of maintenance per square meter is calculated as follows:

a-The cost of maintenance per 1m² = The total cost / No. of m² =1800$ / 100 m² = 18 $/m²

b- The cost of maintenance per 1m² = The total cost / No. of m² =1900$ / 100 m² = 19 $/m²

7. Bleeding: For (100 m²) as shown in Table 3.12.

Table 3.12: Analysis of Cost for Bleeding Maintenance

The Works	Costs
1- Determine the area that requires treatment and clean it well.	200$
2- A coarse crushed aggregate of 6 mm size is prepared and heated to make it hot for 150ºc according to the Iraqi standard specification.	500$
3- Compacting the coarse aggregate over the bleeding area with a roller with rubber wheels	300$
4- When the gravel has cooled, all loose gravel is collected and disposed of out of the way.	200$
The Total Cost	1300$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1300$ / 100 m² = 13 $/m²

8.Raveling & Weathering: For (100 m^2) as shown in Table 3.13.

Table 3.13: Analysis of Cost for Raveling & Weathering Maintenance.

The Works	Costs
1-Peeling for the purpose of roughening the surface	200$
2- Re-paving, including the tar-coat layer, then compacting in less than two hours, thoroughly and examined	1300$
The Total cost	1500$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m^2 = The total cost / No. of m^2 =1500$ / 100 m^2 = 15 $/$m^2$

9.Polished Aggregate: For (100 m^2) as shown in Table 3.14.

Table 3.14: Analysis of Cost for Polished Aggregate Maintenance

The Works	Costs
1- Roughing the surface layer of the road pavement.	200$
2- Re-working the pavement layer and compact well.	1300$
The Total Cost	1500$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m^2 = The total cost / No. of m^2 =1500$ / 100 m^2 = 15 $/$m^2$

10.Sags & Bumps: For (100 m^2) as shown in Table 3.15.

Table 3.15: Analysis of cost for Sags & Bumps maintenance.

The Works	Costs
1- Scraping and roughening the surface layer, achieving the appropriate level.	300$
2- Re-tiling the surface layer, then compacting.	1300$
The Total Cost	1600$

This means that calculation the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m^2 = The total cost / No. of m^2 =1600$ / 100 m^2 = 16 $/$m^2$

11.Corrugation: For (100 m^2) as shown in Table 3.16.

Table 3.16: Analysis of Cost for Corrugation Maintenance

The Works		Costs
a-In the wavy areas, If the pavement is more than 5 cm	1- The wavy is removed by a scraper.	200$
	2- A new layer of pavement is spread.	1300$
	3-Compact the new layer.	200$
	The Total Cost	1700$
b-In the wavy areas, If the pavement is less than 5 cm	1- The pavement layer is broken by a jackhammer and mixed with the foundation and sub-base materials that are already in the road.	200$
	2- It is compacted by a vibrating roller and an adhesive layer is sprayed on top of it.	100$
	3- Then it is spread with a mixture of tar and it is Compact well.	1000$
	The Total Cost	1300$

This means that calculation the cost of maintenance per square meter is calculated as follows:

a-The cost of maintenance per 1m² = The total cost / No. of m² =1700$ / 100 m² = 17 $/m²

b- The cost of maintenance per 1m² = The total cost / No. of m² =1300$ / 100 m² = 13 $/m²

12.Lane Shoulders Drop: For (100 m²) as shown in Table 3.17.

Table 3.17: Analysis of Cost for Lane Shoulders Drop Maintenance.

The Works	Costs
1- Excavation and removal of the area of descent to the strong area.	400$
2- Spreading and compact the subbase in the form of layers, each layer 15 cm, until the appropriate level.	200$
3- Spreading and compacting the paving layer according to specifications.	1000$
The Total Cost	1600$

This means that calculating the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1600$ / 100 m² = 16 $/m²

13.Swelling: For (100 m²) as shown in Table 3.18.

Table 3.18: Analysis of Cost for Swelling Maintenance

The Works	Costs
1- Scraping and removing the paving layer and improper burial works.	200$
2- Repeating the burial and compacting process for Subbase.	400$
3- Re-tiling according to specifications.	1300
The Total Cost	1900$

This means that calculating the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1900$ / 100 m² = 19 $/m²

14. Railroad Crossing: For (100 m²) as shown in Table 3.19.

Table 3.19: Analysis of Cost for Railroad Crossing Maintenance.

The Works	Costs
1- Lifting and scraping 1m wide paving from the rail sides.	200$
2- Working the area with reinforced concrete, with a thickness of not less than 25cm, equal to the paving level, and the sides are inclined towards the asphalt.	2000$
The Total Cost	2200$

This means that calculating the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =2200$ / 100 m² = 22 $/m²

15.Utility Cut Patch: For (100 m²) as Shown in Table 3.20.

Table 3.20: Analysis of Cost for Utility Cut Patch Maintenance.

The Works	Costs
1- Removing all waste and lift it with equipment.	200$
2- Soft places are identified to be treated. And treat it.	200$
3- Re-pavement and compacted well, If need	1000$
The Total Cost	1400$

This means that calculating the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of m² =1400$ / 100 m² = 14 $/m²

16.Joints: For (100 M.L) as shown in Table 3.21.

Table 3.21: Analysis of Cost for Joints Maintenance.

The Works	Costs
1- Full joint lifting and cleaning of the area completely.	1000$
2- Installing a new joint by specialized staff According to specifications.	50000$
3- If there is a concrete problem, the concrete is fixed and the base of the joint is prepared, which consists of two iron angles, and it is welded with concrete reinforcement.	5000$
The Total Cost	56000$

This means that calculating the cost of maintenance per square meter is calculated as follows:

The cost of maintenance per 1m² = The total cost / No. of M.L =56000$ / 100 M.L = 560 $/ M.L

This value is subjected to change according to the type of joint, where there are Turkish joints that are installed at a price of 500 per meter of length with the entire joint, and there are Italian joints that are fully installed at a price of 800 per meter length, and there are Spanish or German joints that cost more than $1,000 $/M.L. The price includes all works and according to specifications. According to experts' opinions, it was recommended to test the values (500$, 1000$, and 1500$) per meter length in the closed questionnaire to cover all cases and obtain an average of the selected values according to the number of voters.

3.3 Closed Questionnaire

After the completion of the open questionnaire, which includes an inventory of the most prominent problems of roads and bridges in Iraq, , as well as obtaining the time and cost required for the maintenance of each square meter of these problems. About 80 questionnaires were distributed and 61 questionnaires were obtained that fulfill the conditions of the questionnaire. These samples were relied upon as the results of the closed-ended questionnaire. The closed questionnaire leads to an inventory of the results of the open questionnaire in order to determine the most realistic results, as the closed questionnaire is directed to all engineers working in the field of roads and bridges, as well as experts in general, not allocated to the category of experts exclusively (as in the open questionnaire) in order to select the most realistic results, and then the Also, finding the mathematical rate of the results to reach the adoption of a specific time and a specific cost that is the most realistic to be adopted in the database to use the expert technique in the MATLAB program.

3.3.1 International highways problems

This part includes 40 questions about 20 problems in the closed questionnaire for each problem there are two questions. A question related to the time required to maintain a unit square meter, and a question related to the cost required to repair and maintain a square meter for each problem on international Highways.

3.3.2 District highways problems

This part also includes 40 questions about 20 problems in the closed questionnaire on district roads themselves. For each problem, there are two questions. A question related to the time required for the maintenance of a square meter, and a question related to the cost required to maintain a square meter on District Highways.

3.3.3 Bridges problems

This part also includes 40 questions related to 20 problems in two parts. A question related to the time required, as well as the cost required to maintain one square meter. With some differences, the crossing of railways does not occur in bridges, and the maintenance of the problem of joints is specific to bridges. To take a perception of the difference between the problems in the International Highways, District Highways, and bridges according to time and cost.

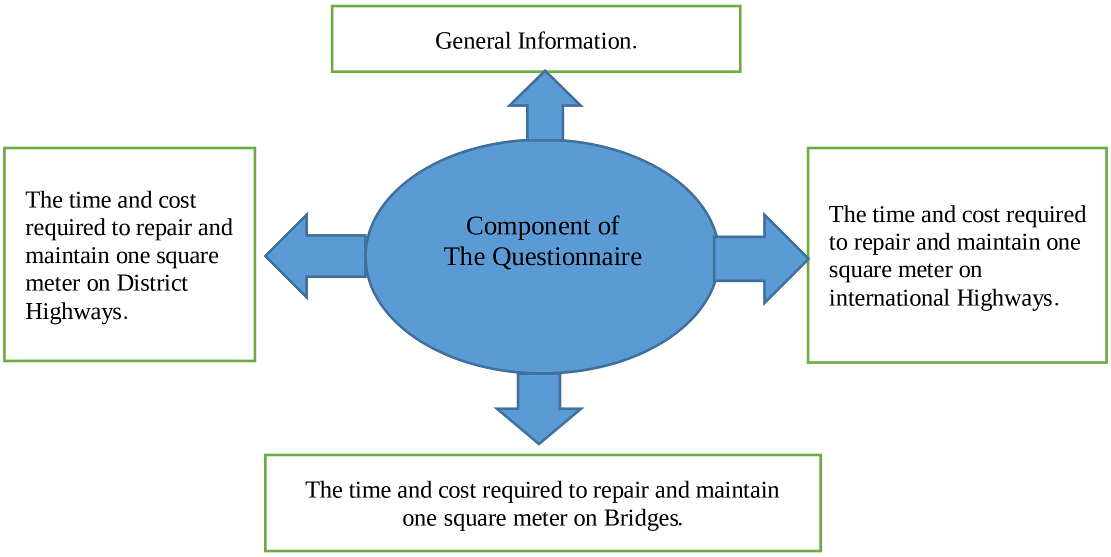

Figure 3.1: Component of the Questionnaire

Source: [RW]

3.3.4 Statistical treatment of the results of the questionnaire

The results were processed on all questionnaire options according to the following equation [79]:

$$The\ value\ of\ the\ question\ answer\ rate\ = \frac{V1*(C1)+V2*(c2)+V3*(c3)}{Vt} \quad \textbf{(3.1)}$$

V1: The number of voters for the first option.

C1: The value of the first option (1day=1, 10$=10, …).

V2: The number of voters for the second option.

C2: The value of the second option.

V3: The number of voters for the third option.

C3: The value of the third option.

Vt: The total number of voters.

Where the number of voters for the first option was multiplied by the value of the first option and added to the number of voters for the second option and multiplied by the value of the second option. It was also added to the number of voters for the third option, which was also in the value of the voters for it, and the total number was divided by the total number of voters, to reach the optimal value for the options rate according to the number of voters to cover all options for each question.

3.3.5 Information's about engineers that fell the questionnaire

This part includes general information about the engineers who filled out the questionnaire. The study includes engineering academic specialization, experience and the number of years of work in the road and bridge sector.

3.3.5.1 The experience

The number of engineers and experts who participated in the questionnaire was 61, where 36 of them had an experience ranging from one to 5 years, 13 of them had an experience of 6 to 10 years, 8 of them had an experience of 11 to 20 years, and 4 of them had more than 21 years of experience working in the road field. and bridges in Iraq.

The following chart shows the number of years of experience for the engineers and experts who participated in the survey.

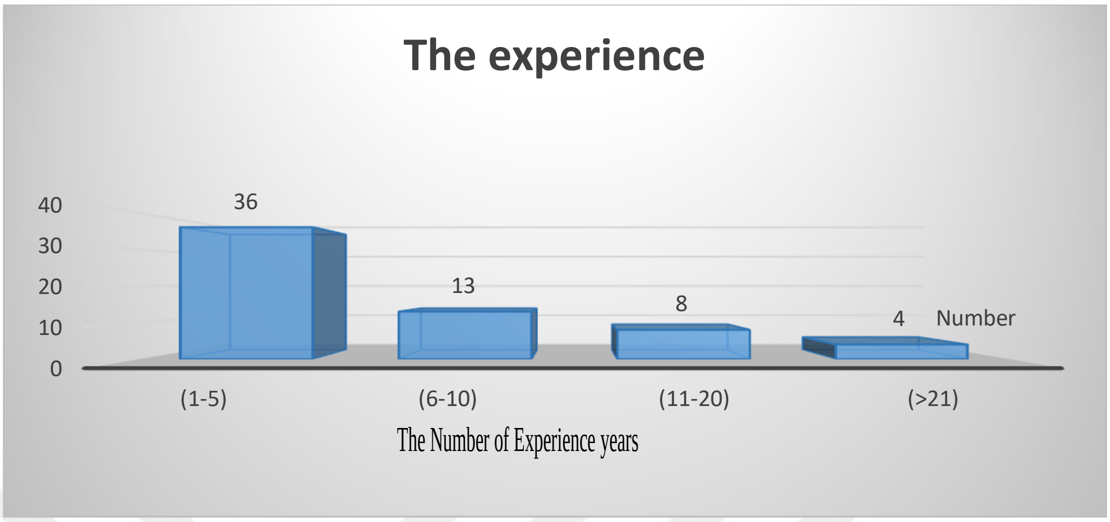

Figure 3.2: The Number of Experience Years

Source: [RW]

3.3.5.2 Engineering specialization

The number of engineers and experts who participated in the questionnaire was 61, where 50 were civil engineering majors and 4 of them specialized in highways. Each of the Engineering management Departments, Environmental Engineering, Structural Engineering, Building and Construction Engineering, Chemical Engineering, Architectural Engineering, and Materials Engineering had one vote.

The following chart shows Engineering specialization for the engineers and experts who participated in the survey.

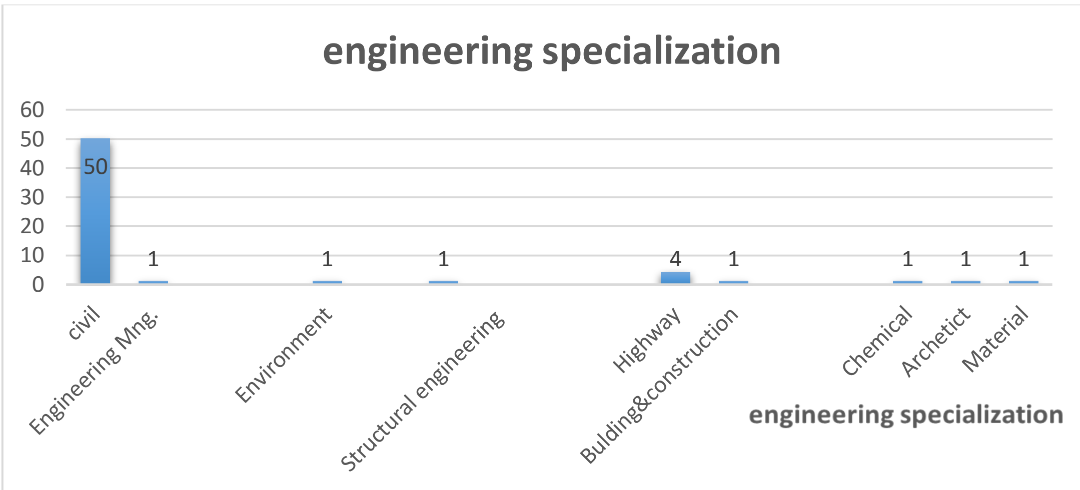

Figure 3.3: Engineering Specialization for Voters

Source: [RW].

3.3.6 Time and cost per square meter, according to the results of the questionnaire

3.3.6.1 The time required to repair and maintain one square meter

1. Cracks:

The results of the voting in the questionnaire on the time required to repair and maintain each unit square meter of Alligator, Longitudinal & Transverse, Block, Edge, Reflection, and Slippage cracks problem in each type of road in Iraq are summarized in Tables (3.22-3.27).

Table 3.22: Summary of the Results of the Questionnaire about the Time Required to Repair Alligator Cracks

No of voters On the time / Alligator- -Cracks in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	38	19	4	1.4
District highways	42	13	6	1.4
Bridges	23	27	11	1.8

Table 3.23: Summary of the Results of the Questionnaire about the Time Required to Repair Longitudinal & Transverse Cracks

No of voters On the time / Long.& Trans. Cracks in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	27	25	9	1.7
District highways	36	18	7	1.5
Bridges	27	22	12	1.75

Table 3.24: Summary of the Results of the Questionnaire about the Time Required to Repair Block Cracks

No of voters On the time / Block- -Cracks in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	28	27	6	1.6
District highways	34	20	7	1.55
Bridges	21	31	9	1.8

Table 3.25: Summary of the Results of the Questionnaire about the Time Required to Repair Edge Cracks

No of voters On the time / Edge--Cracks in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	36	20	5	1.49
District highways	42	16	3	1.36
Bridges	35	22	8	1.62

Table 3.26: Summary of the Results of the Questionnaire about the Time Required to Repair Reflection Cracks

No of voters On the time / Reflection Cracks in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	28	25	8	1.67
District highways	34	21	6	1.54
Bridges	24	25	12	1.8

Table 3.27: Summary of the Results of the Questionnaire about the Time Required to Repair Slippage Cracks

No of voters On the time / Slippage--Cracks in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	29	24	8	1.65
District highways	31	22	8	1.62
Bridges	22	26	13	1.85

2-Patching

In the end of voting for the questionnaire on the time required to repair each unit square meter of patching problem in each kind of roads in Iraq are summarized in Table 3.28.

Table 3.28: Summary of the Results of the Questionnaire about the Time Required to Repair Patching Problem

No of voters On the time / Patching in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	31	25	5	1.57
District highways	38	18	5	1.45
Bridges	26	27	8	1.7

3-Potholes

The voting in the questionnaire on the time required to maintain each unit square meter of Potholes problem in each type of road in Iraq are summarized in Table 3.29.

Table 3.29: Summary of the Results of the Questionnaire about the Time Required to Repair Potholes Problem

No of voters On the time / Potholes in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	25	32	4	1.65
District highways	33	18	10	1.62
Bridges	22	26	13	1.85

4-Shoving

The voting in the questionnaire on the time required to repair and maintain each unit square meter of Shoving problem in each type of road in Iraq can be noted in Table 3.30.

Table 3.30: Summary of the Results of the Questionnaire About the Time Required to Repair Shoving Problem

No of voters On the time / Shoving in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	29	23	9	1.67
District highways	34	17	10	1.6
Bridges	21	23	17	1.93

5-Depression

The questionnaire results on the time required to repair and maintain each square meter of Depression problem in each type of road in Iraq are collected in Table 3.31.

Table 3.31: Summary of the Results of the Questionnaire About the Time Required to Repair Depression Problem

No of voters On the time / Depression in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	26	25	10	1.73
District highways	32	18	11	1.65
Bridges	24	19	18	1.9

6-Rutting

The results of the voting in the questionnaire on the time required to repair and maintain each unit square meter of rutting problem in each type of road in Iraq are summarized in Table 3.32.

Table 3.32: Summary of the Results of the Questionnaire about the Time Required to Repair Rutting Problem

No of voters On the time / Rutting in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	25	18	18	1.88
District highways	27	18	16	1.82
Bridges	20	21	20	2

7-Bleeding

The voting results in the questionnaire on the time required to repair and maintain each unit square meter of Bleeding problem in each type of road in Iraq can be noted in Table 3.33.

Table 3.33: Summary of the Results of the Questionnaire about the Time Required to Repair Bleeding Problem

No of voters On the time / Bleeding in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	32	18	11	1.65
District highways	30	17	14	1.73
Bridges	27	16	18	1.85

8-Raveling&Weathering

The voting in the questionnaire results on the time required to repair and maintain each square meter of Raveling & Weathering problem in each type of road in Iraq are collected in Table 3.34.

Table 3.34: Summary of the Results of the Questionnaire about the Time Required to Repair Raveling & Weathering Problem

No of voters On the time / Raveling& Weathering in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	28	22	11	1.72
District highways	32	20	9	1.62
Bridges	23	22	16	1.88

9-Polished Aggregate

In the end of the voting in the questionnaire on the time required to repair and maintain each square meter of Polished Aggregate problem in each type of road in Iraq can be noted in Table 3.35.

Table 3.35: Summary of the Results of the Questionnaire about the Time Required to Repair Polished Aggregate Problem

No of voters On the time / Polished- -Aggregate in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	27	24	10	1.72
District highways	32	20	9	1.62
Bridges	23	23	15	1.86

10-Sags & Bumps

After the voting in the questionnaire on the time required to repair and maintain each square meter of Sags & Bumps problem in each type of road in Iraq are collected in Table 3.36.

Table 3.36: Summary of the Results of the Questionnaire about the Time Required to Repair Shoving Problem

No of voters On the time / Sags & Bumps in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	23	25	13	1.84
District highways	29	21	11	1.7
Bridges	21	21	19	1.96

11-Corrugation

The voting results in the questionnaire on the time required to repair and maintain each square meter of Corrugation problem in each type of road in Iraq are summarized in Table 3.37.

Table 3.37: Summary of the Results of the Questionnaire about the Time Required to Repair Corrugation Problem

No of voters On the time / Corrugation in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	24	24	13	1.8
District highways	29	23	9	1.67
Bridges	20	26	15	1.9

12-Lane Shoulders Drop

For Lane Shoulders drop problem the results of the voting in the questionnaire on the time required to repair and maintain each unit square meter in each type of road in Iraq are summarized in Table 3.38.

Table 3. 38: Summary of the Results of the Questionnaire about the Time Required to Repair Lane Shoulders Drop Problem

No of voters On the time / Lane- -Shoulders drop in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	31	19	11	1.67
District highways	30	22	9	1.65
Bridges	25	22	14	1.8

13-Swelling

The results of the voting of Swelling problem in the questionnaire on the time required to repair and maintain each unit square meter in each type of road in Iraq are summarized in Table 3.39.

Table 3.39: Summary of the Results of the Questionnaire about the Time Required to Repair Swelling Problem

No of voters On the time / Swelling in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	28	22	11	1.7
District highways	28	23	10	1.7
Bridges	25	18	18	1.8

14-Railroad Crossing

In the results of the voting in the questionnaire on the time required to repair and maintain each unit square meter of Railroad crossing problem in each type of road in Iraq are collected in Table 3.40.

Table 3.40: Summary of the Results of the Questionnaire about the Time Required to Repair Railroad Crossing Problem

No of voters On the time / Railroad- -crossing in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	23	24	14	1.85
District highways	27	23	11	1.7

15- Utility Cut Patch

The results of the voting in the questionnaire on the time required to repair and maintain each square meter of Utility cut patch problem in each type of road in Iraq are summarized in Table 3.41.

Table 3.41: Summary of the Results of the Questionnaire about the Time Required to Repair Utility cut patch Problem

No of voters On the time / Utility cut- -patch in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
International Highways	29	22	10	1.85
District highways	33	17	11	1.6
Bridges	21	25	15	1.9

16- Joints (Only in Bridges)

For joints problem in bridges the results of the voting in the questionnaire on the time required to repair and maintain each unit length meter of it, in Iraq are summarized in

Table 3.42.

Table 3.42: Summary of the Results of the Questionnaire about the Time Required to Repair Joint Problem

No of voters On the time / Joints in	Voters for 1 day	Voters for 2 days	Voters for 3 days	Average (day)
Bridges	27	16	18	1.85

3.3.6.2 Modification of time

The time obtained through the questionnaire and the opinions of experts is the time required for the repair and maintenance of one square meter, and this includes all the necessary work in the pre-project stage of preparing the site, cadres and mechanisms, and completing administrative transactions. Thus, most of the time allotted for one square meter is to prepare for the start of work.

As for more than one square meter, the time is not inclusive of preparation because the preparation time was calculated within the time required for maintenance and repair of one square meter. Thus, the increase in time after the first square meter is a relative increase in percentage for each problem. This percentage was set through interviews with experts in the field of roads. Based on a mathematical equation, it was formulated as follows:

$$TTM = \mathrm{MTP} + \mathrm{MTP} * (\mathrm{N} - 1) * \text{Ọ̄} \qquad \textbf{(3.2)}$$

Whereas

TTM: The total time required to maintain more than unit square meter

MTP: Maintenance time per square meter

N: The number of unit square meters of the problem in roads and bridges

Ọ̄: (MFT) Modification Factor of Time

3.3.6.2.1 Modification factor of time (MFT)

It is a coefficient for increasing the time required for the maintenance of road and bridge problems in Iraq for more than one square meter, or it represents the time required for the maintenance of each square meter after the first square meter, preparation for work, site preparation, and administrative transactions.

Several maintenance projects were studied to repair the problems of roads and bridges. These projects were implemented by the Directorate of Roads and Bridges in Salah al-Din Governorate, to cover all problems. In addition to the opinions of experts, for the deducing a coefficient of change that represents the cumulative increase in time for more than one square meter for each problem. The following Table 3.43 shows the adjustment factor for each road and bridge problem in Iraq.

Table 3.43: Modification Factor of Time Requirement to Maintenance for More Than Square Meter

Item	Type of the road		International Highways	District Highways	Bridges
	Type of the Problem		Modification factor %	Modification factor %	Modification factor %
1	Cracks	Alligator Cracks	2	2	2
		Longitudinal &Transverse	2	2	2
		Block cracks	3	3	3
		Edge Cracks	3	3	3
		Reflection cracks	2	2	2
		Slippage Cracks	2	2	2
2	Patching		2	2	2
3	Potholes		2	2	2
4	Shoving		2	2	2
5	Depression		2	2	2
6	Rutting		3	3	3
7	Bleeding		1	1	1
8	Raveling& Weathering		2	2	2
9	Polished Aggregate		2	2	2
10	Sags& Bumps		3	3	3
11	Corrugation		2	2	2
12	Lane shoulders drop		2	2	2
13	Swelling		5	5	5
14	Railroad crossing		2	2	N.H
15	Utility cut patch		1	1	1
16	Joints				15

Source: [RW].

3.3.6.2.1 The Cost Required to Repair and Maintain of unit square meter / meter of length

1. Cracks:

The results of the voting in the questionnaire on the cost required to repair and maintain each unit square meter of Alligator, Longitudinal & Transverse, Block, Edge, Reflection, and Slippage cracks problem in each type of road in Iraq are summarized in Tables (3.44-3.49).

Table 3.44: Summary of the Results of the Questionnaire about the Cost Required to Repair Alligator Cracks

No of voters On the Cost / Alligator- -Cracks in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	17	38	6	22.3
District highways	33	23	5	18.1
Bridges	10	31	20	27.5

Table 3.45: Summary of the Results of the Questionnaire about the Cost Required to Repair Alligator Cracks

No of voters On the Cost / Long. & Trans. cracks in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	18	32	11	23.3
District highways	27	29	5	19.6
Bridges	8	35	18	27.5

Table 3.46: Summary of the Results of the Questionnaire about the Cost Required to Repair Block Cracks

No of voters On the Cost / Block Cracks in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	21	29	11	22.5
District highways	24	30	7	20.8
Bridges	12	28	21	27.2

Table 3.47: Summary of the Results of the Questionnaire about the Cost Required to Repair Edge Cracks

No of voters On the Cost / Edge Cracks in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	25	30	6	20.3
District highways	36	19	6	17.6
Bridges	14	30	17	25.7

Table 3.48: Summary of the Results of the Questionnaire about the Cost Required to Repair Reflection Cracks

No of voters On the Cost / Reflection--Cracks in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	18	31	12	23.5
District highways	25	28	8	20.8
Bridges	13	23	25	27.9

Table 3.49: Summary of the Results of the Questionnaire about the Cost Required to Repair Slippage Cracks

No of voters On the Cost / Slippage--Cracks in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	17	31	13	24
District highways	24	27	10	21.5
Bridges	12	25	24	28

2. Patching

In the end of voting for the questionnaire on the cost required to repair each unit square meter of Patching problem in each kind of roads in Iraq are summarized in Table 3.50.

Table 3.50: Summary of the Results of the Questionnaire about the Cost Required to Repair Patching Problem

No of voters On the Cost / Patching in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	22	32	7	21.3
District highways	26	27	8	20.6
Bridges	15	31	15	25

3. Potholes

The voting in the questionnaire on the cost required to maintain each unit square meter of Potholes problem in each type of road in Iraq are summarized in Table 3.51.

Table 3.51: Summary of the Results of the Questionnaire about the Cost Required to Repair Potholes Problem

No of voters On the Cost / Potholes in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	15	37	9	23.5
District highways	26	27	8	20.6
Bridges	14	26	21	26.7

4. Shoving

The voting in the questionnaire on the cost required to repair and maintain each unit square meter of Shoving problem in each type of road in Iraq can be noted in Table 3.52.

Table 3.52: Summary of the Results of the Questionnaire about the Cost Required to Repair Shoving Problem

No of voters On the Cost / Shoving in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	17	33	11	23.5
District highways	27	21	13	21.6
Bridges	13	28	20	26.7

5. Depression

The questionnaire results on the cost required to repair and maintain each square meter of Depression problem in each type of road in Iraq are collected in Table 3.53.

Table 3.53: Summary of the Results of the Questionnaire about the Cost Required to Repair Depression Problem

No of voters On the Cost / Depression in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	13	37	11	24.5
District highways	21	28	12	22.8
Bridges	12	26	23	27.7

6. Rutting

The results of the voting in the questionnaire on the cost required to repair and maintain each unit square meter of Rutting problem in each type of road in Iraq are summarized in Table 3.54.

Table 3.54: Summary of the Results of the Questionnaire about the Cost Required to Repair Rutting Problem

No of voters On the Cost / Rutting in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	14	26	21	26.7
District highways	19	25	17	24.5
Bridges	8	23	30	30.4

7. Bleeding

The voting results in the questionnaire on the cost required to repair and maintain each unit square meter of Bleeding problem in each type of road in Iraq can be noted in Table 3.55.

Table 3.55: Summary of the Results of the Questionnaire about the Cost Required to Repair Bleeding Problem

No of voters On the Cost / Bleeding in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	15	30	16	25.2
District highways	29	19	13	21
Bridges	16	25	20	26

8. Raveling & Weathering

The voting in the questionnaire results on the cost required to repair and maintain each square meter of Raveling & Weathering problem in each type of road in Iraq are collected in Table 3.56.

Table 3.56: Summary of the Results of the Questionnaire about the Cost Required to Repair Raveling & Weathering Problem

No of voters On the Cost / Raveling& weathering in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	19	27	15	24
District highways	32	19	10	19.6
Bridges	19	25	17	24.5

9. Polished Aggregate

In the end of the voting in the questionnaire on the cost required to repair and maintain each square meter of Polished Aggregate problem in each type of road in Iraq can be noted in Table 3.57.

Table 3.57: Summary of the results of the Questionnaire about the Cost Required to Repair Polished Aggregate Problem

No of voters On the Cost / Polished--Aggregate in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	17	33	11	23.5
District highways	27	22	12	21.3
Bridges	16	29	16	25

10. Sags & Bumps

After the voting in the questionnaire on the cost required to repair and maintain each square meter of Sags & Bumps problem in each type of road in Iraq are collected in Table 3.58.

Table 3.58: Summary of the Results of the Questionnaire about the cost Required to Repair Sags & Bumps Problem

No of voters On the Cost / Sags & Bumps in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	14	32	15	25.2
District highways	19	29	13	23.5
Bridges	10	22	29	29.7

11. Corrugation

The voting results in the questionnaire on the cost required to repair and maintain each square meter of Corrugation problem in each type of road in Iraq are summarized in Table 3.59.

Table 3.59: Summary of the Results of the Questionnaire about the Cost Required to Repair Corrugation Problem

No of voters On the Cost / Corrugation in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	14	35	12	24.5
District highways	21	30	10	22.3
Bridges	11	29	21	27.5

12. Lane Shoulders Drop

For Lane Shoulders drop problem the results of the voting in the questionnaire on the cost required to repair and maintain each unit square meter in each type of road in Iraq are summarized in Table 3.60.

Table 3.60: Summary of the Results of the Questionnaire about the Cost Required to Repair Lane Shoulders Drop Problem

No of voters On the Cost / Lane Shoulders--drop in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	17	28	16	24.8
District highways	19	32	10	22.8
Bridges	10	26	25	28.7

13. Swelling

The results of the voting of Swelling problem in the questionnaire on the cost required to repair and maintain each unit square meter in each type of road in Iraq are summarized in Table 3.61.

Table 3.61: Summary of the Results of the Questionnaire about the Cost Required to Repair Swelling Problem

No of voters On the Cost / Swelling in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	17	28	16	24.8
District highways	28	21	12	21
Bridges	13	25	23	27.5

14. Railroad Crossing

In the results of the voting in the questionnaire on the cost required to repair and maintain each unit square meter of Railroad crossing problem in each type of road in Iraq are collected in Table 3.62.

Table 3.62: Summary of the Results of the Questionnaire about the Cost Required to Repair Railroad Crossing Problem

No of voters On the Cost / Railroad--Crossing in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	9	33	19	27.5
District highways	22	25	14	23

15. Utility Cut Patch

The results of the voting in the questionnaire on the cost required to repair and maintain each square meter of Utility cut patch problem in each type of road in Iraq are summarized in Table 3.63.

Table 3.63: Summary of the Results of the Questionnaire about the Cost Required to Repair Utility Cut Patch Problem

No of voters On the Cost / Utility cut Patch in	Voters for 10 $	Voters for 20 $	Voters for 30 $	Average $
International Highways	18	28	15	24.3
District highways	23	25	13	22.5
Bridges	15	29	17	25.5

16. Joints (in Bridges)

For joints problem in bridges the results of the voting in the questionnaire on the cost required to repair and maintain each unit length meter of it, in Iraq are summarized in Table 3.64.

Table 3.64: Summary of the Results of the Questionnaire about the Cost Required to Repair Joints Problem

No of voters On the Cost / Joints in	Voters for 500 $	Voters for 1000 $	Voters for 1500 $	Average $
Bridges	16	28	17	1008.2

3.3.6.3 The Summery of questionnaire about sustainability of roads & bridges problems in Iraq results

The table attached shows a group of results summaries for the time and cost required to maintain and repair one square meter for each problem after processing the results from the questionnaire through statistical operations.

Table 3.65: The Summery of Questionnaire about Sustainability of Roads & Bridges Problems in Iraq Results

Item	Requirements / No. Problems		National Highways		District Highways		Bridges	
			Time	Cost	Time	Cost	Time	Cost
			Day/m²	$/m²	Day/m²	$/m²	Day/m²	$/m²
1	Cracks	Alligator Cracks	1.4	22.3	1.4	18.1	1.8	27.5
		Longitudinal &Transverse	1.7	23.3	1.5	19.6	1.75	27.5
		Block cracks	1.6	22.5	1.55	20.8	1.8	27.2
		Edge Cracks	1.49	20.3	1.36	17.6	1.62	25.7
		Reflection cracks	1.67	235	1.54	20.8	1.8	27.9
		Slippage Cracks	1.65	24	1.62	21.5	1.85	27.95
2	Patching		1.57	21.3	1.45	20.6	1.7	25
3	Potholes		1.65	23.5	1.62	20.6	1.85	26.7
4	Shoving		1.67	23.5	1.6	21.6	1.93	26.72
5	Depression		1.73	24.5	1.65	22.8	1.9	27.7
6	Rutting		1.88	26.7	1.82	24.5	2	30.4
7	Bleeding		1.65	25.5	1.73	21	1.85	26
8	Raveling& Weathering		1.72	24	1.62	19.6	1.88	24.5
9	Polished Aggregate		1.72	23.5	1.62	21.3	1.86	25
10	Sags& Bumps		1.84	25.2	1.7	23.5	1.96	29.7
11	Corrugation		1.8	24.5	1.67	22.3	1.9	27.5
12	Lane shoulders drop		1.67	24.8	1.65	22.8	1.8	28.7
13	Swelling		1.7	24.8	1.7	21	1.8	27.5
14	Railroad crossing		1.85	27.5	1.7	23	N.H	N.H
15	Utility cut patch		1.68	24.3	1.6	22.5	1.9	25.5
16	Joints (meter of length)						1.85	1008

3.3.7 The summary

The necessary results were obtained from the time and cost required to maintain each square meter of road and bridge problems in Iraq, which will serve as a database for the use of the expert system. It is noted in the results of time and cost that bridges are often the most in terms of time and the highest in terms of the cost required to maintain one square meter for each problem in it, because bridges often need more work requirements as well as administrative approvals and more practical and technical expertise. The international roads are in the second rank in terms of the most time and the highest cost, because they also have structural characteristics and requirements such as the layers that are more and the width of the road is more, and they are different from the district roads, which are often the least in terms of time and cost.

4. EXPERT SYSTEM APPLICATION

4.1 General

The application of the expert system is included in this chapter, which depends on the results of the questionnaires that were processed by statistical and mathematical methods in order to be a database for the expert system, which was designed using MATLAB as a programming language.

4.2 Create an Expert System

Expert systems are usually designed to solve problems that are difficult for human energies to solve or difficult to solve in a record short time, by feeding them groups of required information The expert system is configured in two parts The first part is collecting information and data to feed the system through the field side, literature and questionnaires, and processing them mathematically and statistically to be ready to be a useful database for the expert system that is programmed to deal with this data according to specific and mechanisms to ensure obtaining correct and valuable results and outputs that are suitable for the purpose of establishing this expert system Figure 4.1 shows how the expert system works.

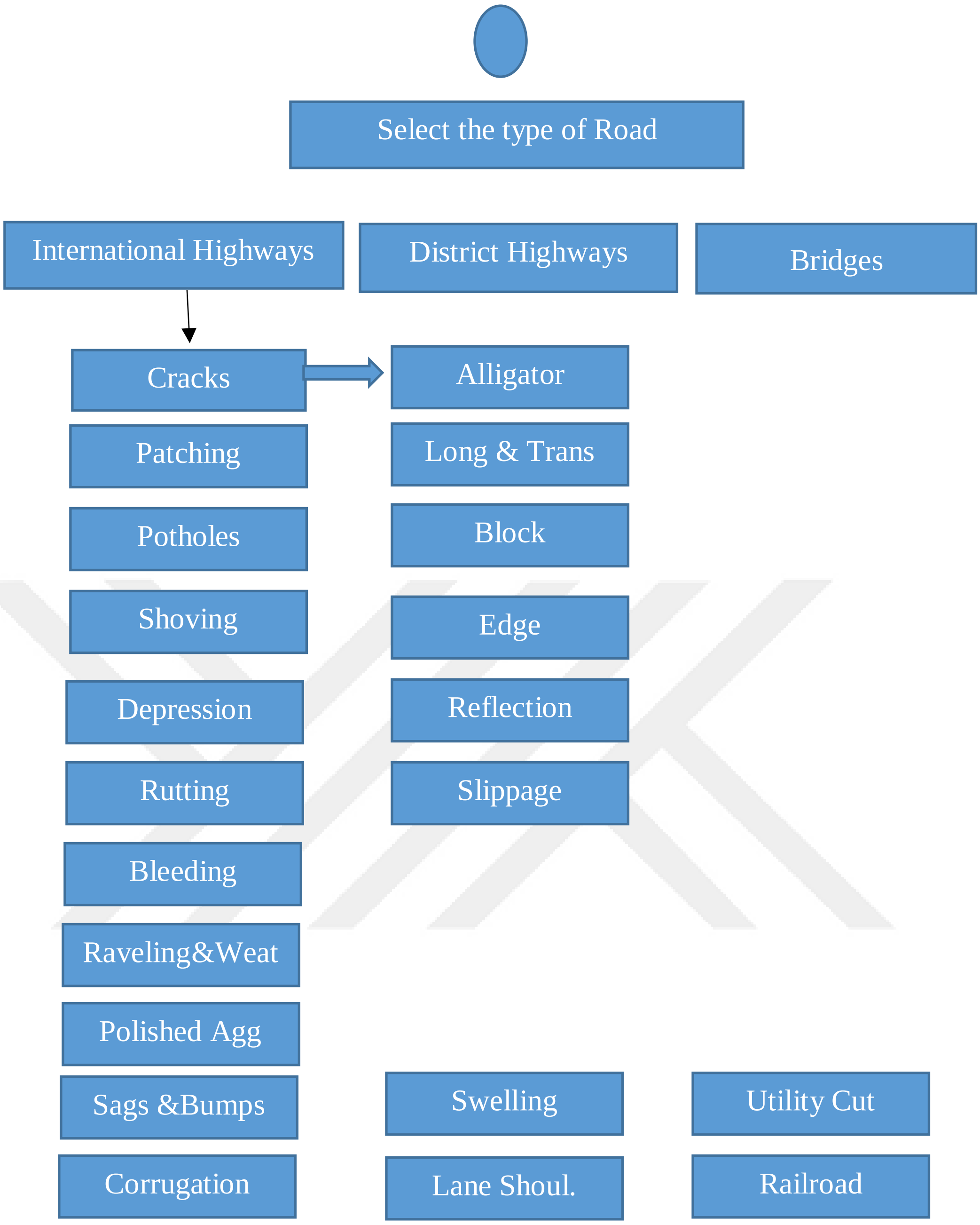

Figure 4.1: The Expert System Work

Source: [RW].

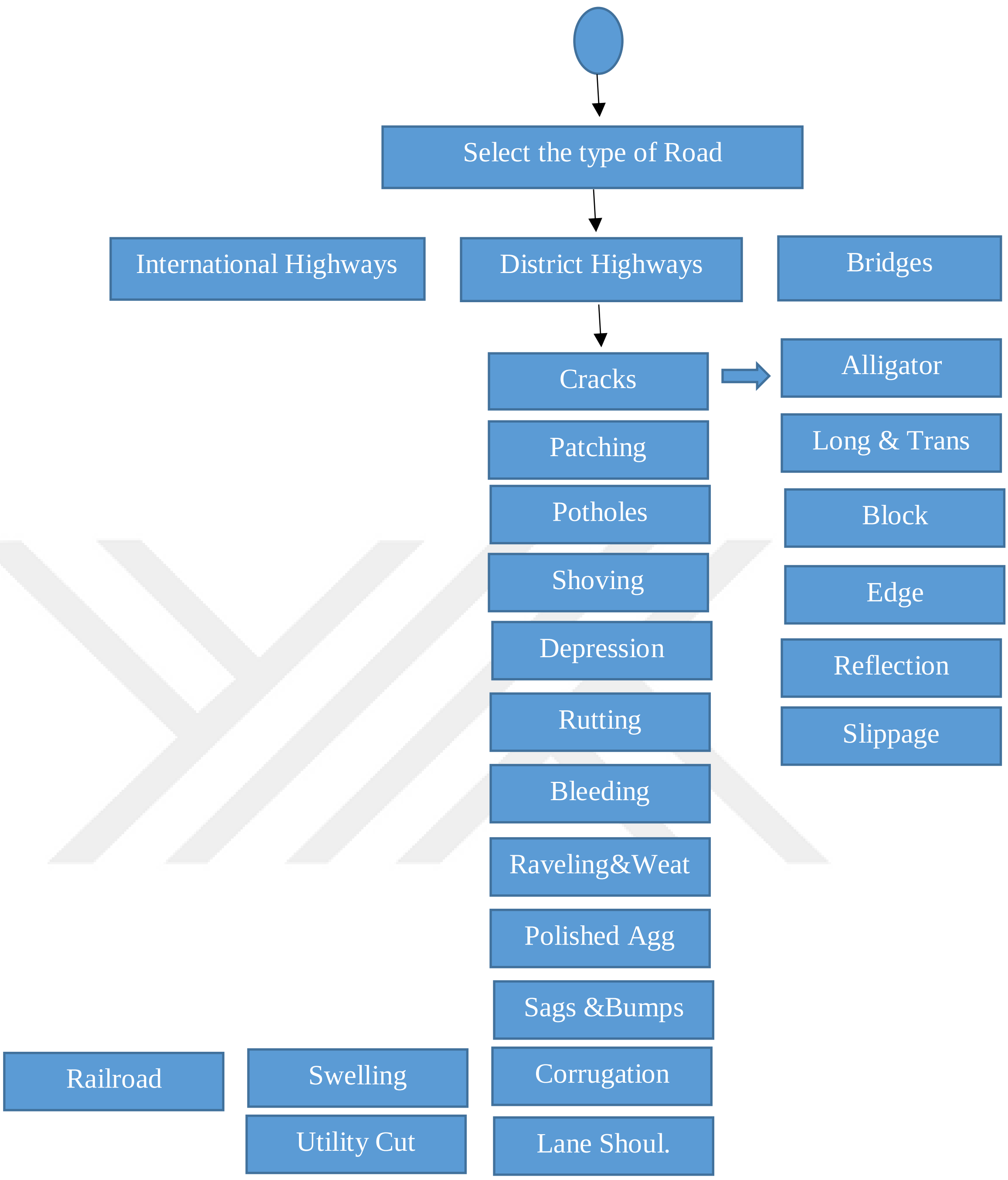

Figure 4.1: (Cont.) The Expert System Work

Source: [RW].

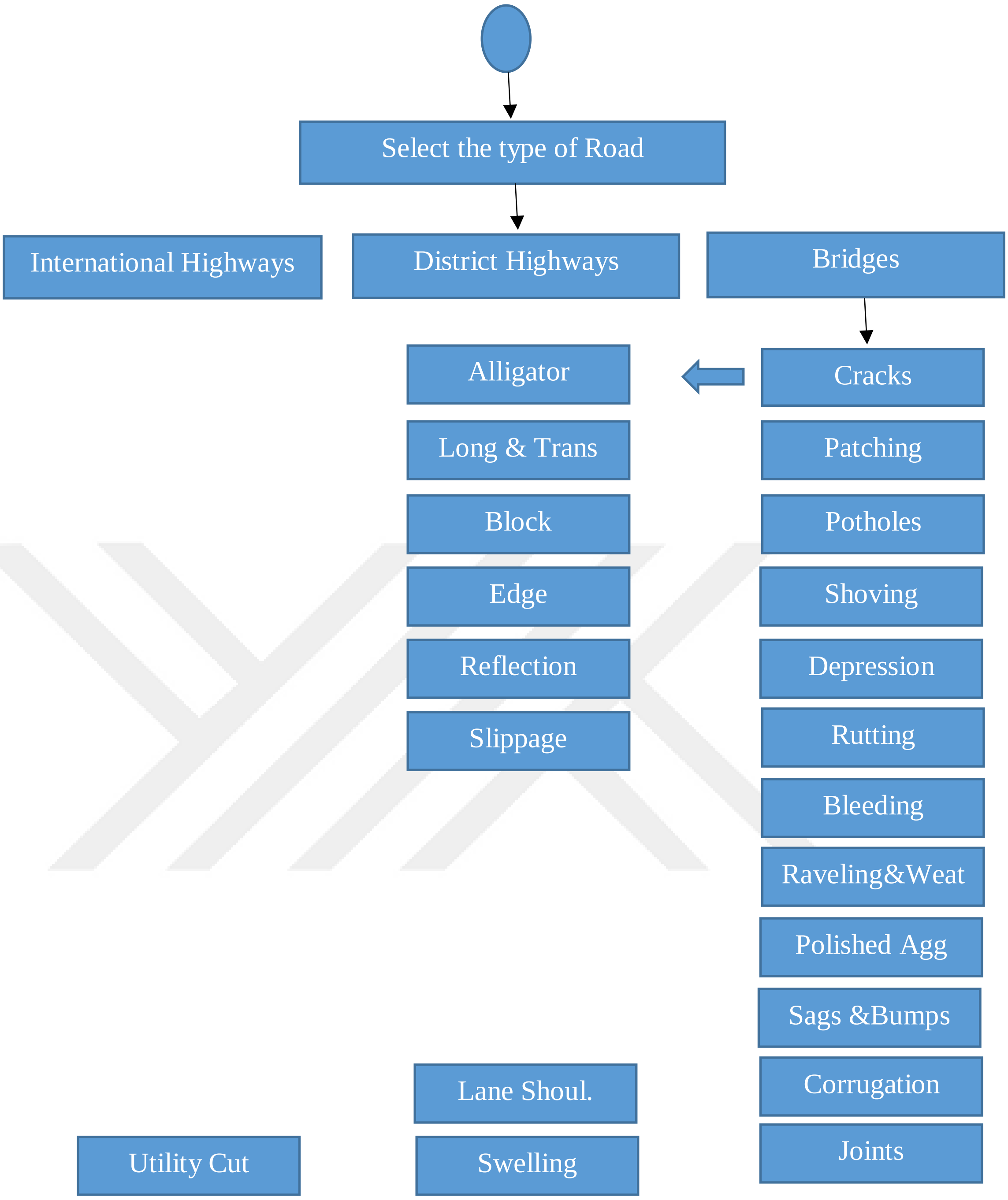

Figure 4.1: (Cont.) The Expert System Work

Source: [RW].

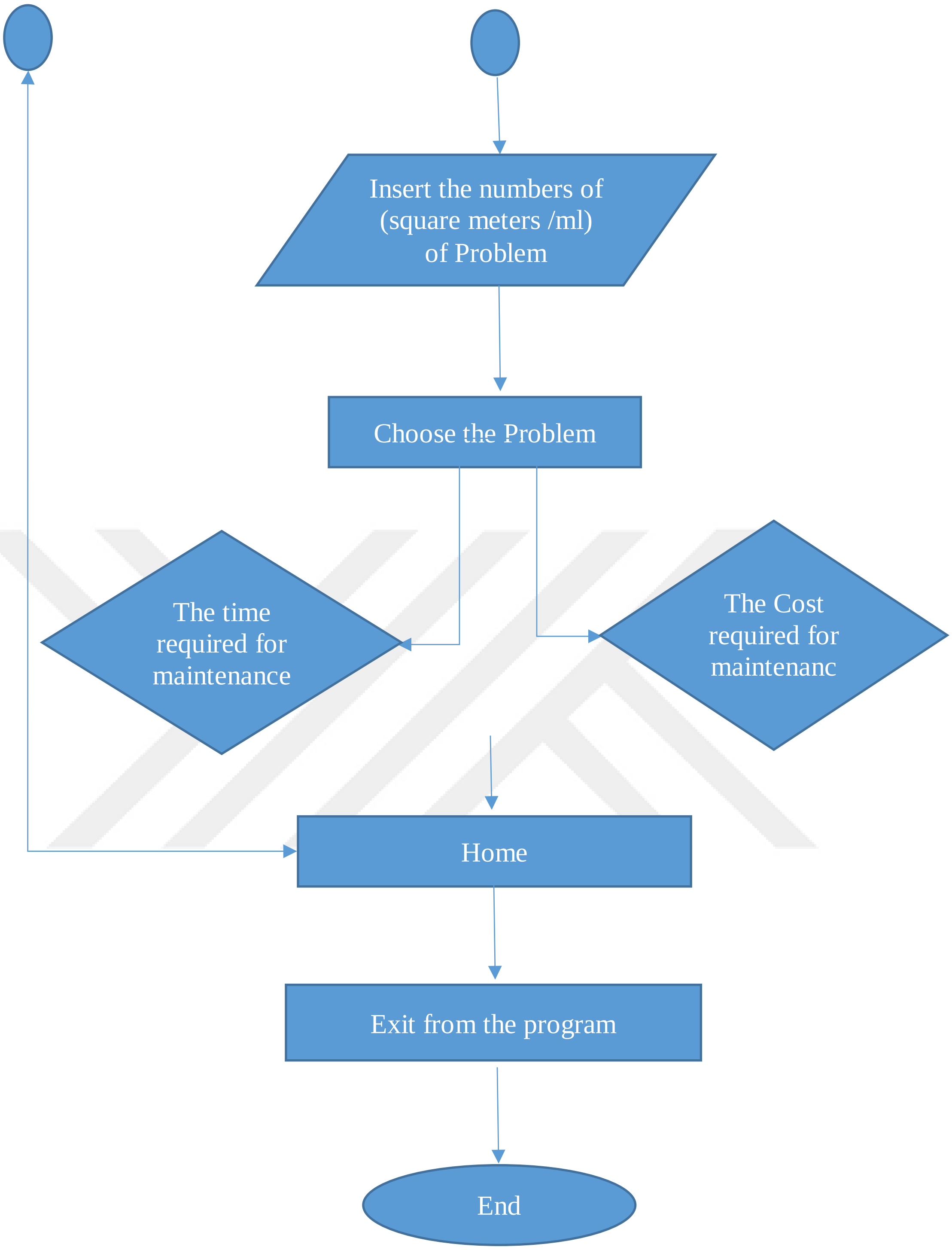

Figure 4.1: (Cont.) The Expert System Work

Source: [RW]

The second part of the expert system includes the function of information and human expertise that has been fed to the expert system to support the decision of the expert system to be integrated so that the system can be used in time and cost management in road and bridge repair and maintenance projects, which includes special programming for the programmer about the data produced or developed by this study that depends on the MATLAB programming language, When the expert system is operated by the user after that the program interface appears as in Figure 4.2, which includes the name of the program or system.

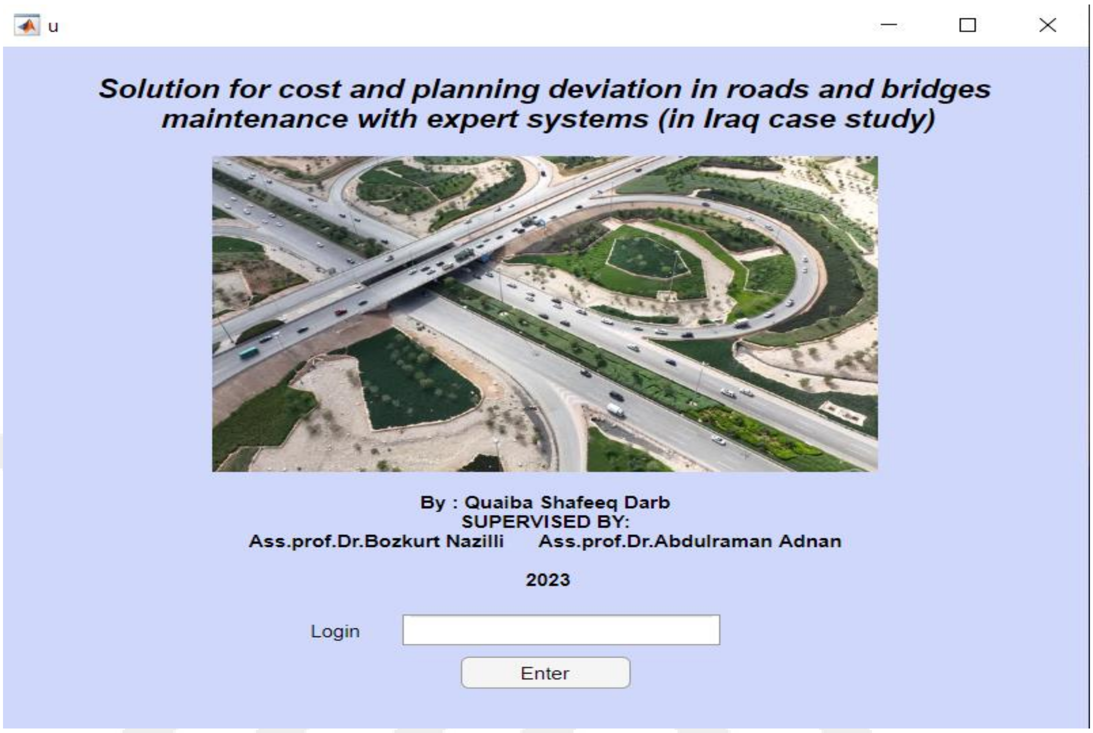

Figure 4.2: The Interface of Expert System Program

Source: [RW]

After opening the program, it will ask for the passcode to enter, as shown in Figure 4.3.

Figure 4.3: The Window of Passcode

Source: [RW]

After entering the Passcode, then you choose the type of road that contains problems or needs repair and maintenance from the following list shown in Figure 4.4.

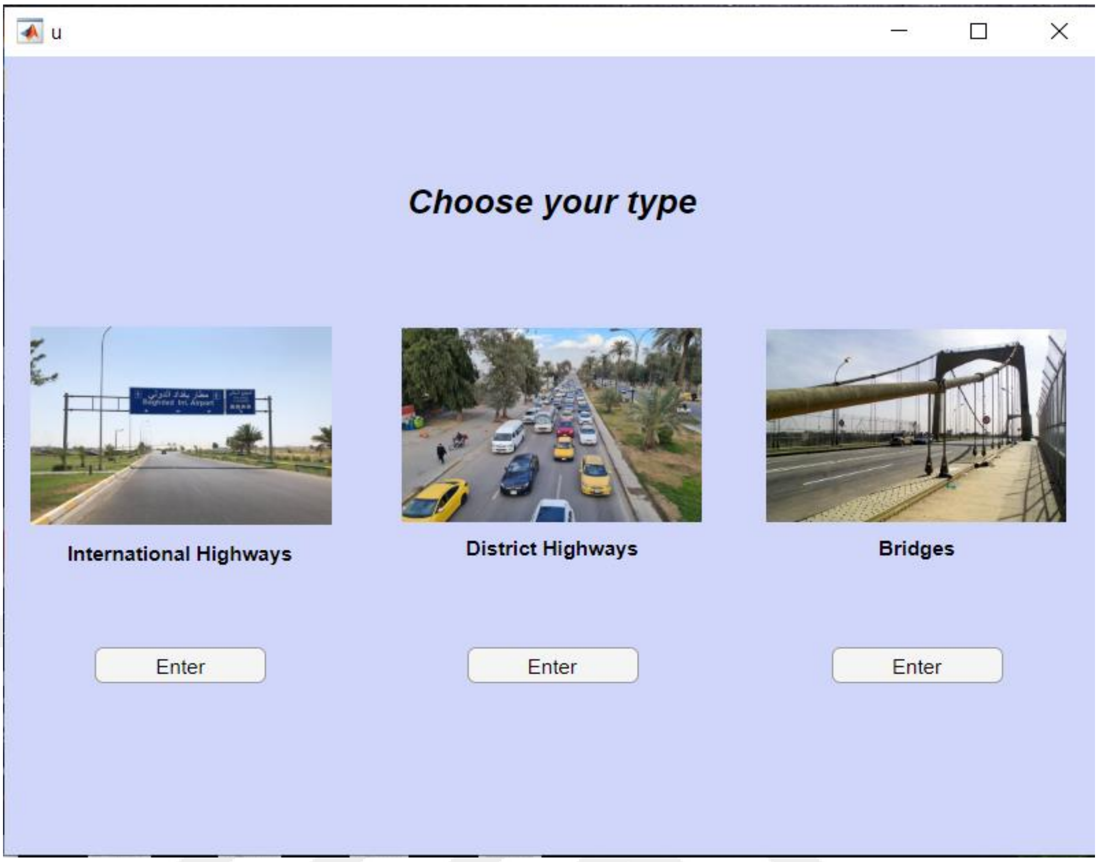

Figure 4.4: The Window That Contain the Type of Road

Source: [RW]

After selecting the type of road, for example, the international roads are chosen, and a package of problems will appear to us, as shown in Figure 4.5 a, 4.5 b, and 4.5 c.

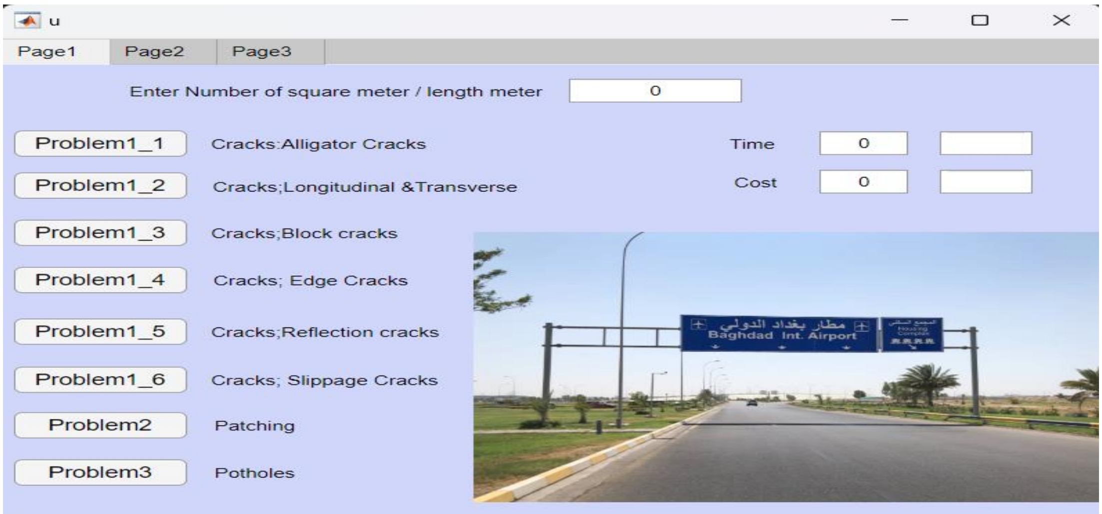

Figure 4.5: The Window of Problems Package in International Highways

Source: [RW]

For example, when choosing the type of local District Highways, a list of problems will appear to us, as shown in Figures 4.6.

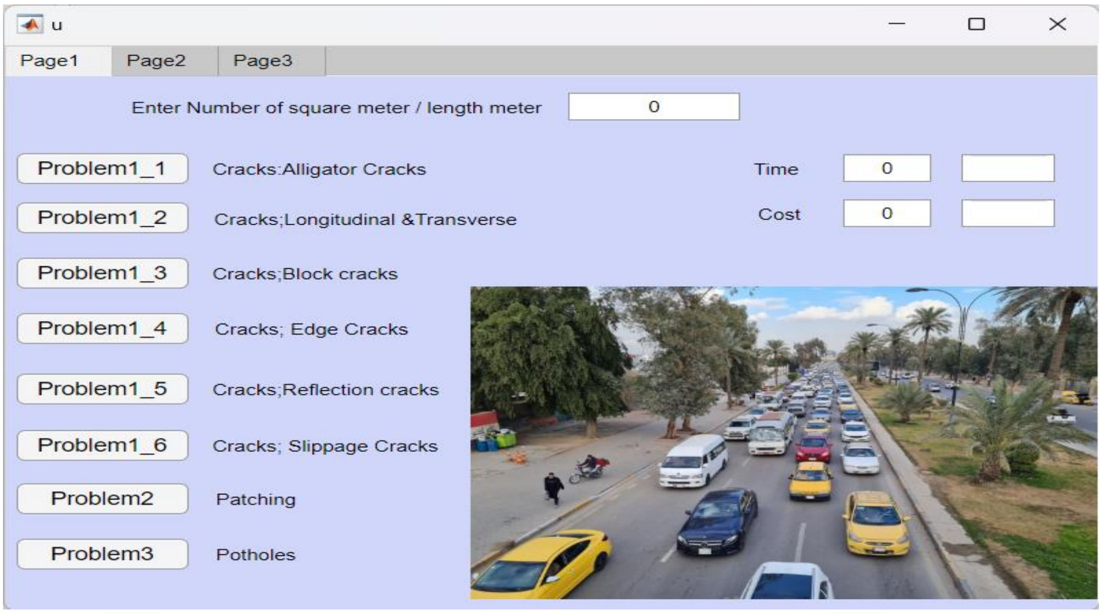

Figure 4.6: Show the Problems of District Highways

Source: [RW]

For example, also when choosing the type of bridges, a list of problems will appear, as shown in Figure 4.7.

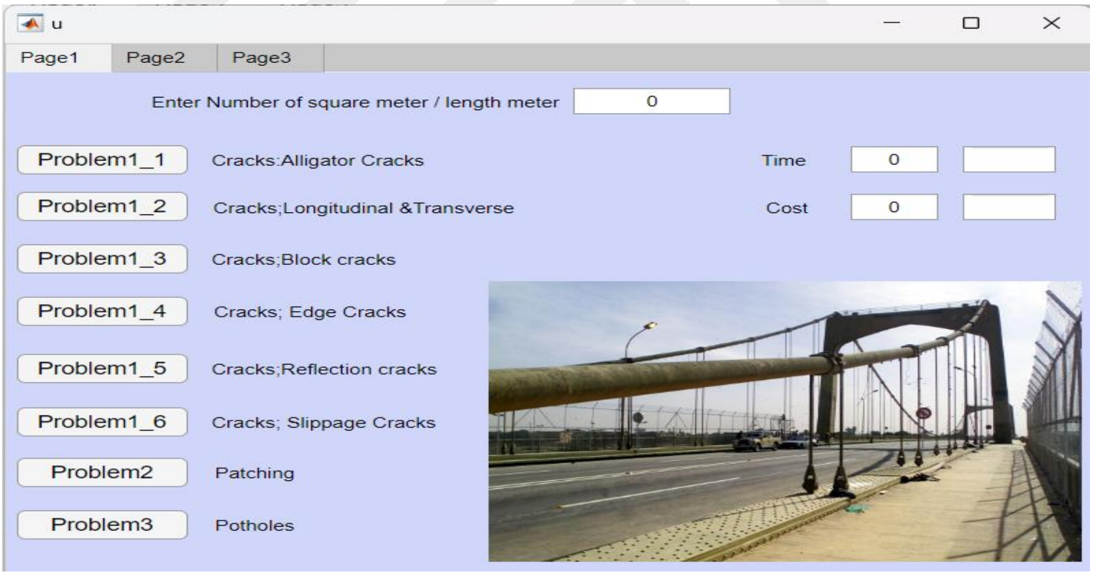

Figure 4.7: The Window of Problems in Bridges

Source: [RW]

When the number of meters of problems is entered in the space provided at the top of the form and clicking on the type of problem, the time and cost required for repair and maintenance will be obtained Figure 4.8 Show that the results of time and cost as example When the Problem of Alligator cracks in Bridges are chosen.

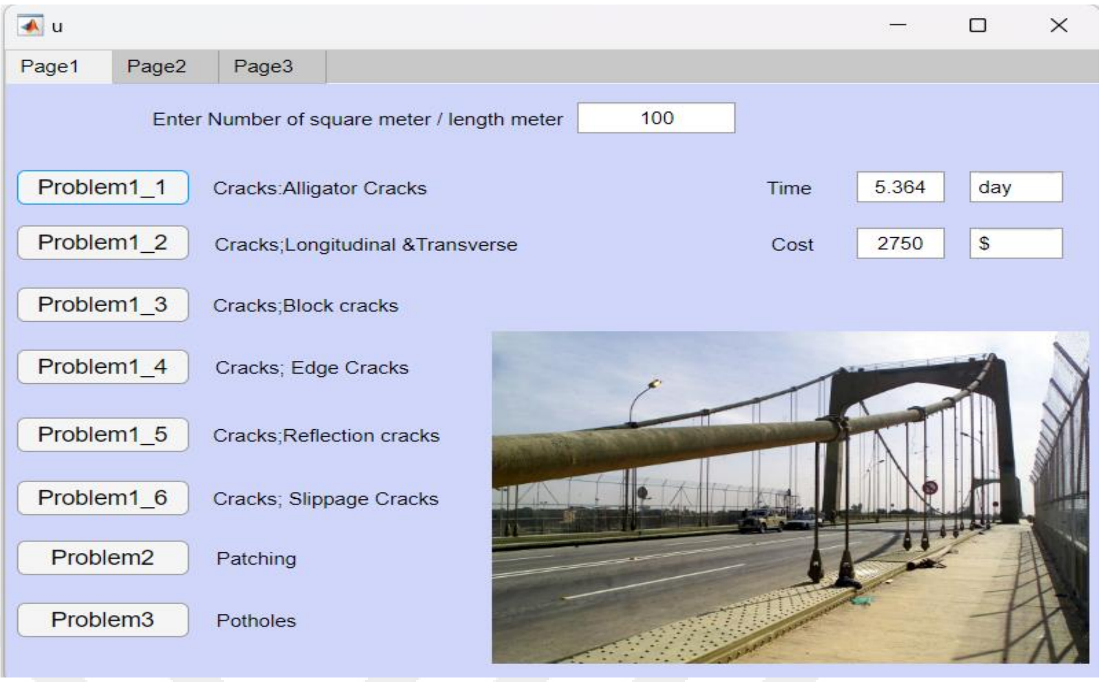

Figure 4.8: Show That the Results of Time and Cost as Example When the Problem of Alligator Cracks in Bridges

Source: [RW]

And when you press Home, it will return to the list of main roads, Figure 4.4.

Finally, you can Exit and end the program.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 General

This research, consisting of the practical part and the theoretical part, was able to determine the time and cost required to repair and maintain each square meter of road and bridge problems in Iraq through field research with experts and engineers in the field of roads and bridges to obtain the necessary information and data. Through it, to reach accurate results regarding time and cost according to a specific program or programming language on the computer to apply what is known as the expert system to give time and cost accurately, and this is the secret of the usefulness of the program. In this chapter, the results and conclusions are summarized as well as the recommendations that enable a successful engineering management of projects to repair and maintain roads and bridges problems in Iraq.

5.2 Conclusions

1- Expert system in this study can help engineers and consultants working in the roads and bridges sector in Iraq to estimate timetables and determine budgets for road and bridge maintenance projects in Iraq.

2- Expert system in this study can help contractors who intend to implement road and bridge maintenance projects in Iraq, as they can make the executive decision very quickly based on more effective and realistic assumptions.

3- Expert system in this study can help in drawing up the economic policy of the Iraqi state with regard to the advancement of infrastructure maintenance projects, especially the roads and bridges sectors, according to timetables and budgets that have been realistically estimated.

4- The process of cost analysis of defects that appear in roads and bridges in Iraq that the cost per square meter per square meter ranges between (10-30) $ and for the joints of bridges, the cost per length meter is (500-1500) $.

5-There is no clear standard for determining the cost required for road and bridge maintenance projects in Iraq.

6- There is no clear standard for determining the duration of completion of road and bridge maintenance projects in Iraq.

7- The amount of cost and time required for road and bridge maintenance projects in Iraq is variable depending on the type of road, type of problem, location, environmental conditions, method of use, amount of traffic, weight of wheels, etc.

8-There is not any interest in periodic maintenance or follow-up of roads and bridges in Iraq, despite the important need for periodic maintenance, which reduces costs. Rather, we find that when any minor defect occurs, it is left until the defect becomes large and cannot be easily repaired, which requires more time and a greater cost to repair.

9-There is not limitation of the loads that pass on the roads and bridges in Iraq, which causes the emergence of problems in roads and bridges.

10-There is not an interest in conducting training courses for the purpose of increasing the efficiency of cadres working in the field of road and bridge maintenance in Iraq.

11-Lack of attention to the design age in the use of roads and bridges in Iraq, when the road exceeds the design age, maintenance work does not be useful with it.

12- The problem of joints maintenance in bridges required the most cost.

13- The edge cracks problem requires the lowest maintenance cost.

14- The rutting problem requires more time for maintenance than the rest of the problems.

15- The edge cracks problem requires the lowest maintenance time.

5.3 Recommendations

1-Using the "Solutions For Cost And Planning Deviations In Roads And Bridges Maintenance With Expert Systems (In Iraq Case Study)" program to raise the level of performance and adhere to the correct engineering management principles to save time and money.

2-Paying attention to periodic maintenance and following up the condition of roads and bridges in Iraq to ensure that road and bridge problems do not develop in order to reduce maintenance costs.

3-The need to limitation the loads that pass on roads and bridges in Iraq by placing traffic signs to reduce the problems of roads and bridges.

4- It is necessary to pay attention to conducting training courses for the purpose of increasing the efficiency of cadres and workers in the field of road and bridge maintenance in Iraq.

5- Paying attention to the design age in the use of roads and bridges in Iraq to be their effective maintenance process.

6- The need to pay attention and follow up on the continuous maintenance of the joints of bridges, as they require the highest cost for their maintenance and repair.

7- The need to pay attention and follow up on the continuous maintenance of the rutting problem, as they require the more time for their maintenance and repair.

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APPENDICES

Appendix A: The Questionnaires

Open questionnaire about sustainability of Roads & Bridges problems in Iraq / (For Experts)

Table A.1: The Open Questionnaire Form

Years of experienc   The scientific title: Engineering Degree:

Requirements		National Highways		District Highways		Bridges	
No. Problems		Time/m^2	Cost/m^2	Time/m^2	Cost/m^2	Time/m^2	Cost/m^2
1- Cracks	Alligator Cracks						
	Longitudinal &Transverse						
	Block cracks						
	Edge Cracks						
	Reflection cracks						
	Slippage Cracks						

Table A.1: (Cont.) The Open Questionnaire Form

Requirements	National Highways		District Highways		Bridges	
No. Problems	Time/m²	Cost/m²	Time/m²	Cost/m²	Time/m²	Cost/m²
2- Patching						
3- Potholes						
4- Shoving						
5-Depression						
6-Rutting						
7-Bleeding						
8-Raveling& Weathering						
9-Polished Aggregate						
10-Sags& Bumps						
11-Corrugation						
12-Lane shoulders drop						
13-Swelling						

Table A.1: (Cont.) The Open Questionnaire Form

Requirements	National Highways		District Highways		Bridges	
No. Problems	Time/m²	Cost/m²	Time/m²	Cost/m²	Time/m²	Cost/m²
14-Railroad crossing						
15- Utility cut patch						
16- Joints						

If you want to add other problems that we did not mention them, write them in the Table please:

Requirements	National Highways		District Highways		Bridges	
No. Problems	Time/m²	Cost/m²	Time/m²	Cost/m²	Time/m²	Cost/m²
17-						
18-						
19-						

Notes:

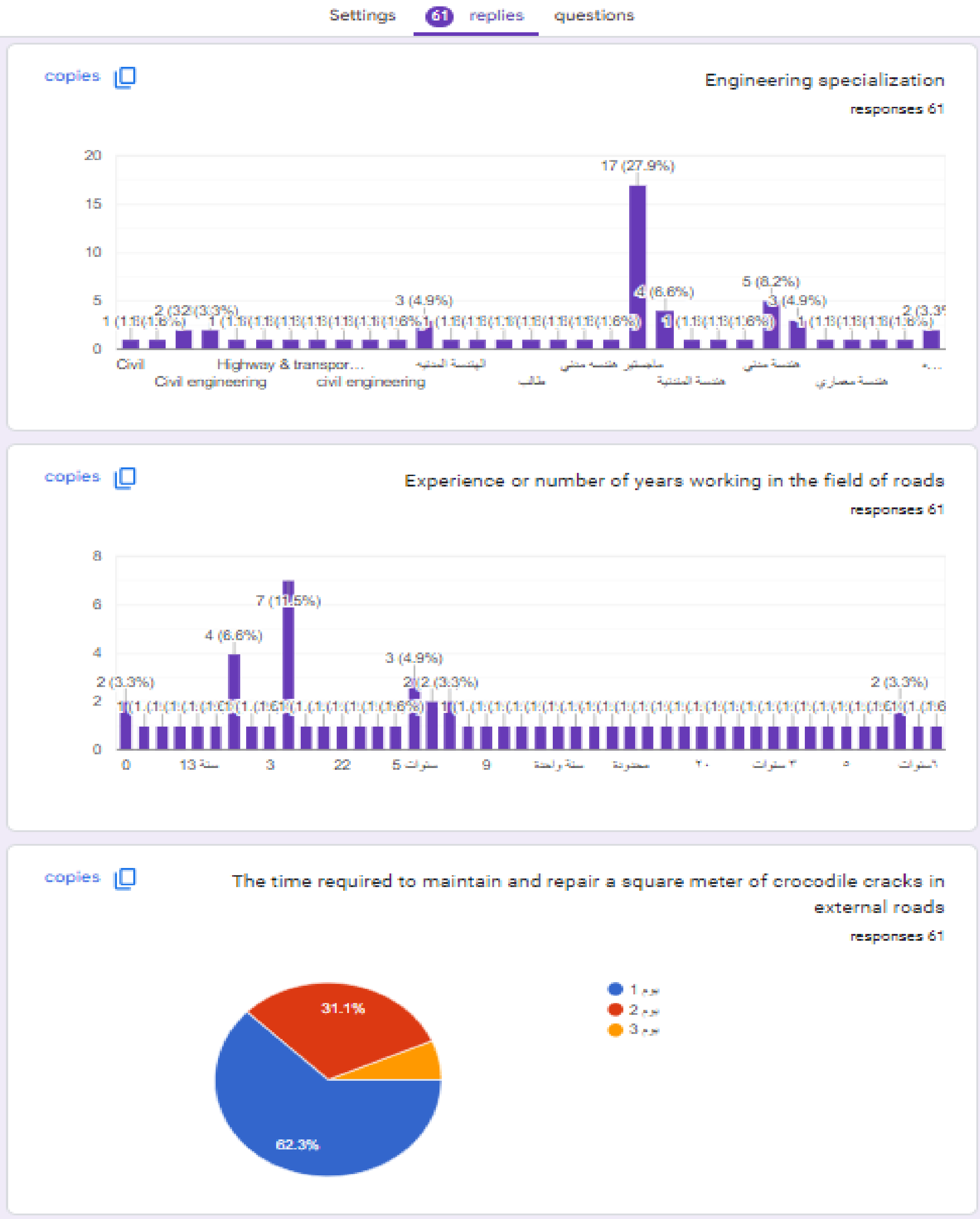


Figure A.1: The Closed Questionnaire Form

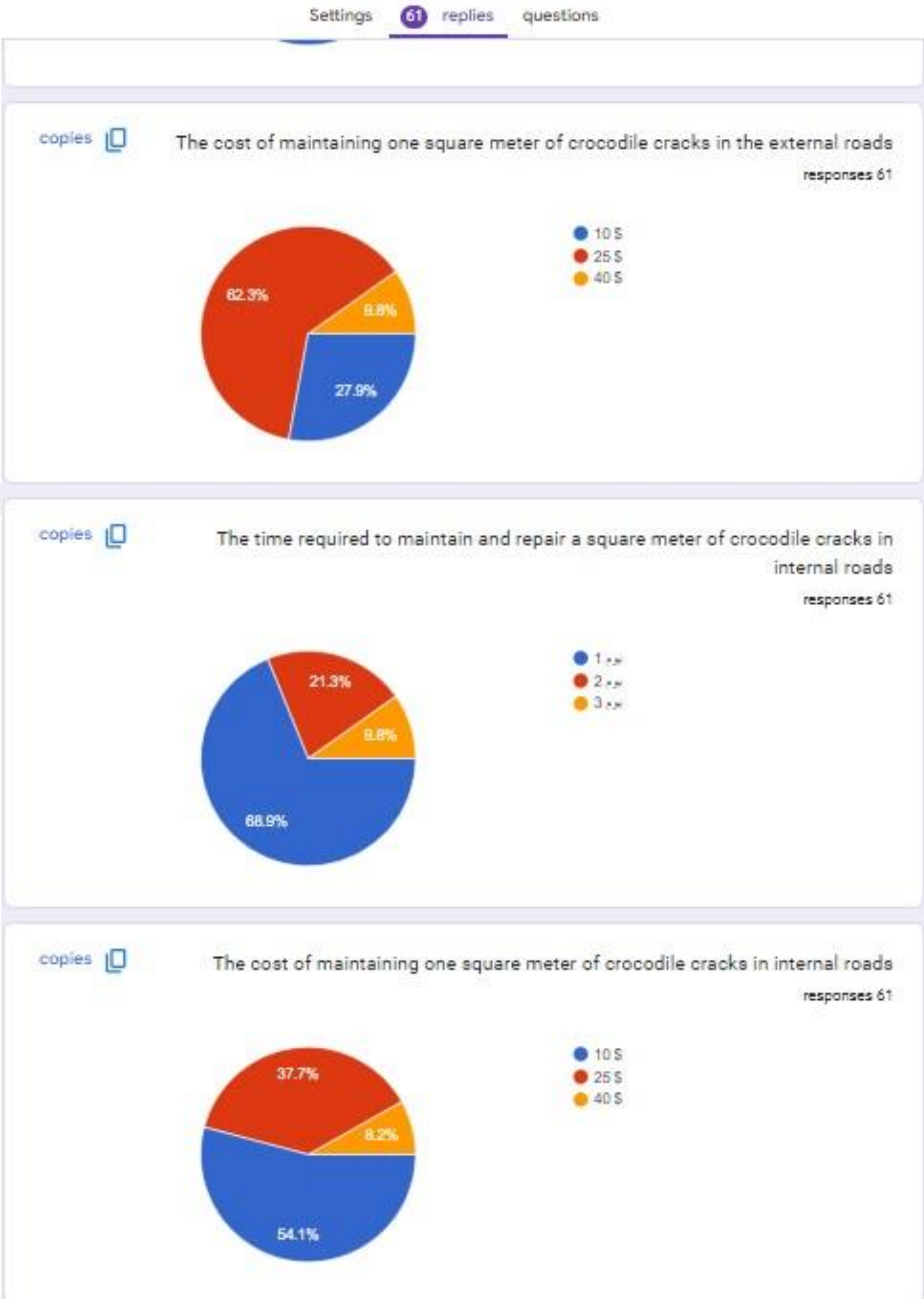


Figure A.1: (Cont.) The Closed Questionnaire Form

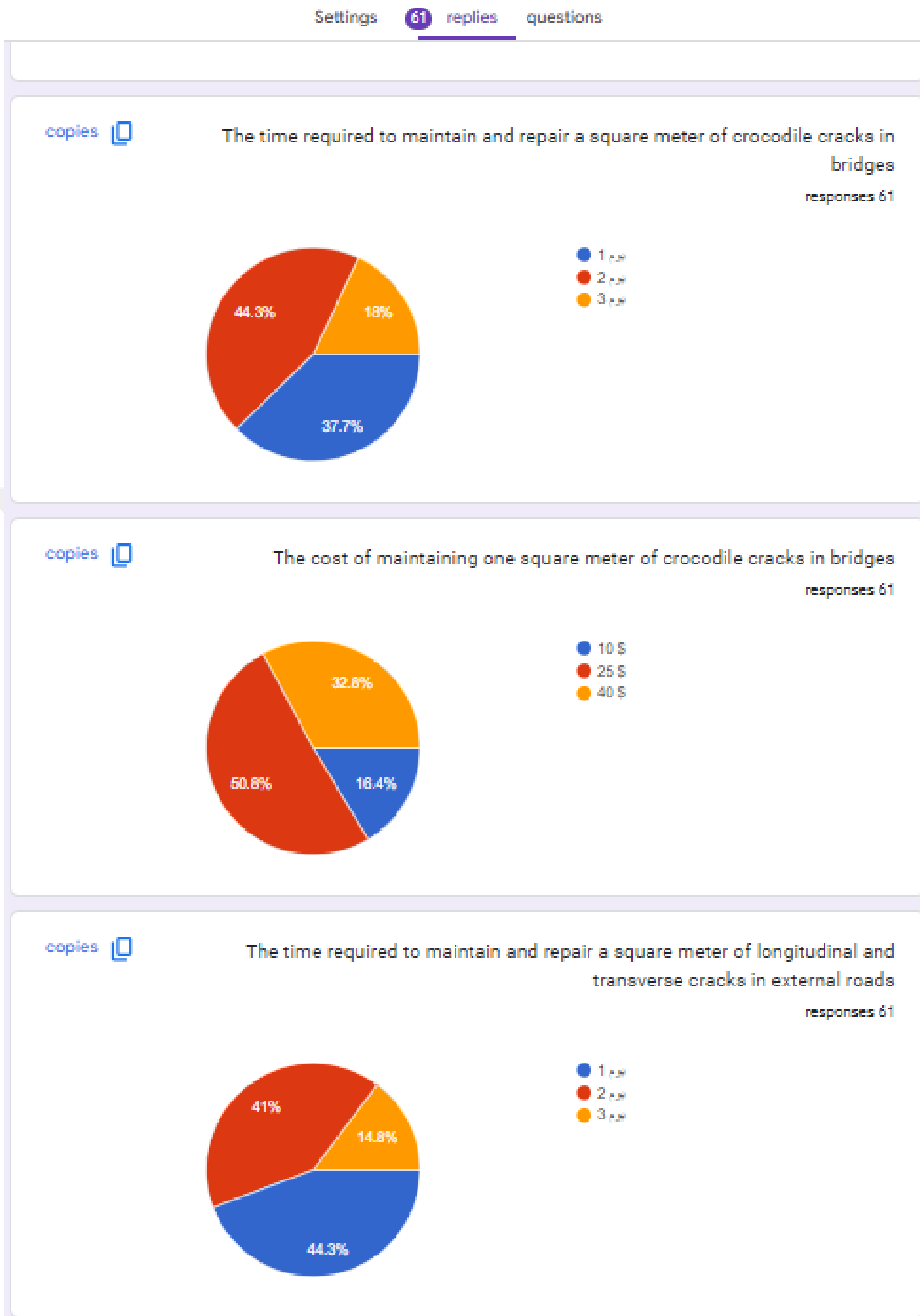


Figure A.1: (Cont.) The Closed Questionnaire Form

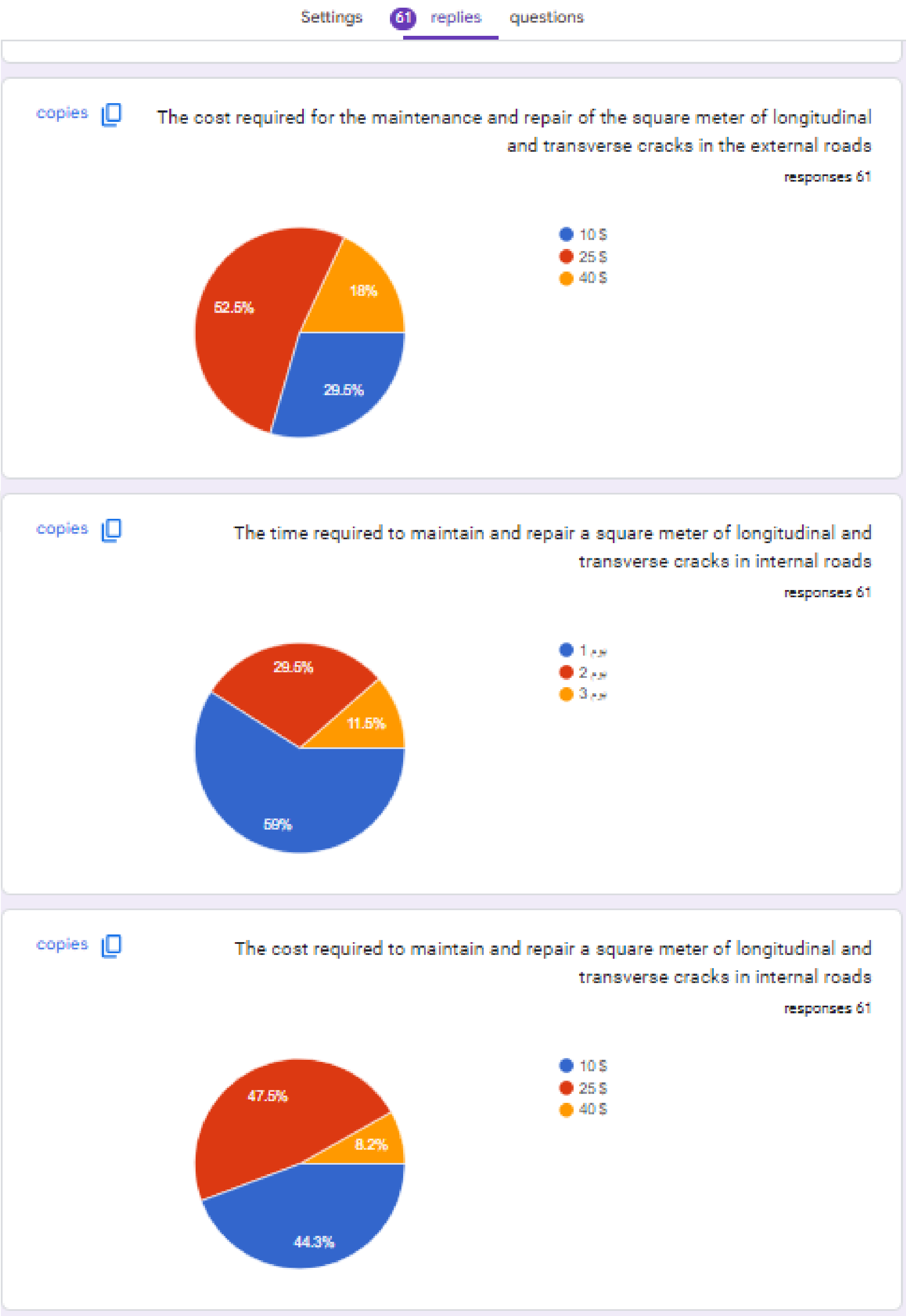


Figure A.1: (Cont.) The Closed Questionnaire Form

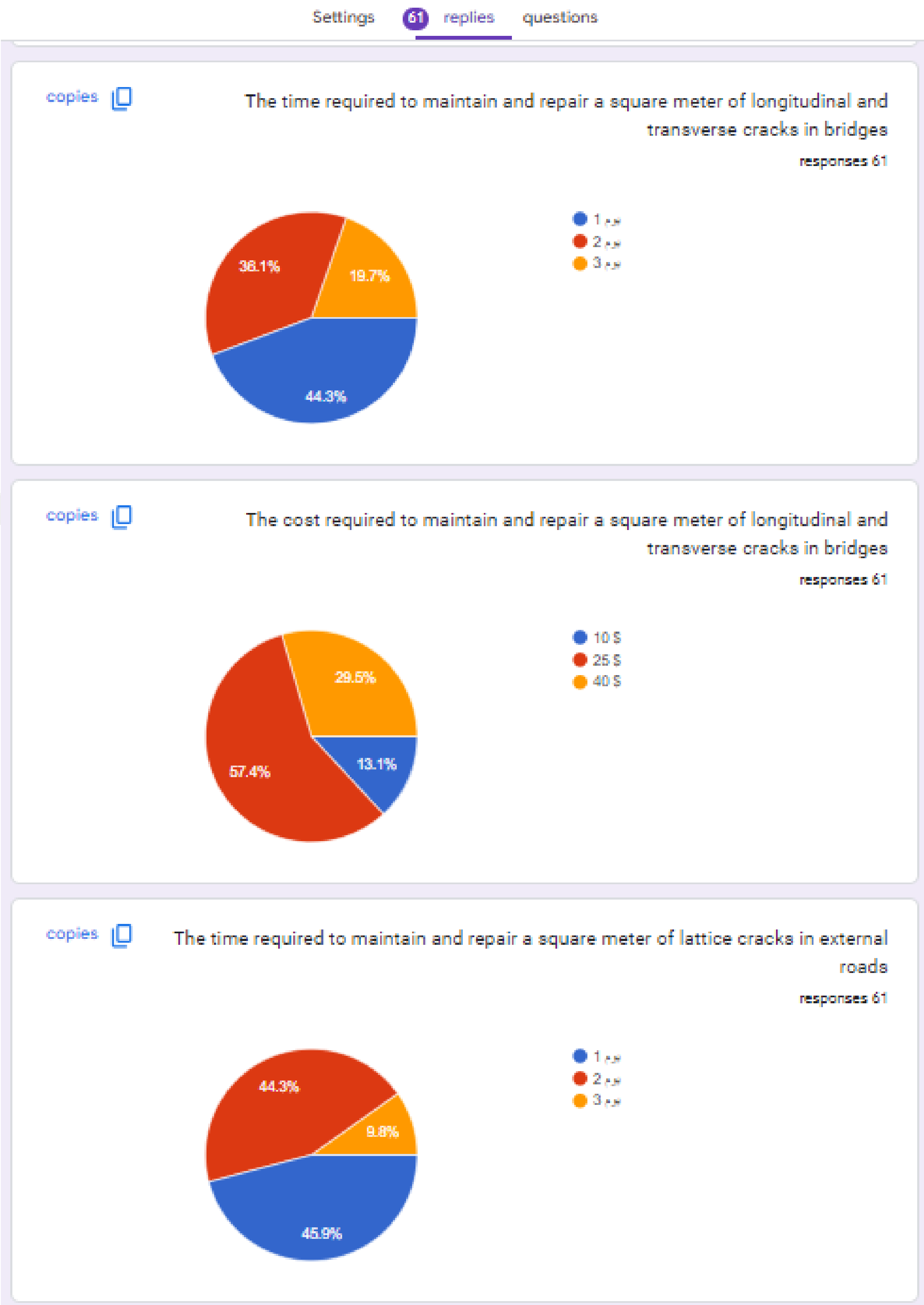


Figure A.1: (Cont.) The Closed Questionnaire Form

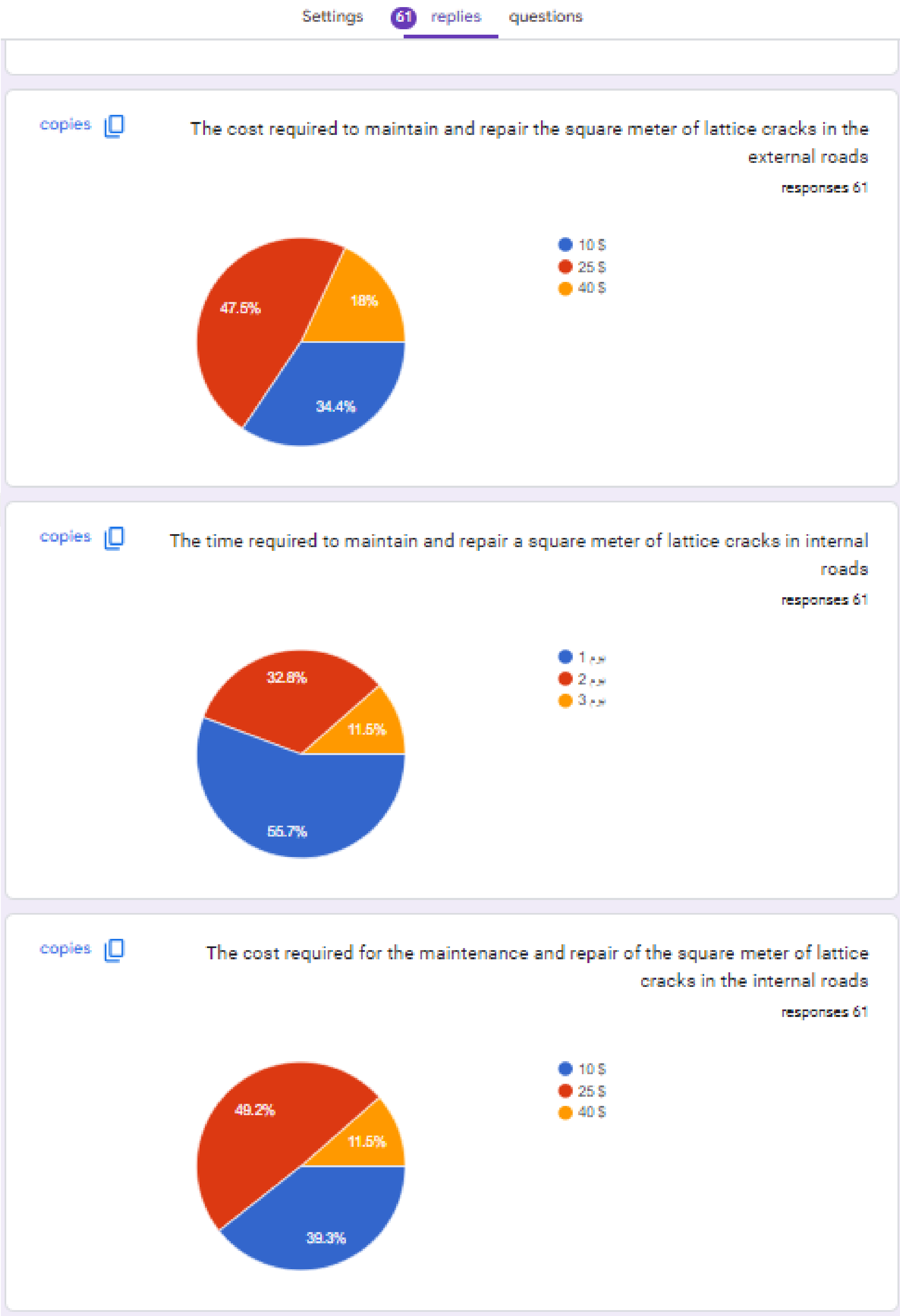


Figure A.1: (Cont.) The Closed Questionnaire Form

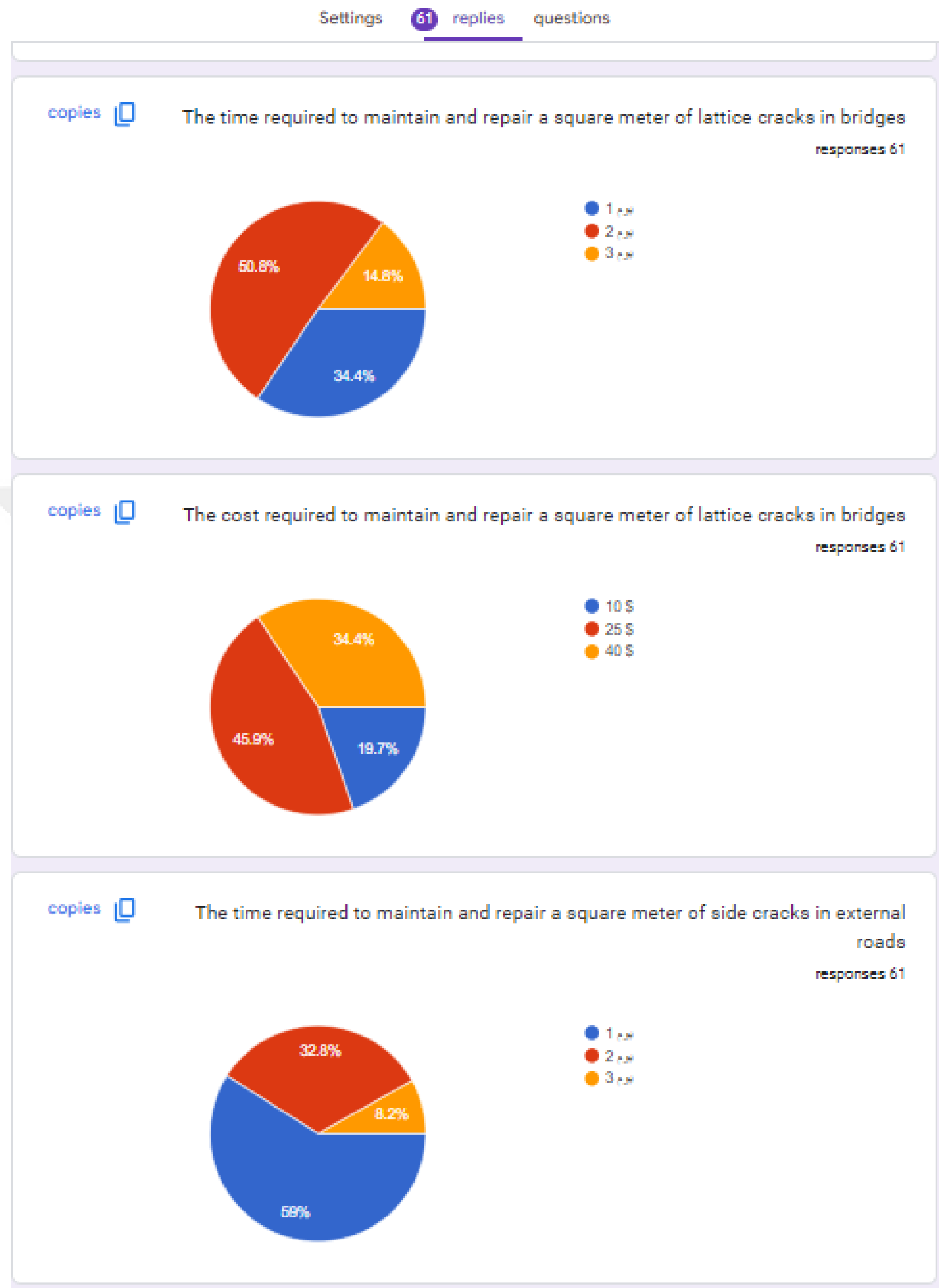


Figure A.1: (Cont.) The Closed Questionnaire Form

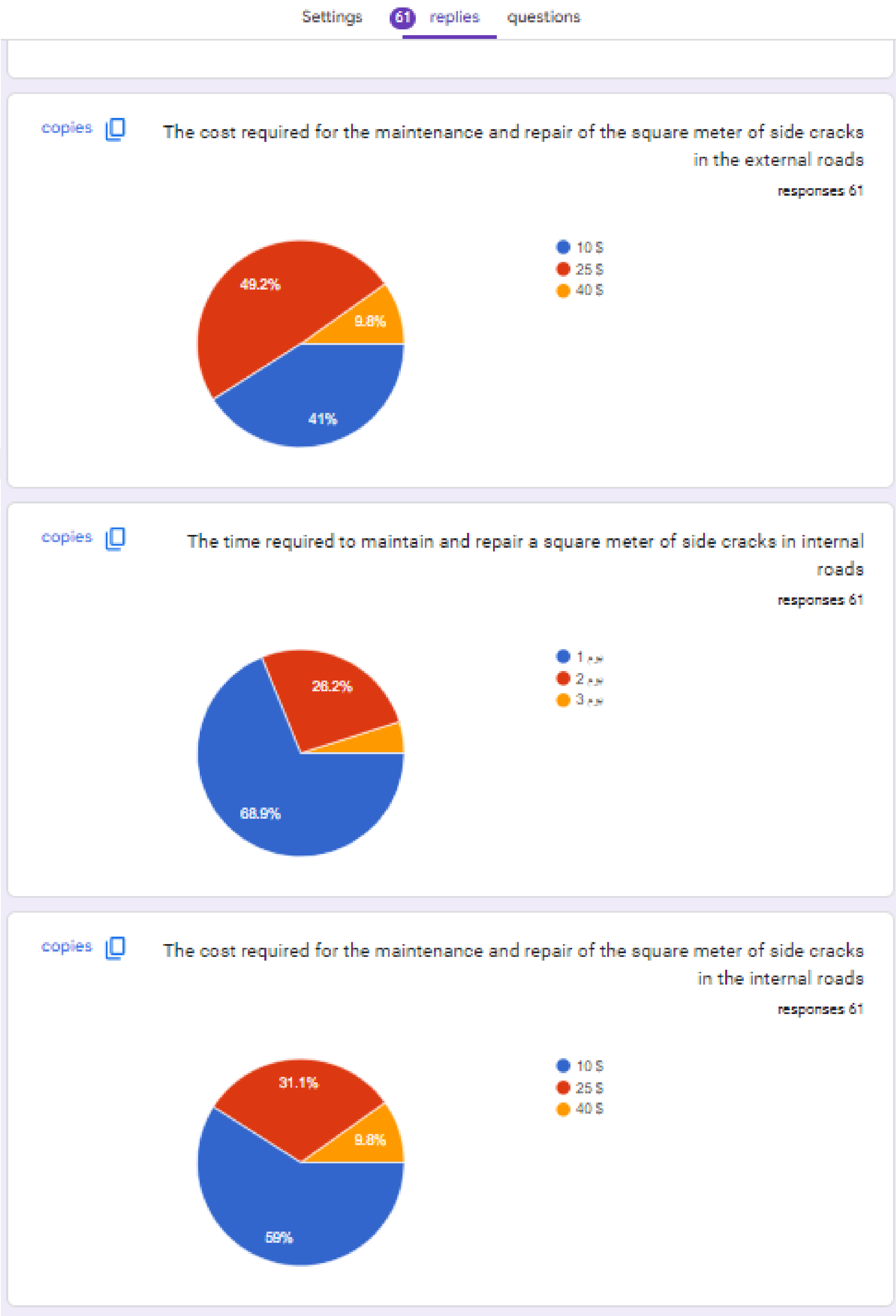


Figure A.1: (Cont.) The Closed Questionnaire Form

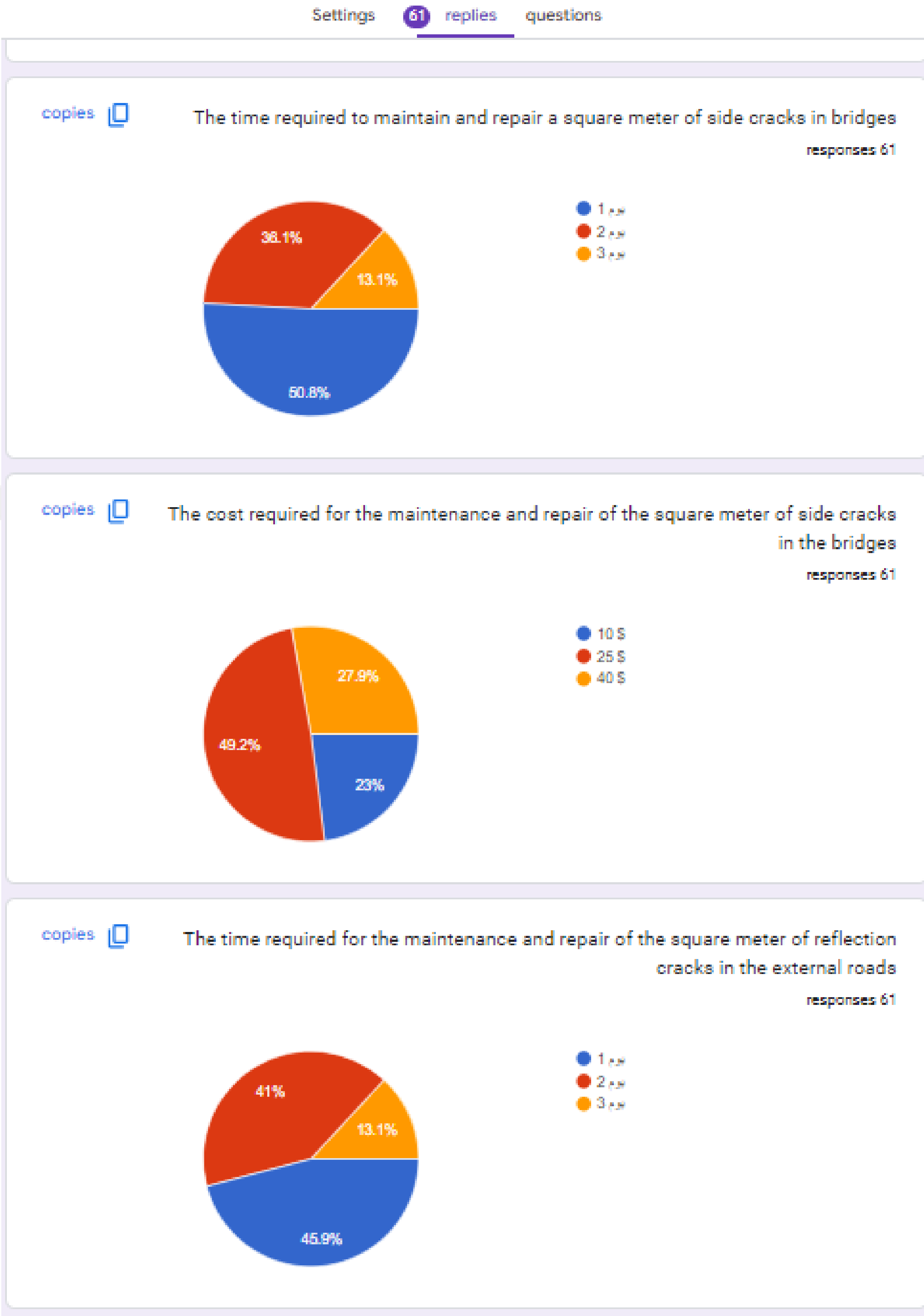
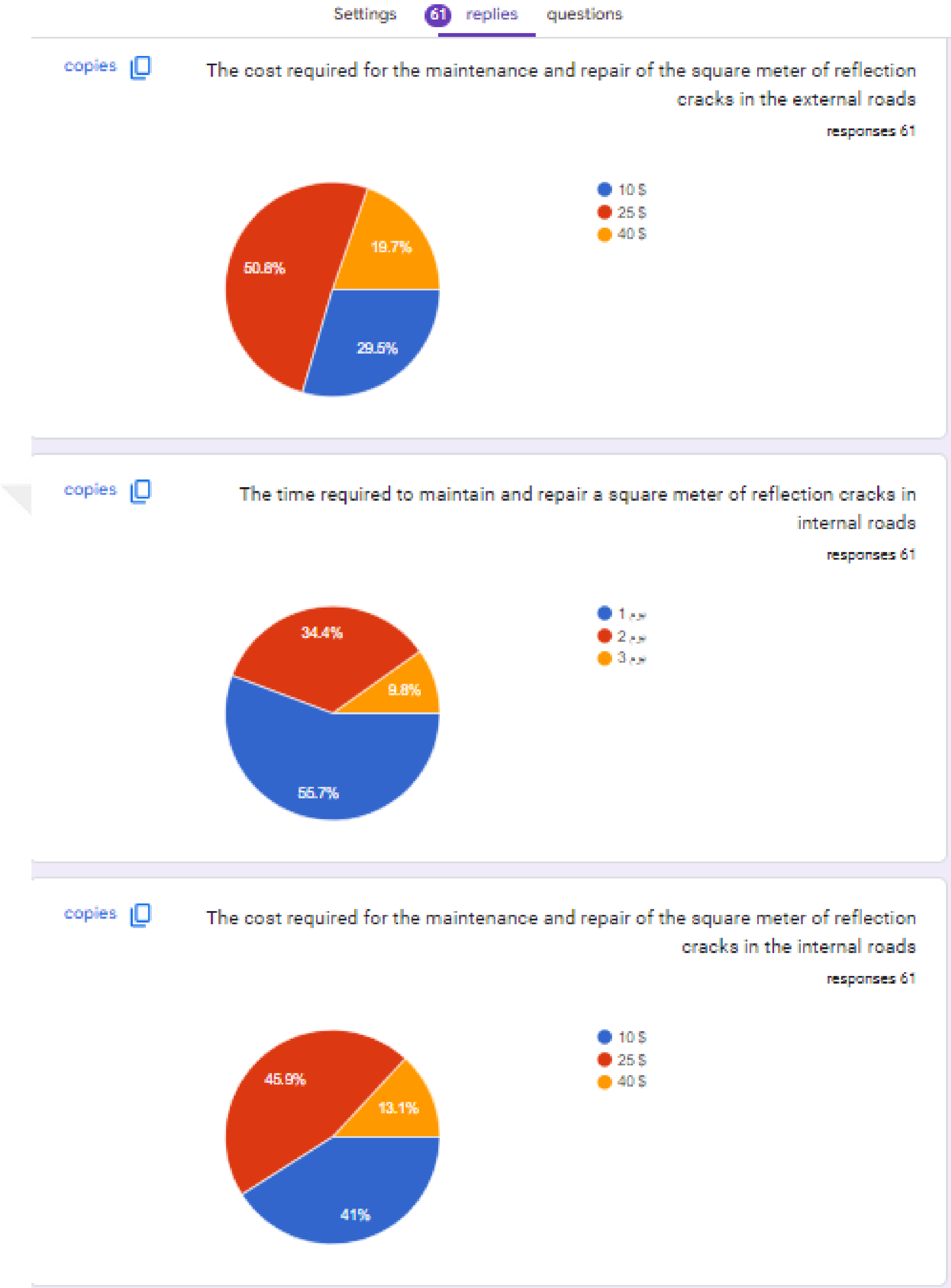


Figure A.1: (Cont.) The Closed Questionnaire Form



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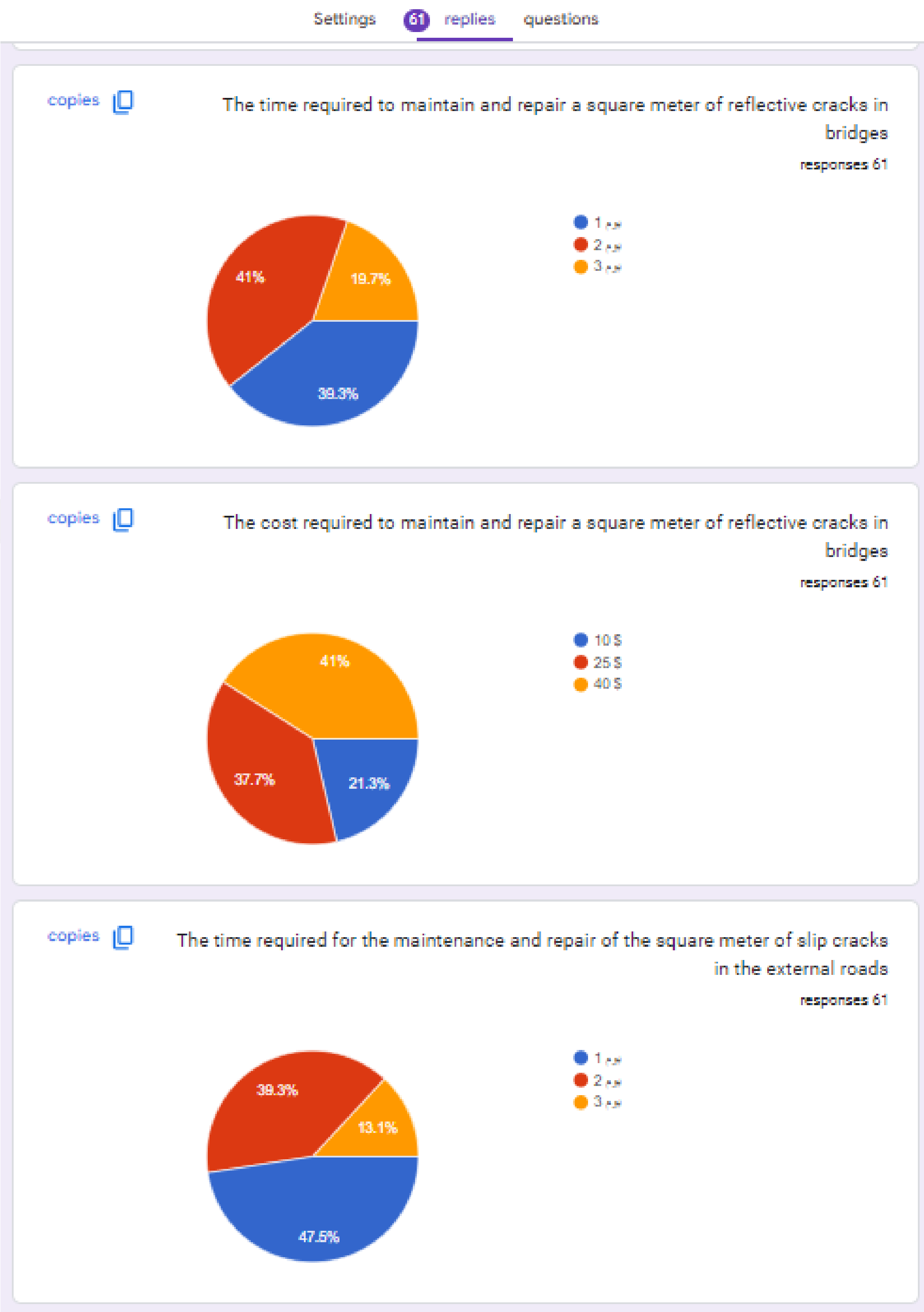

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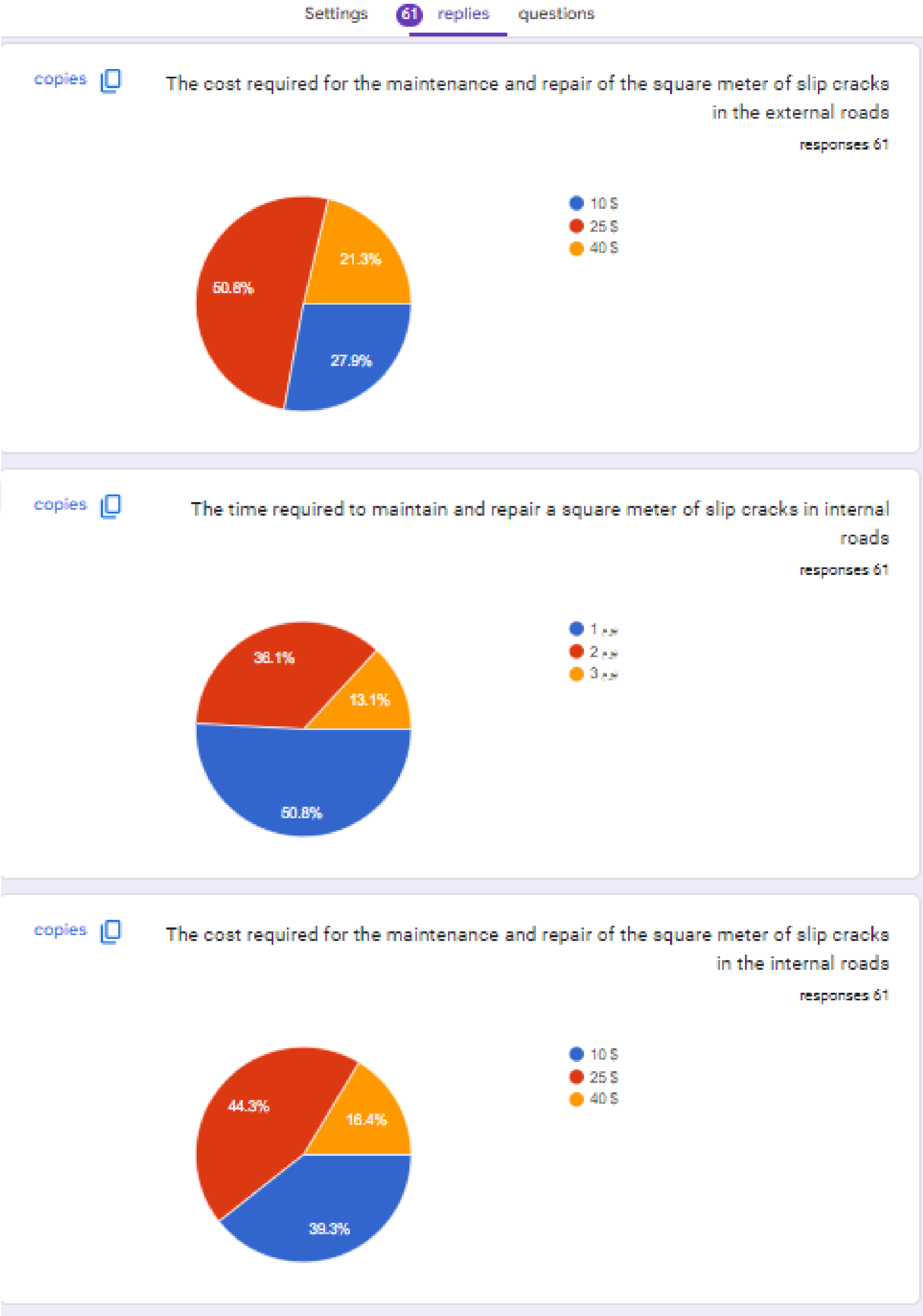

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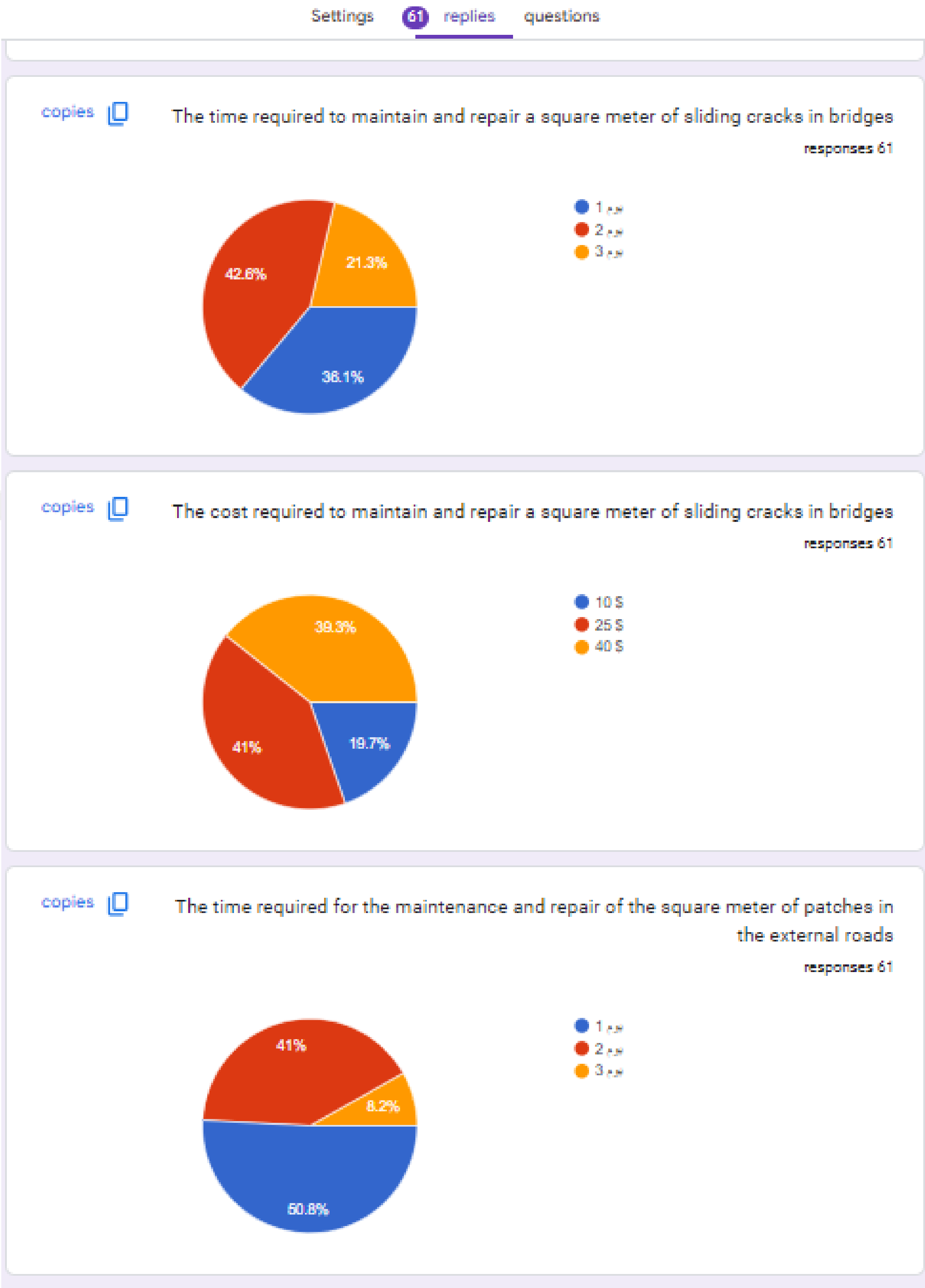

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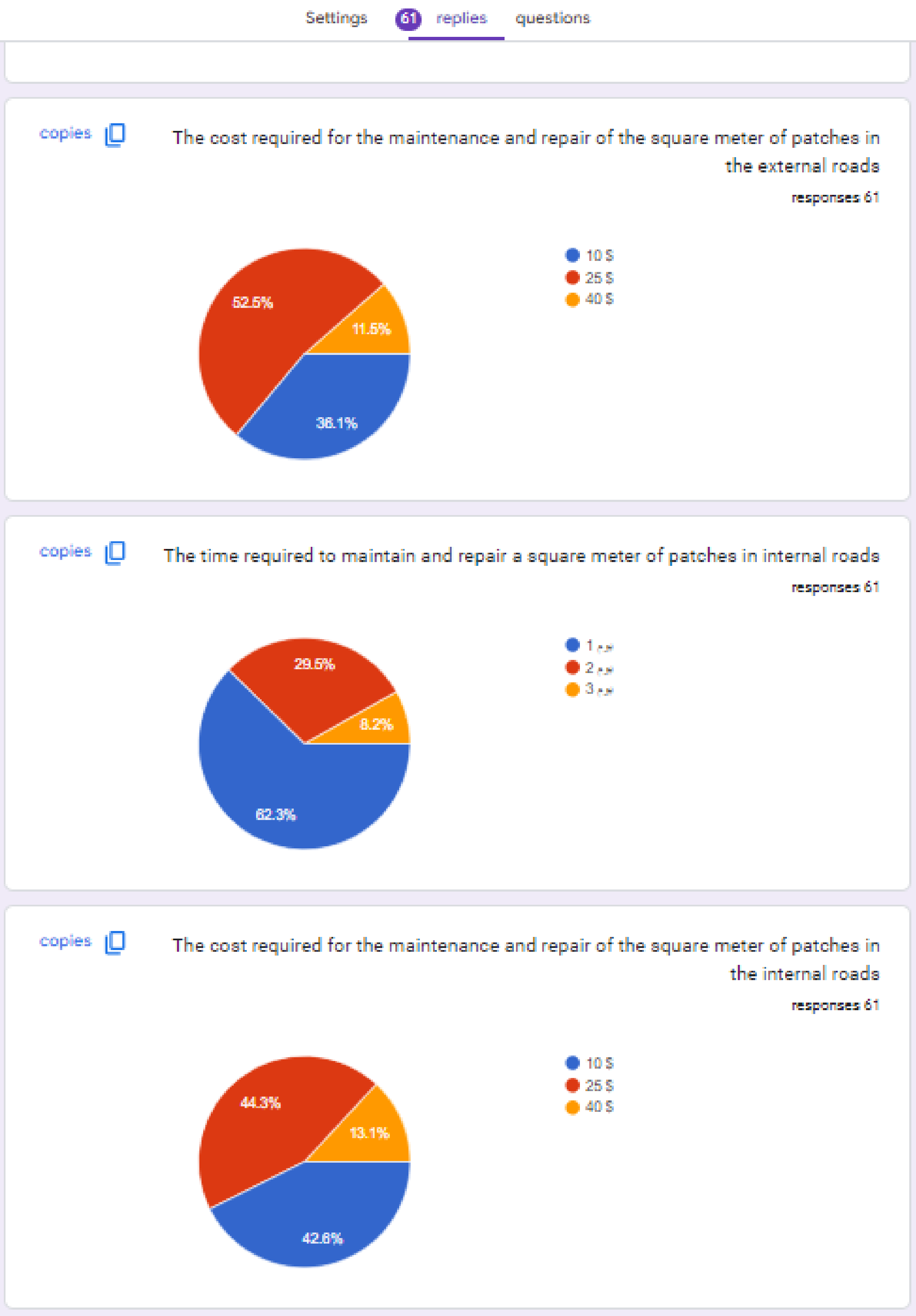

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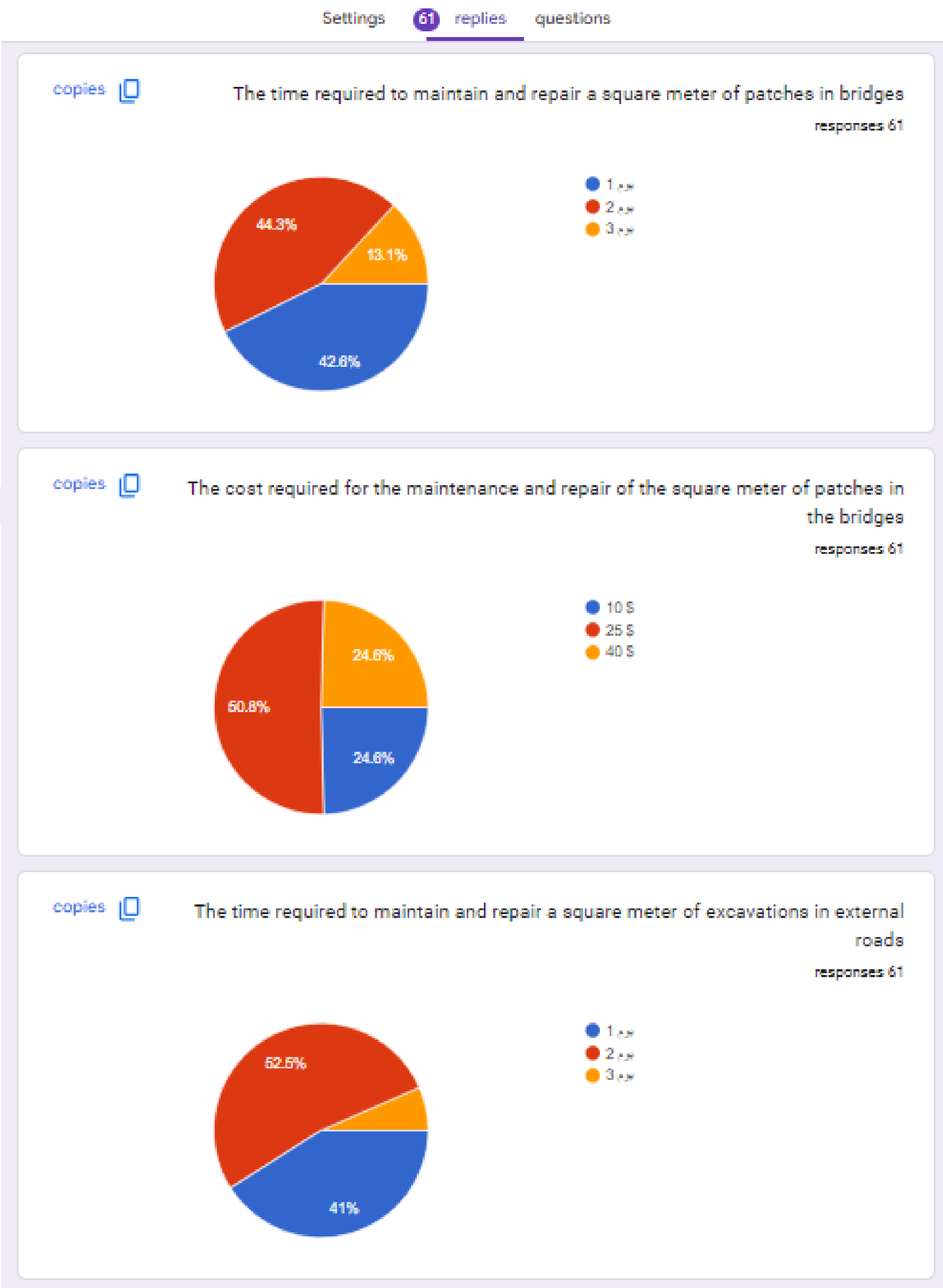

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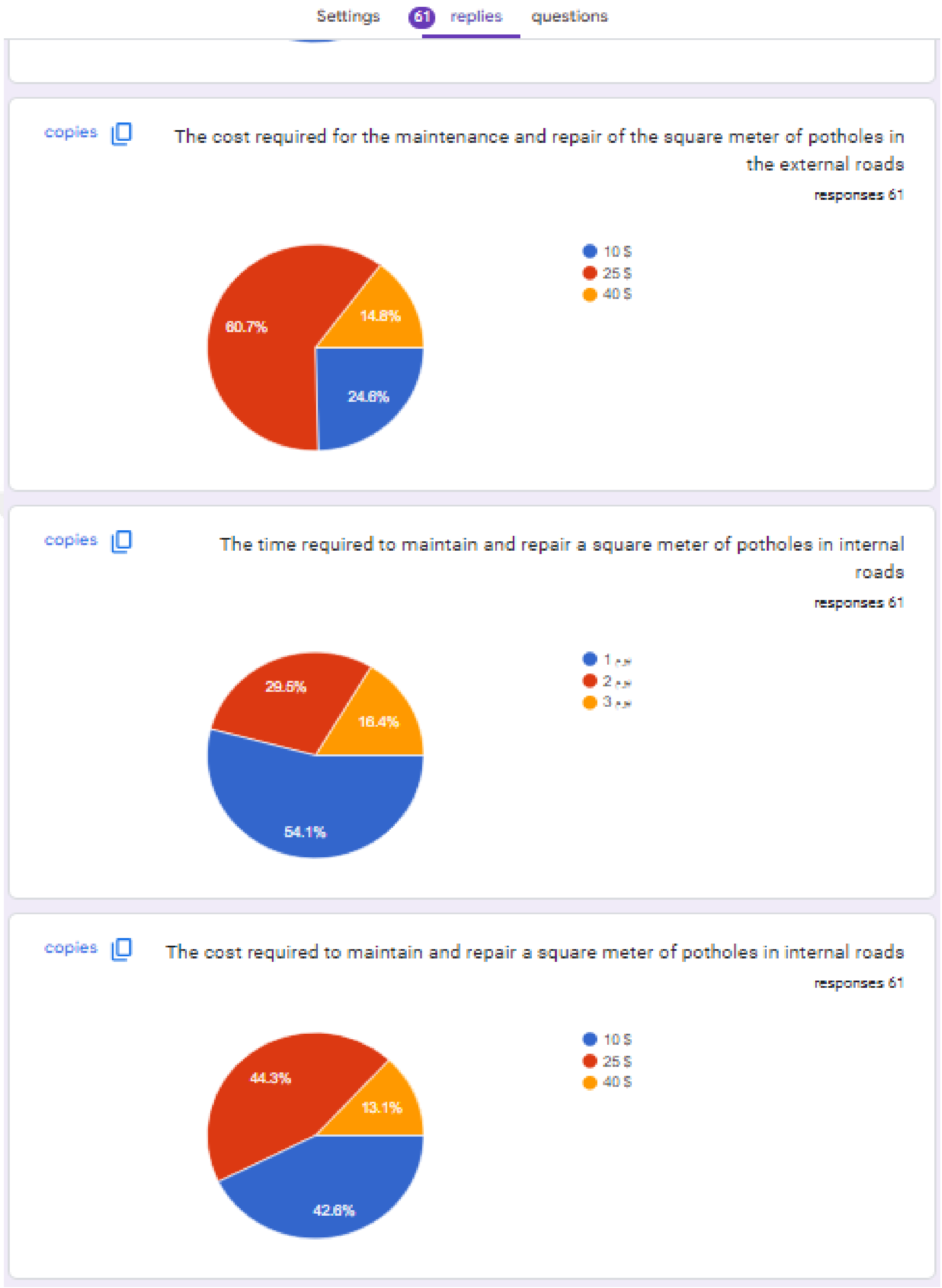

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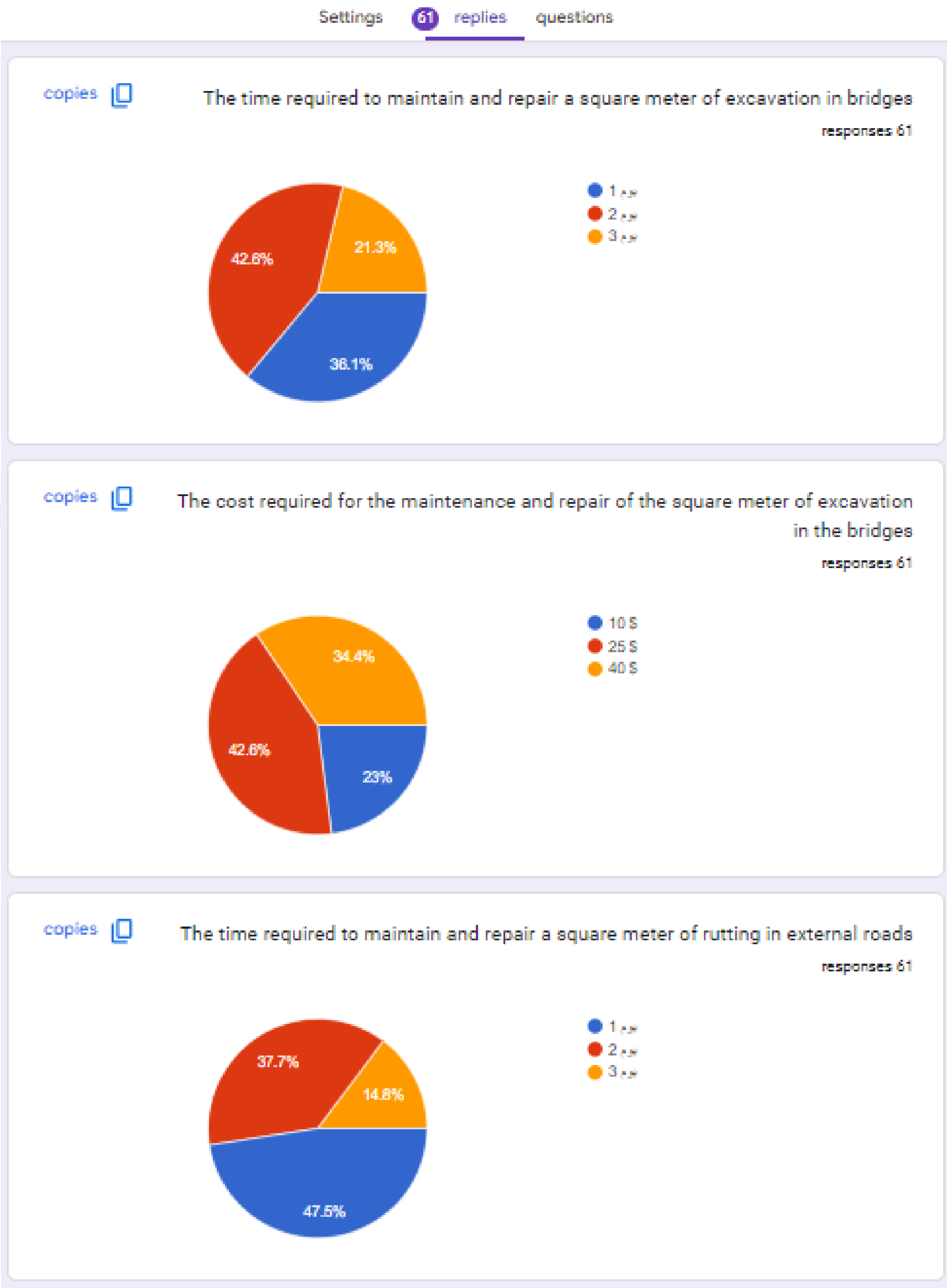

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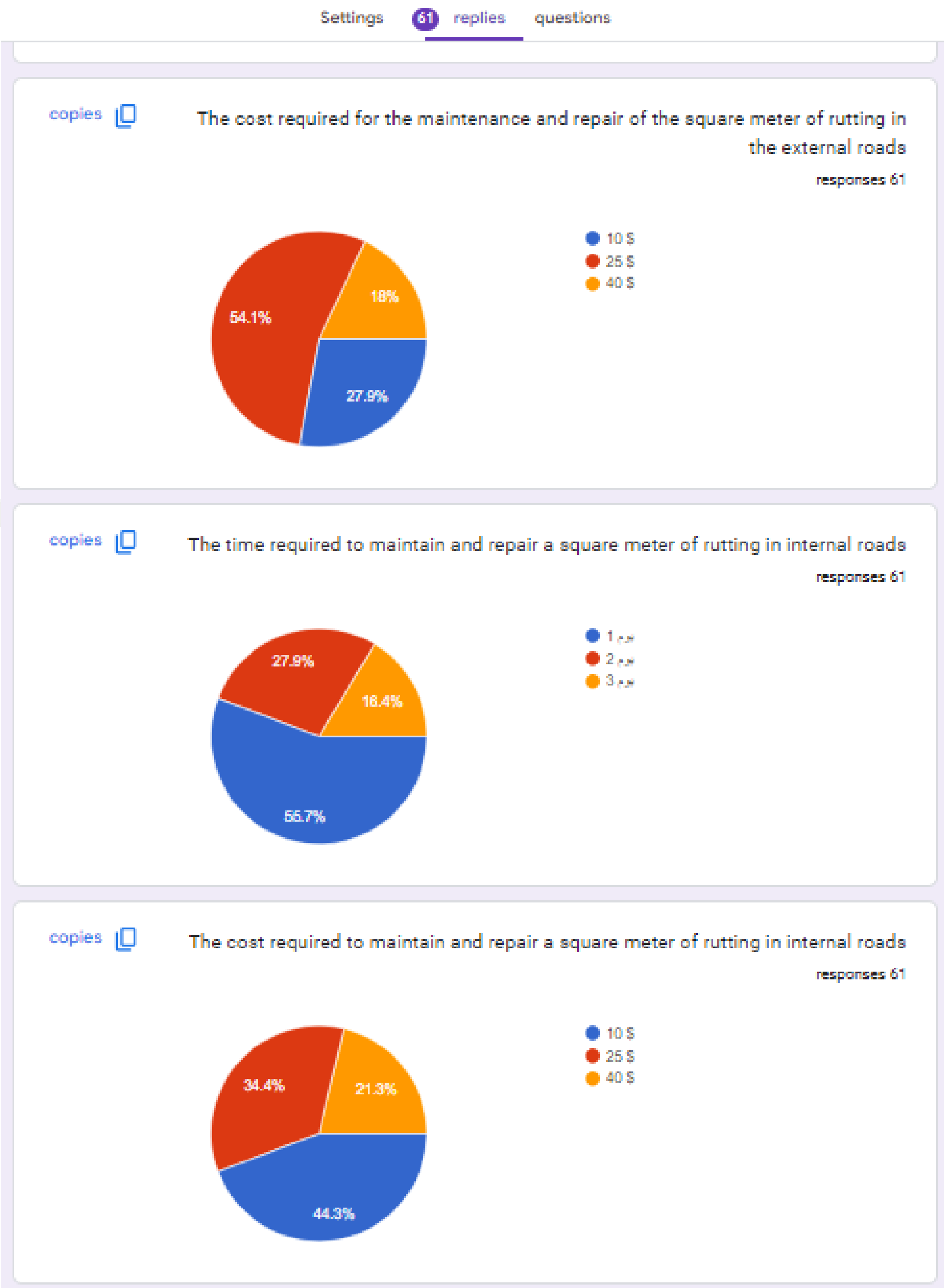

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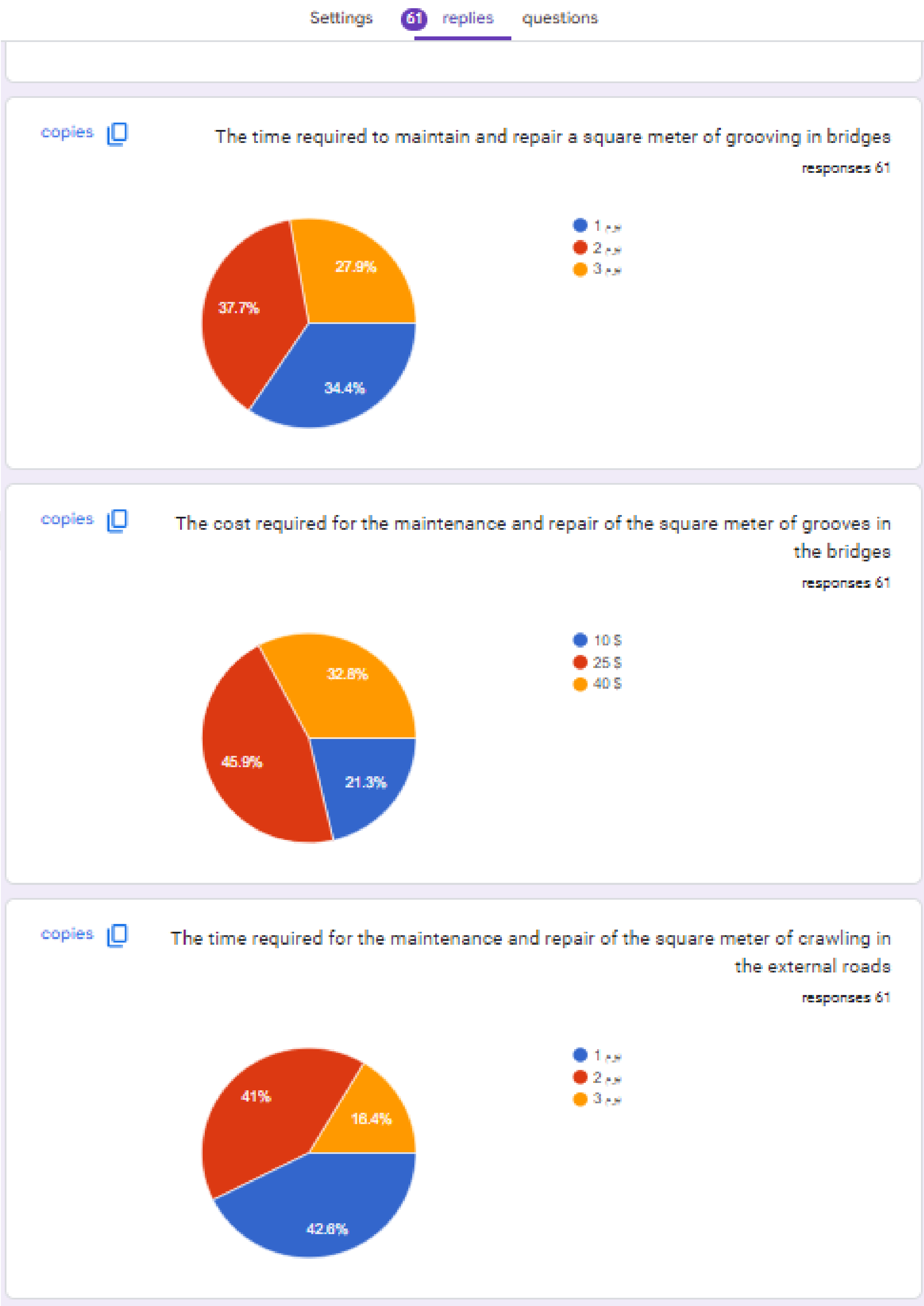

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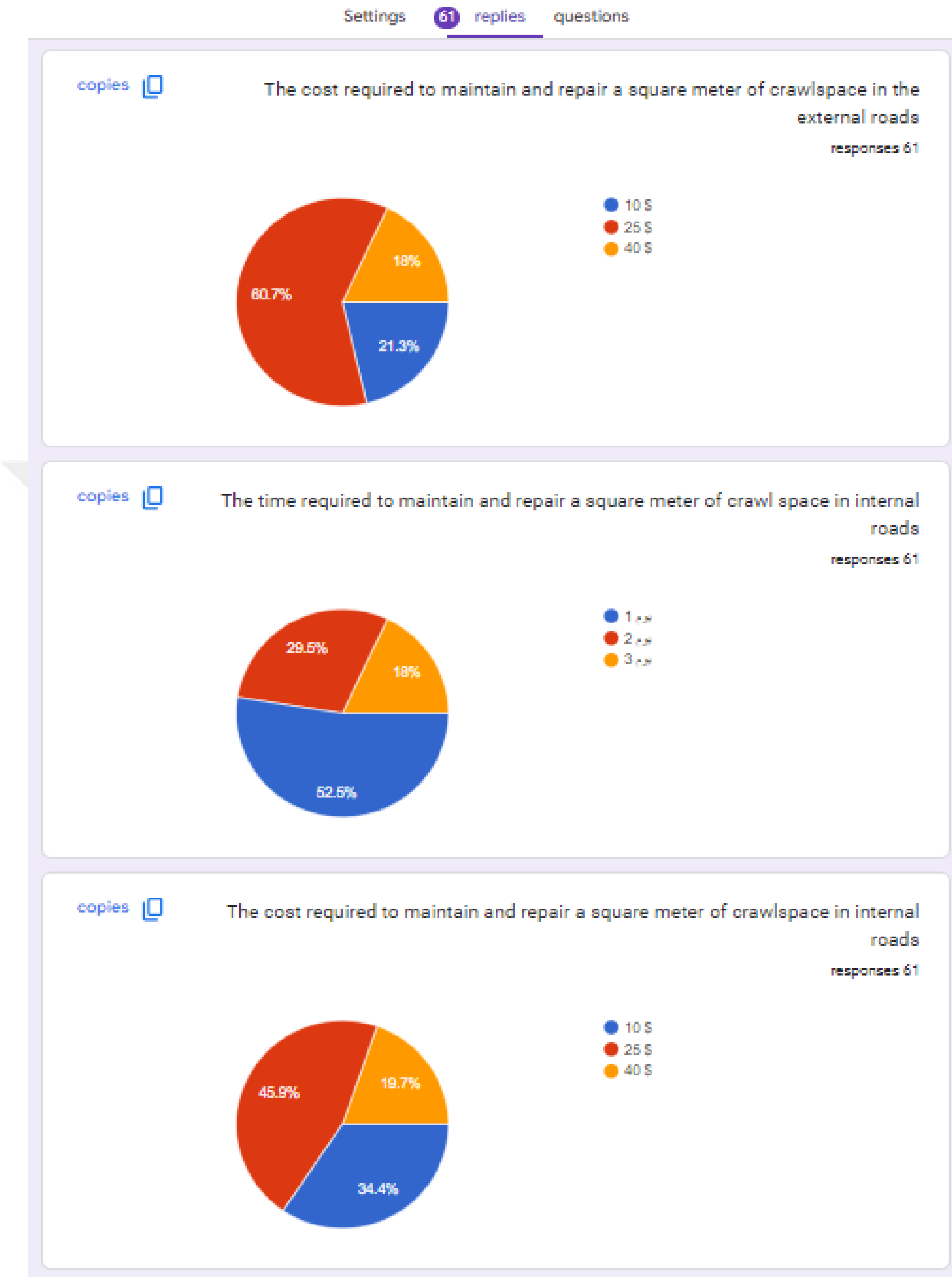

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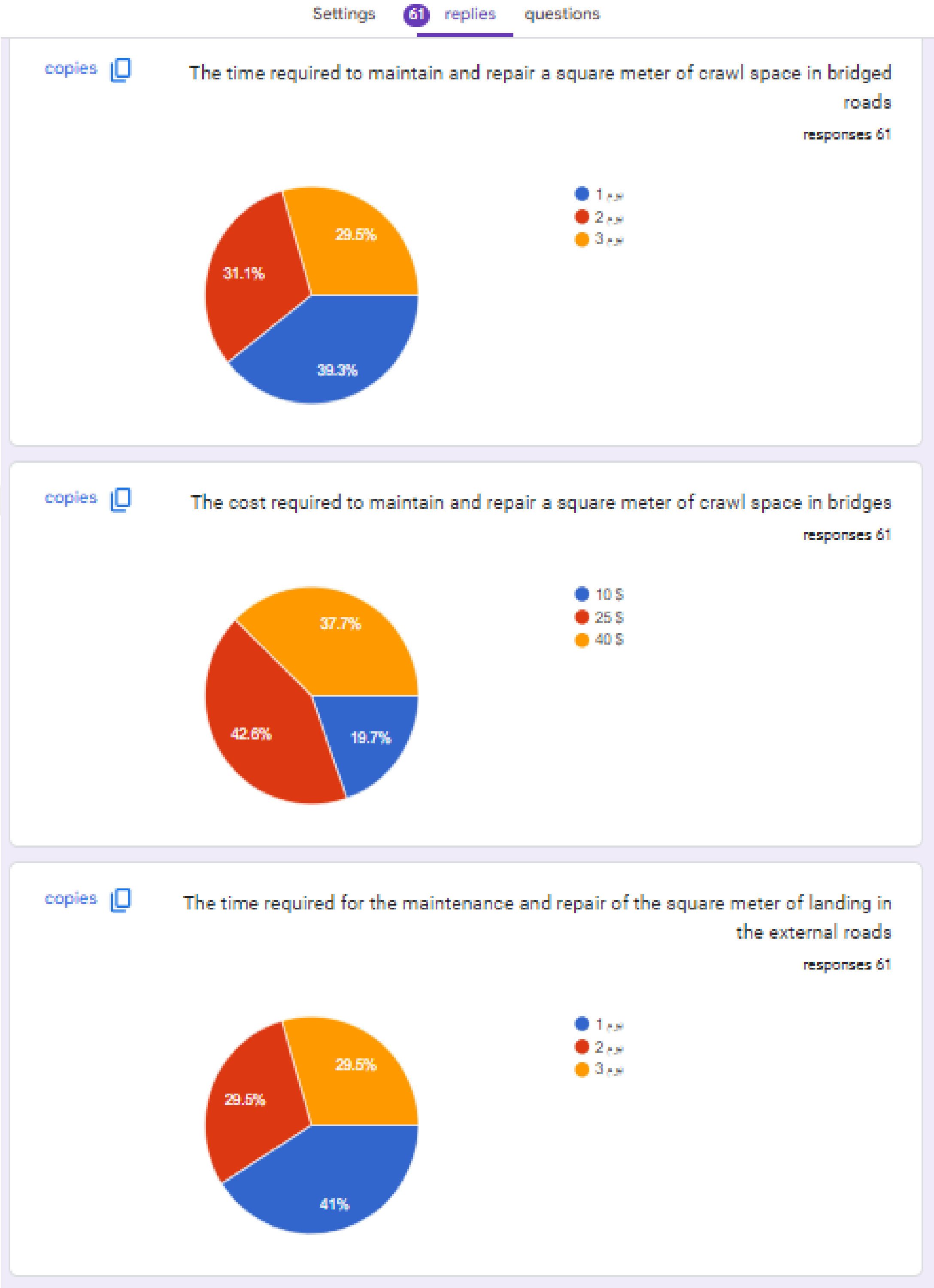

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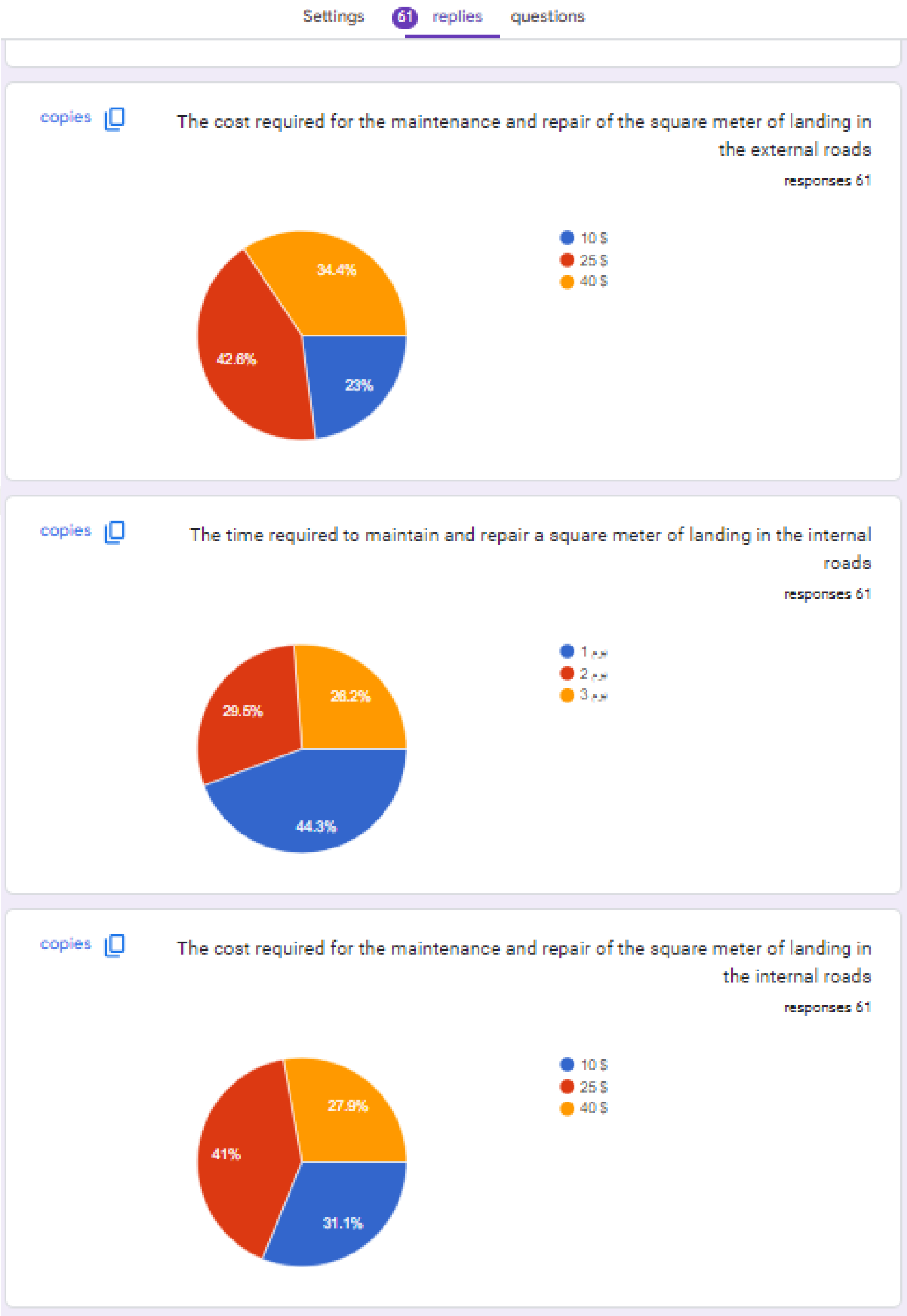

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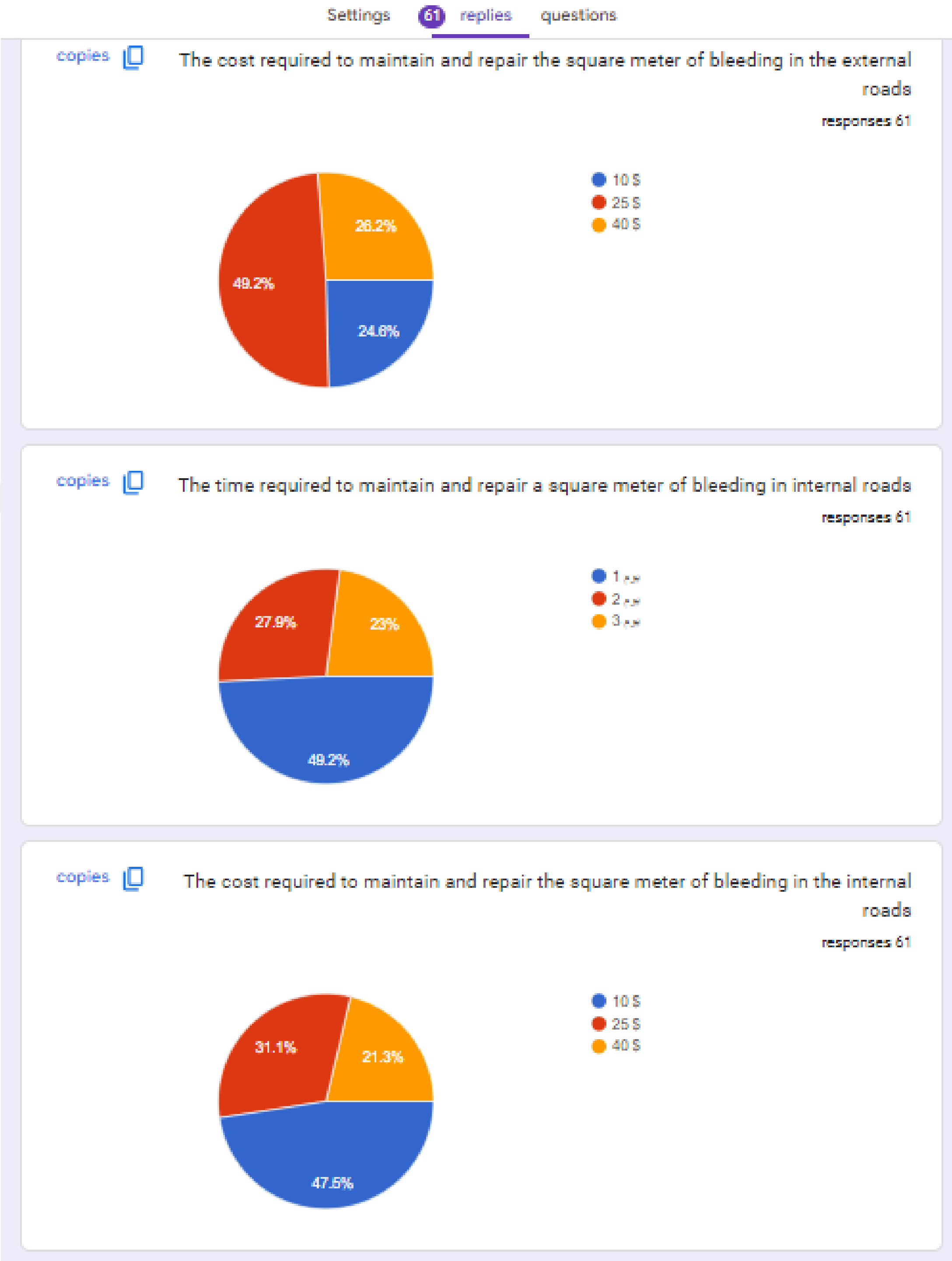

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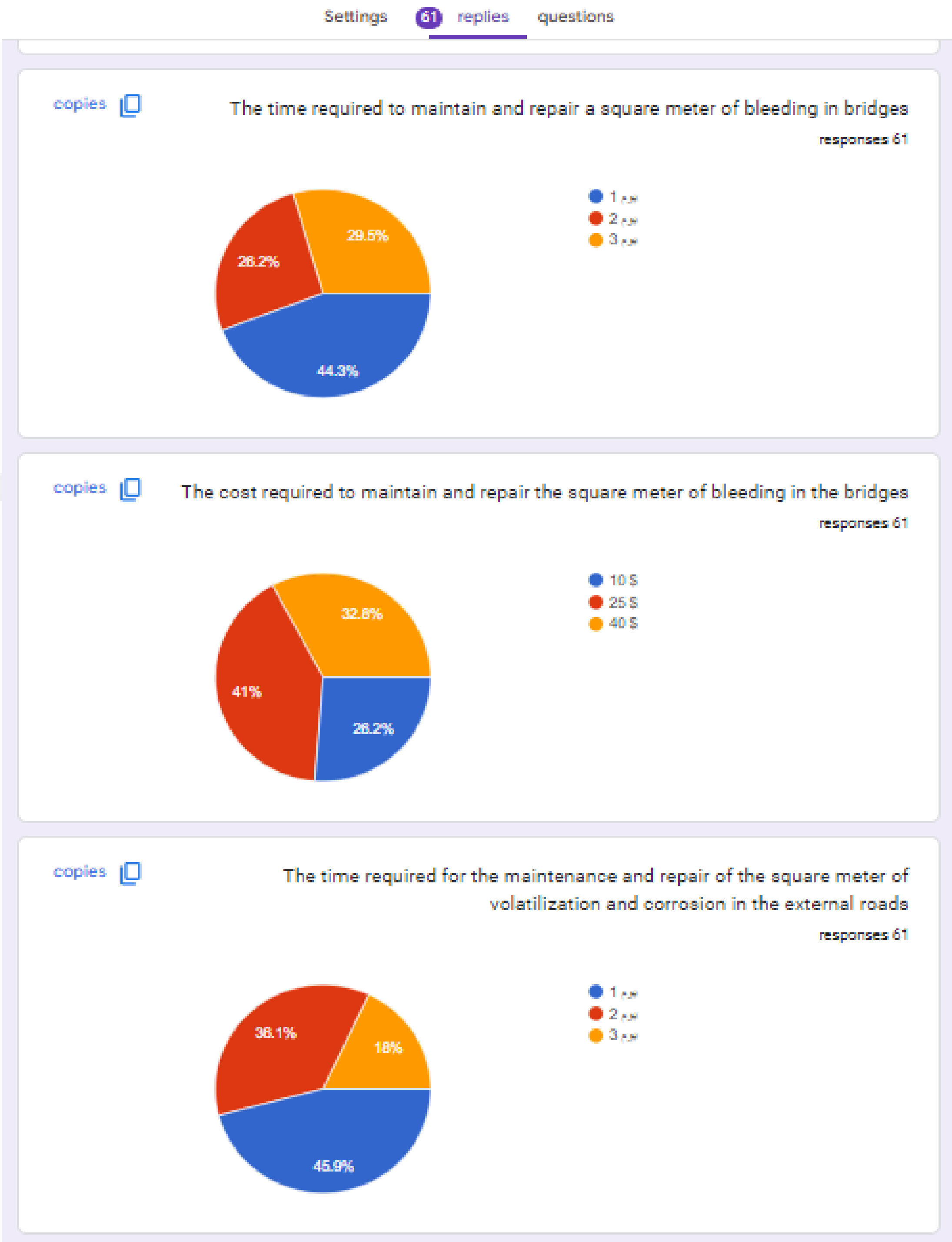

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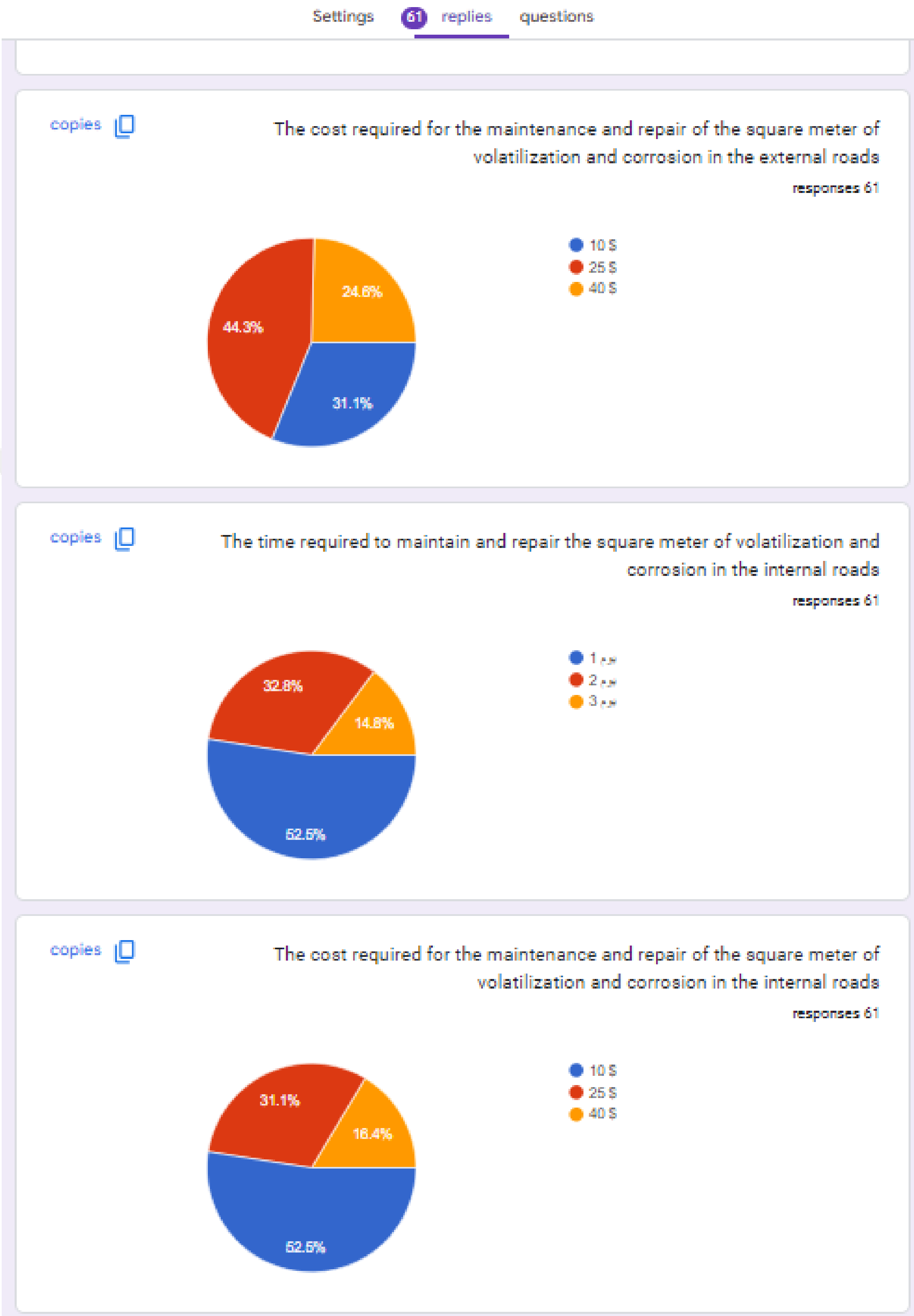

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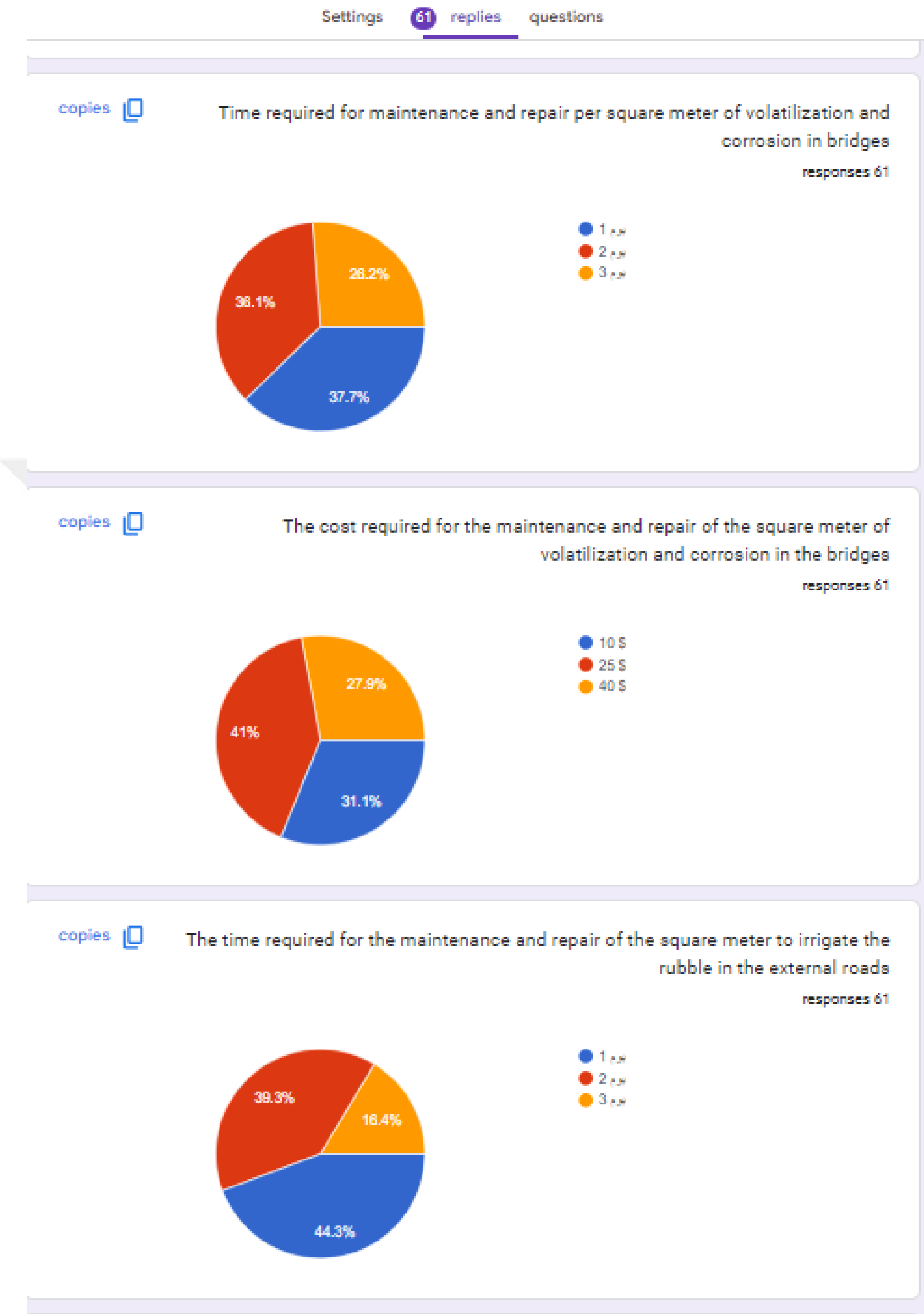

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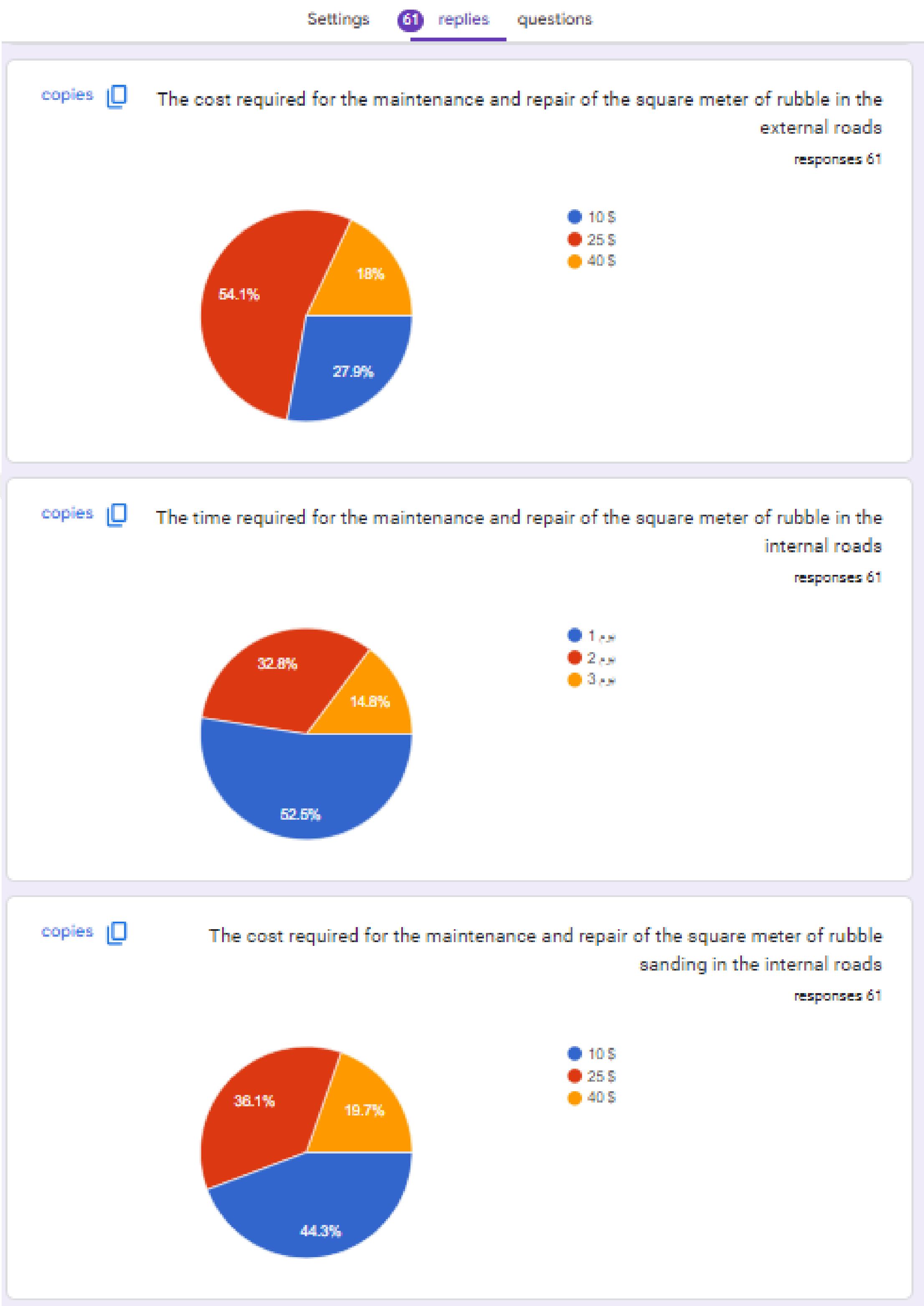

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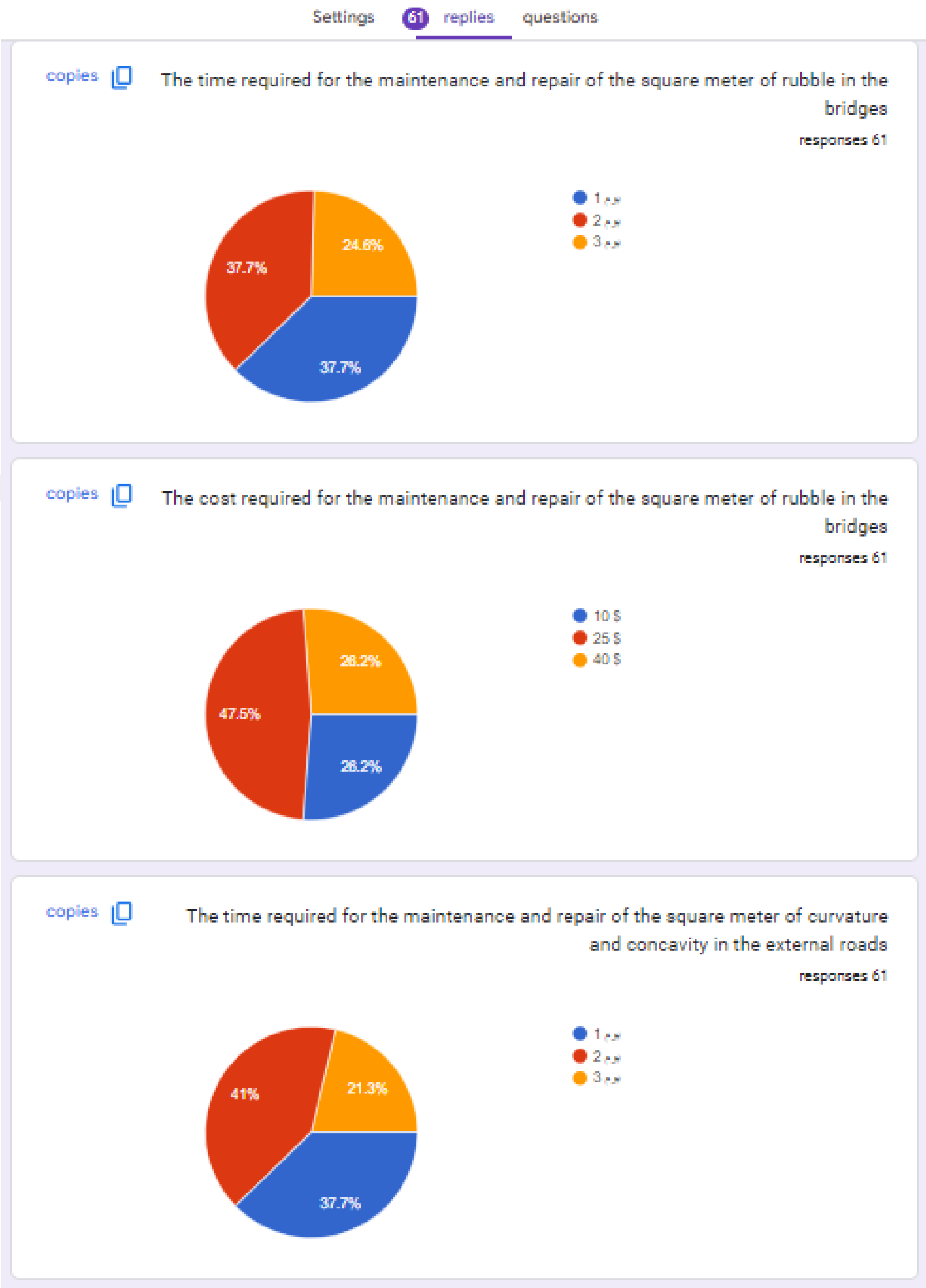

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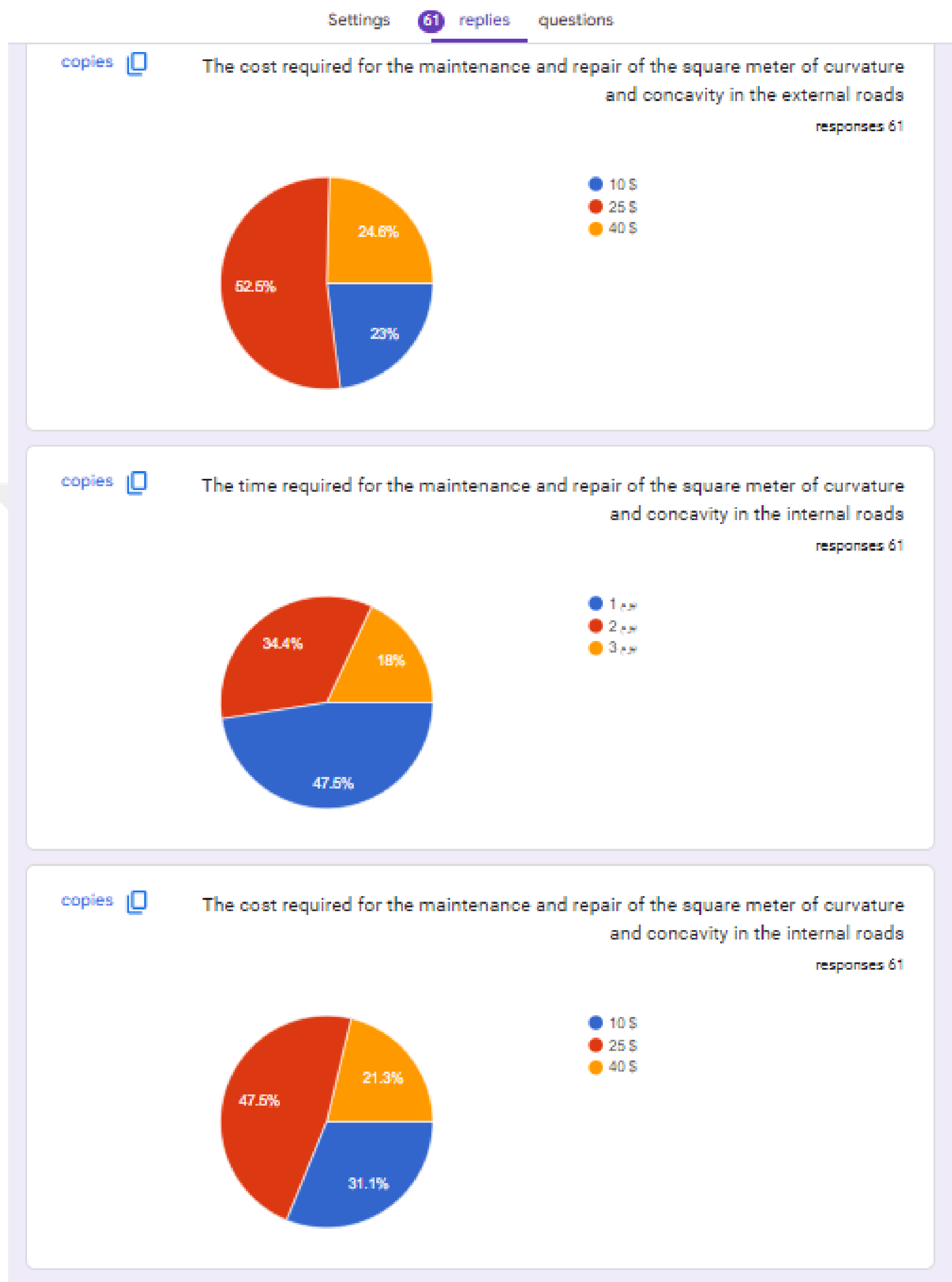

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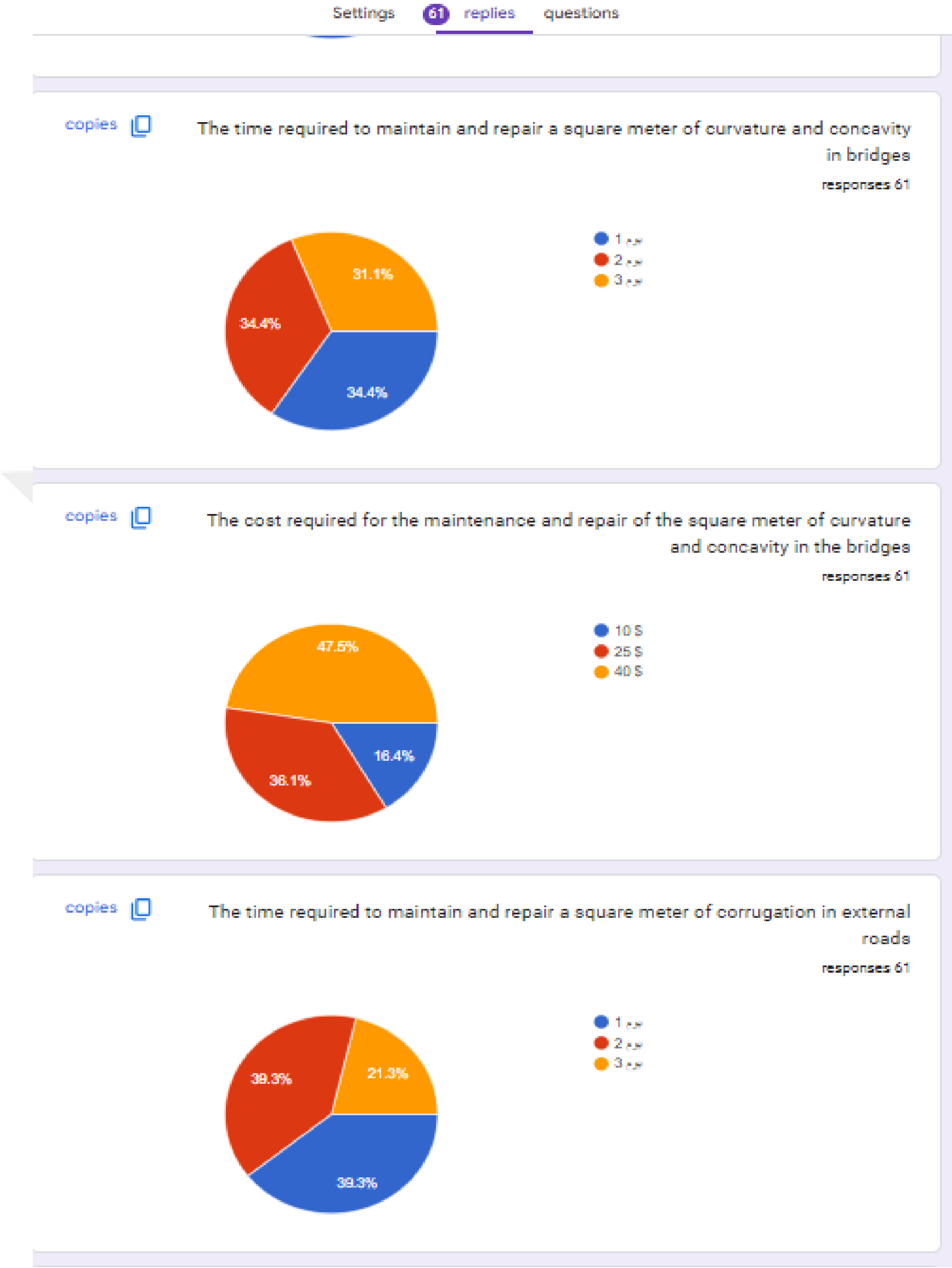

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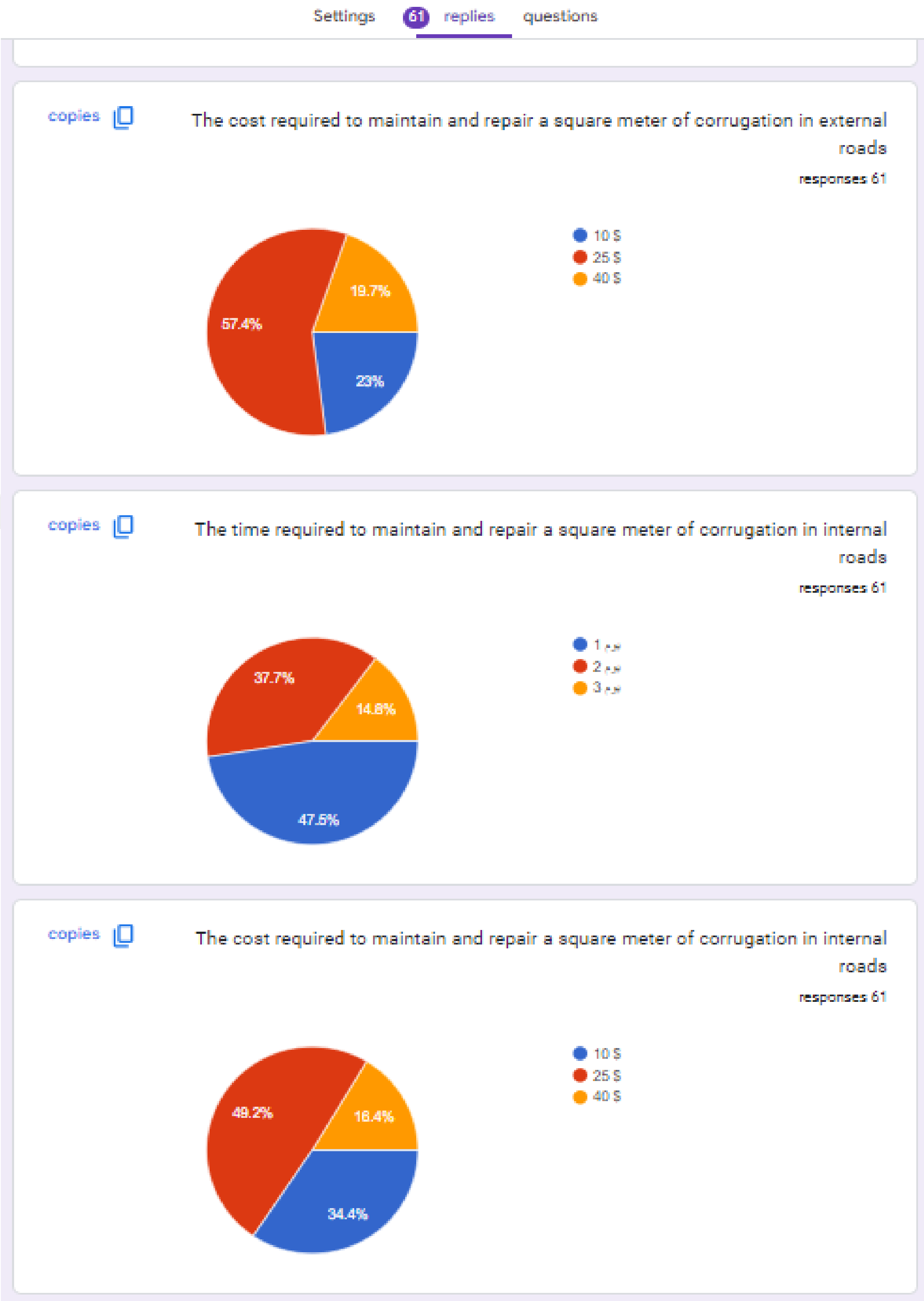

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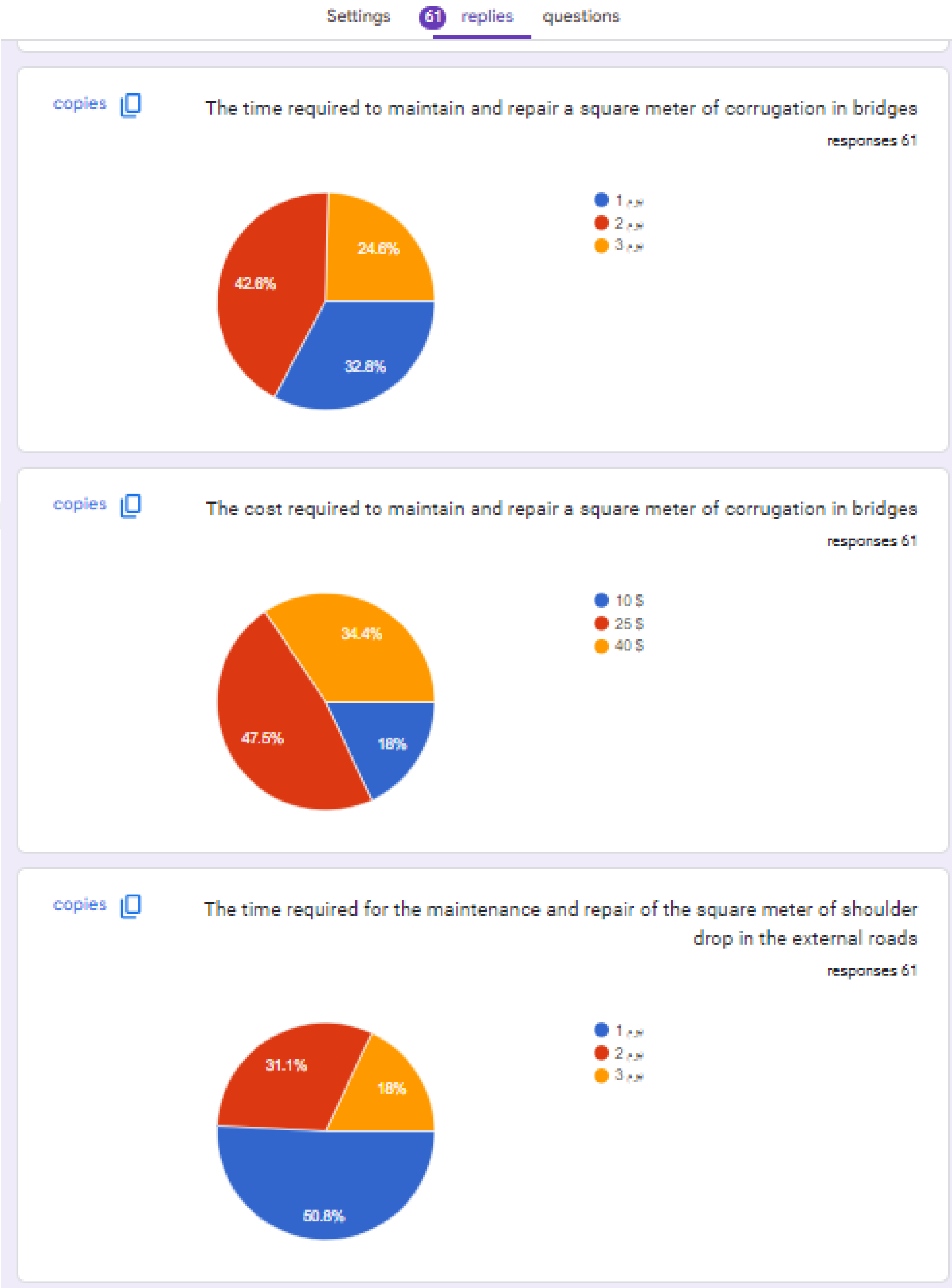

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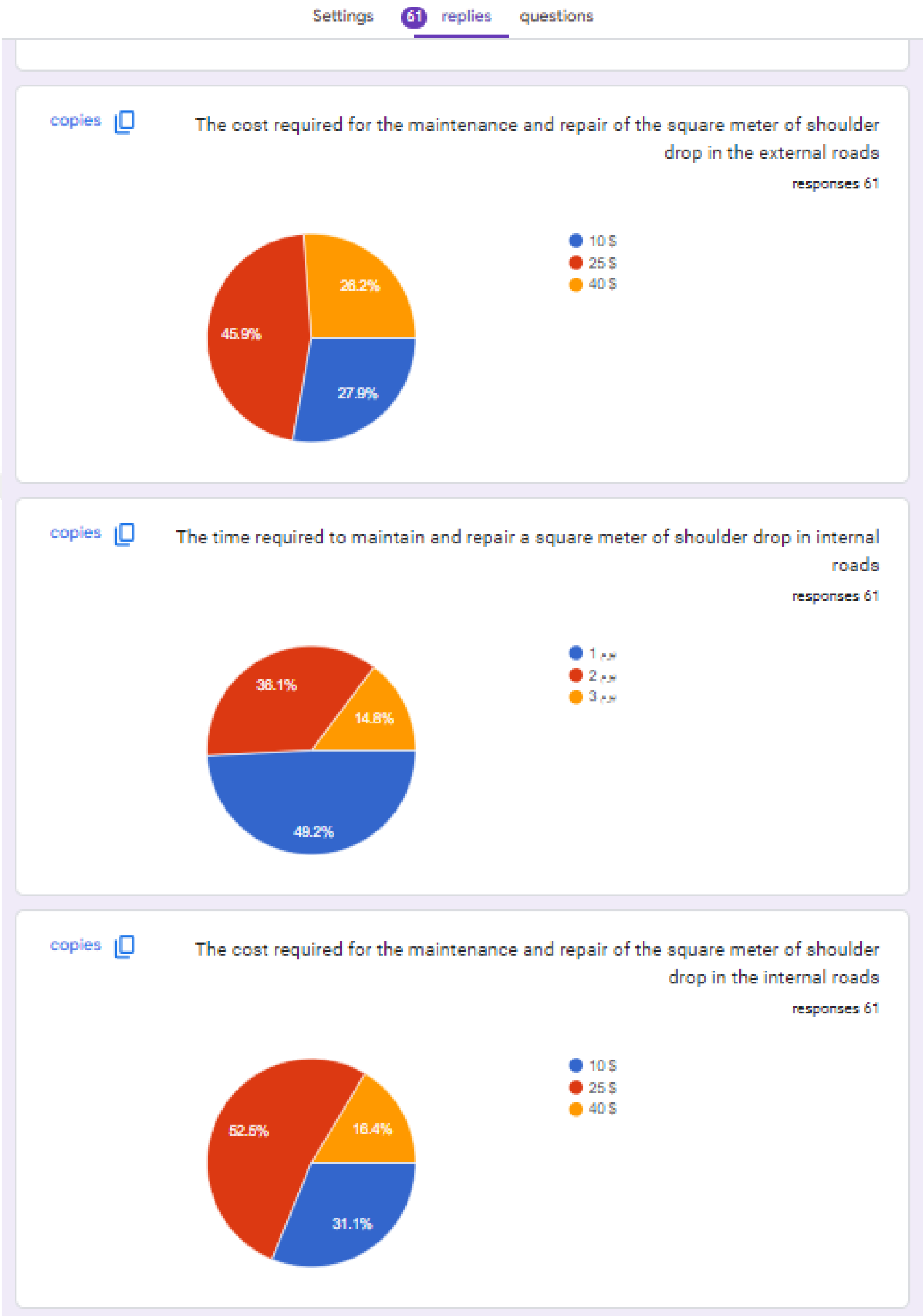

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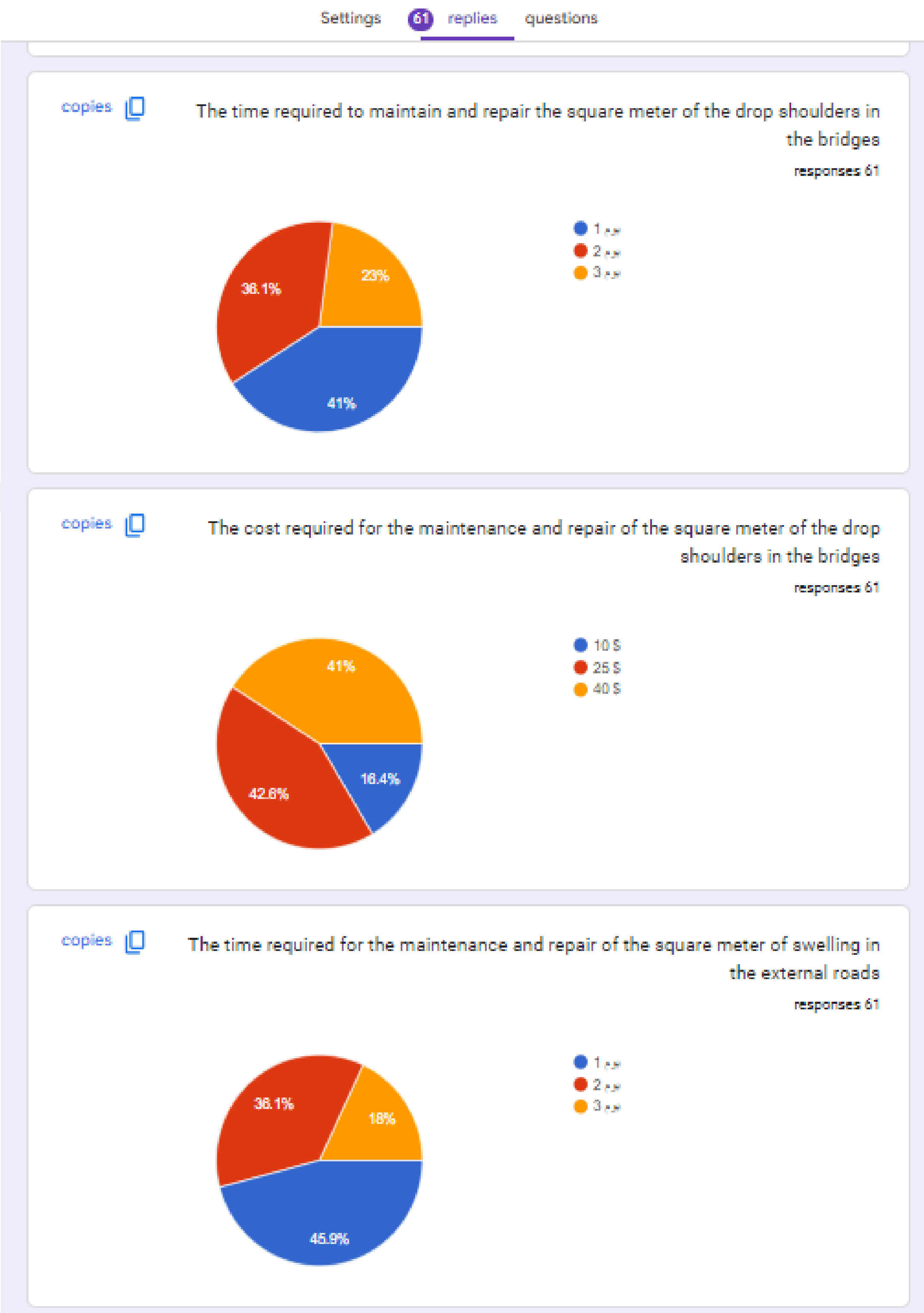

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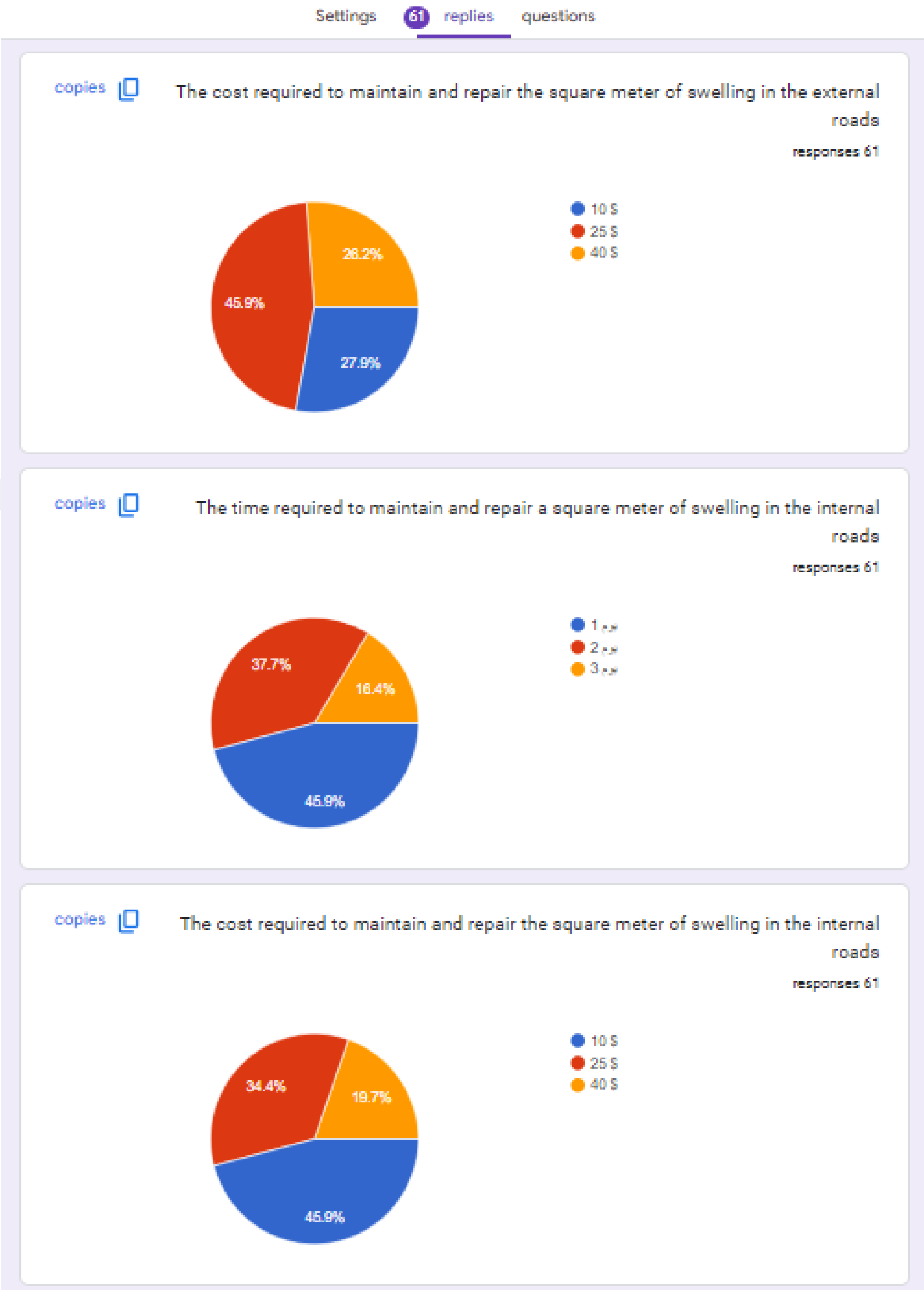

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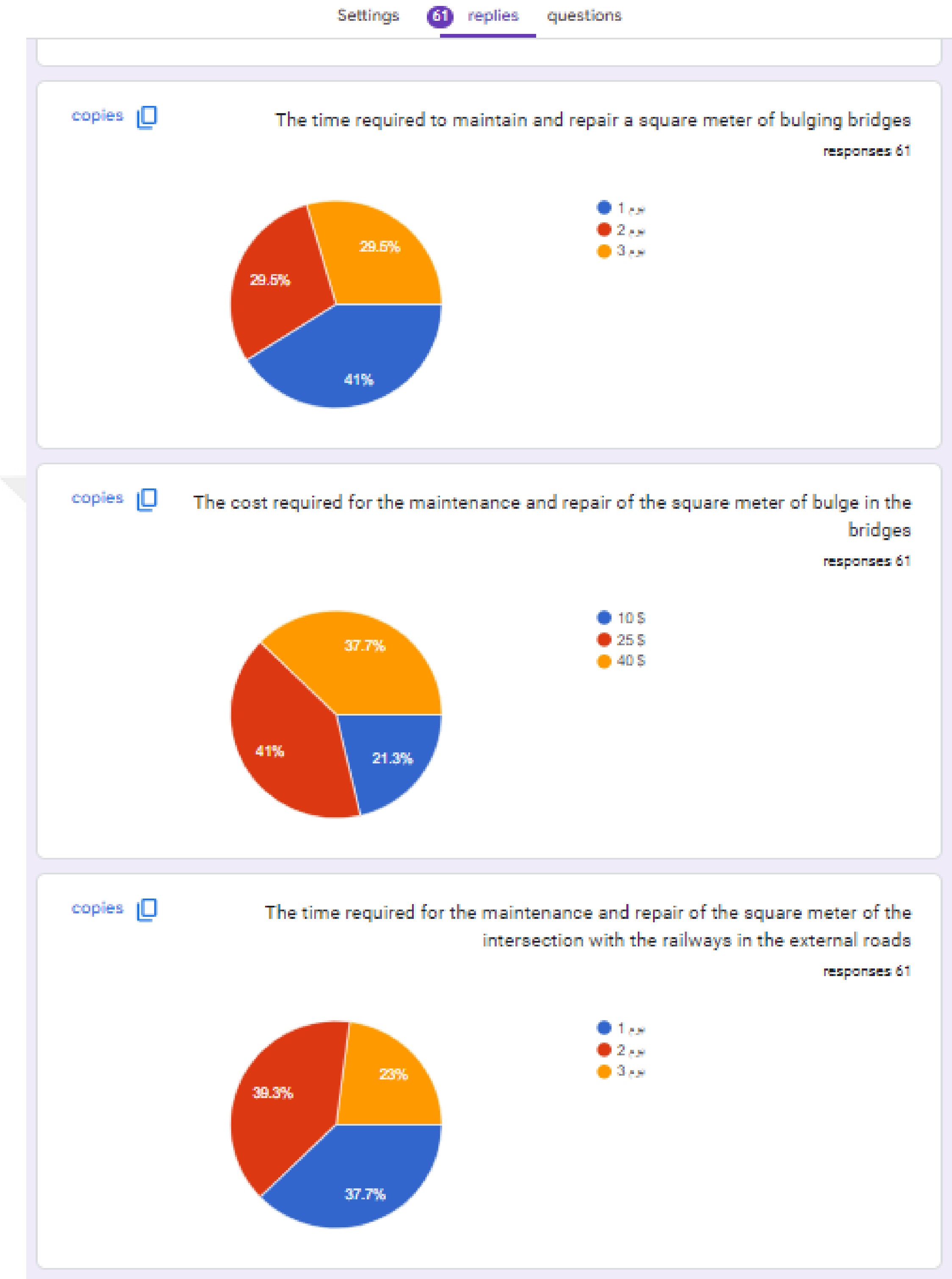

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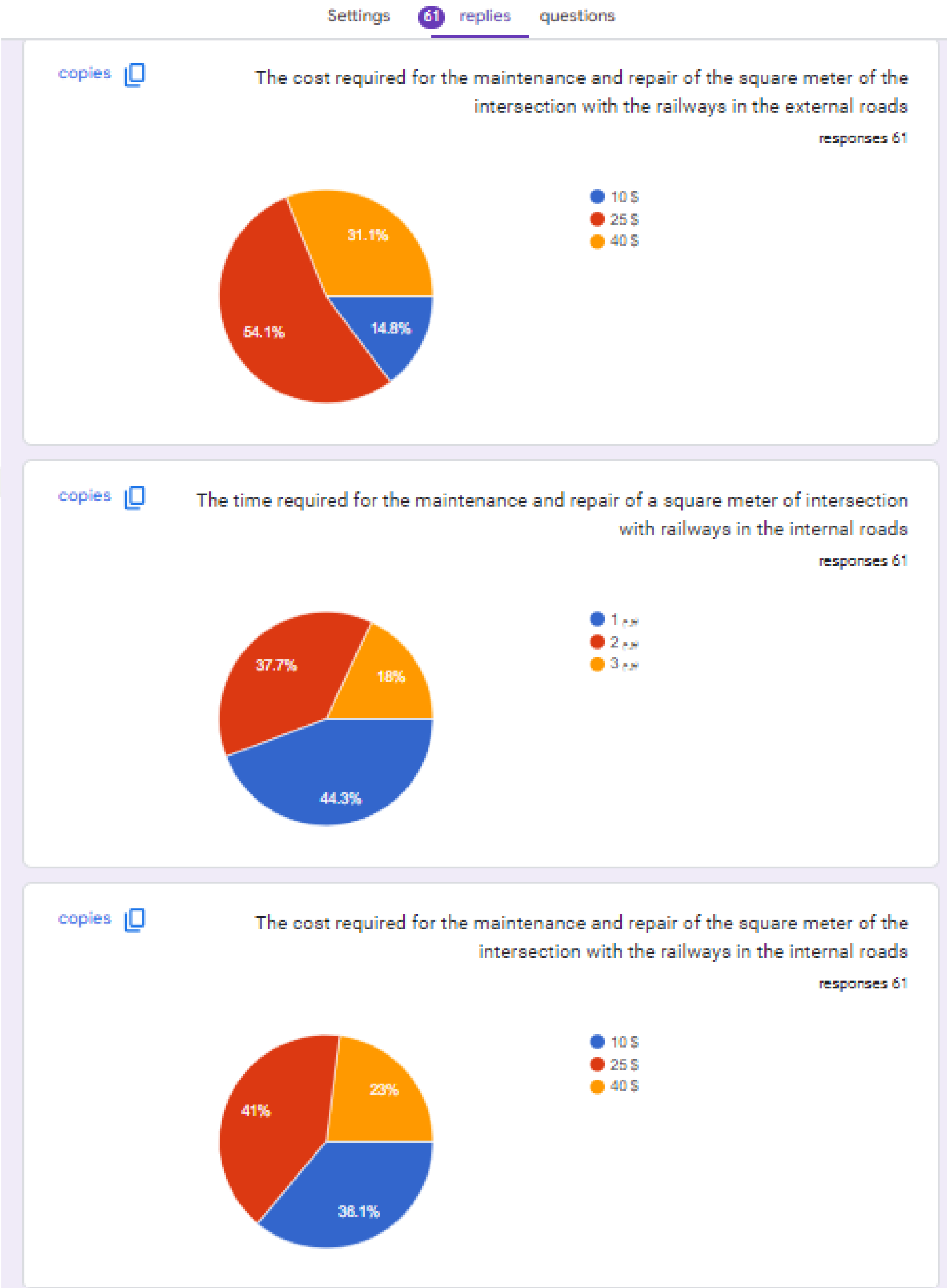

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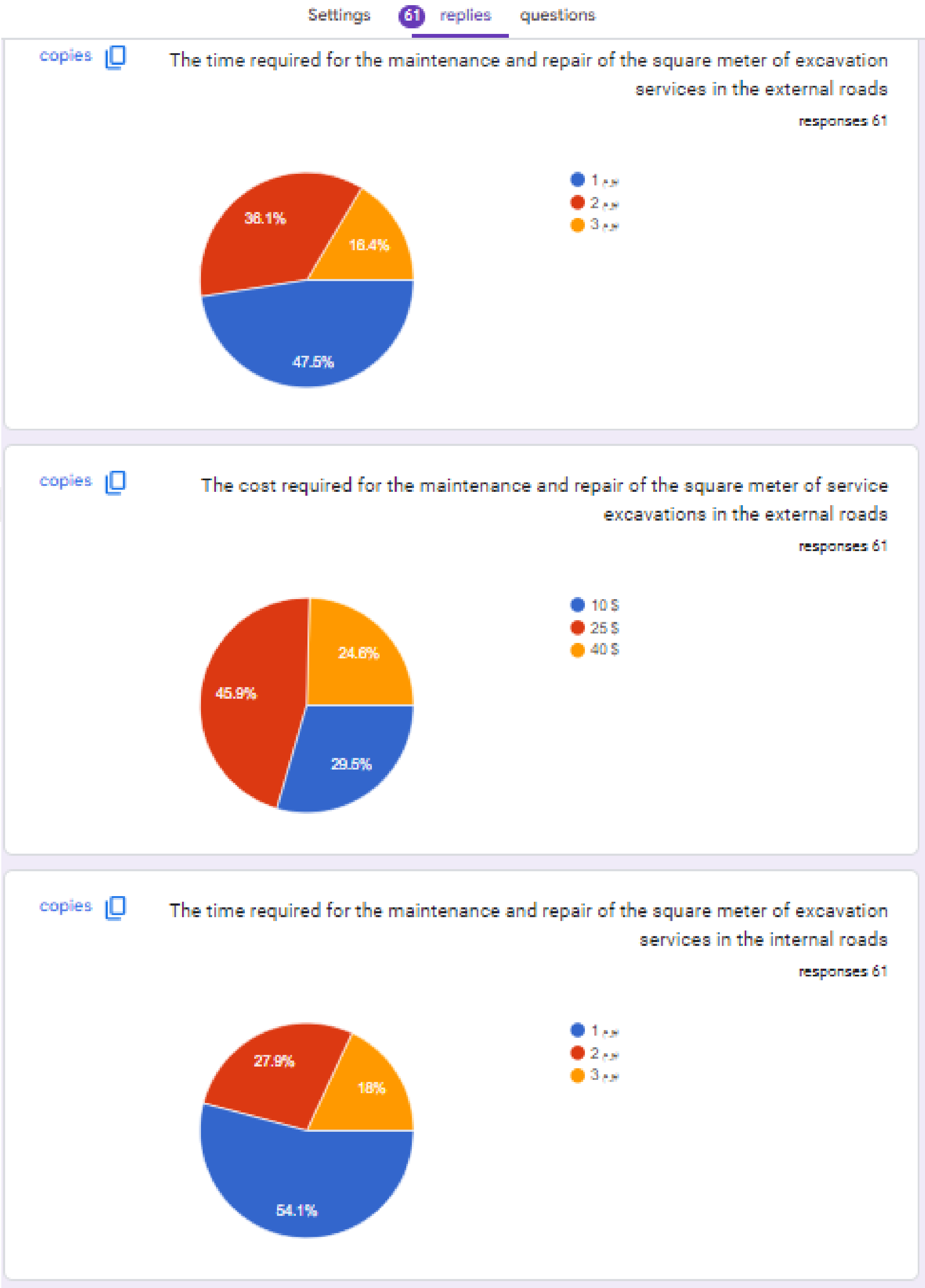

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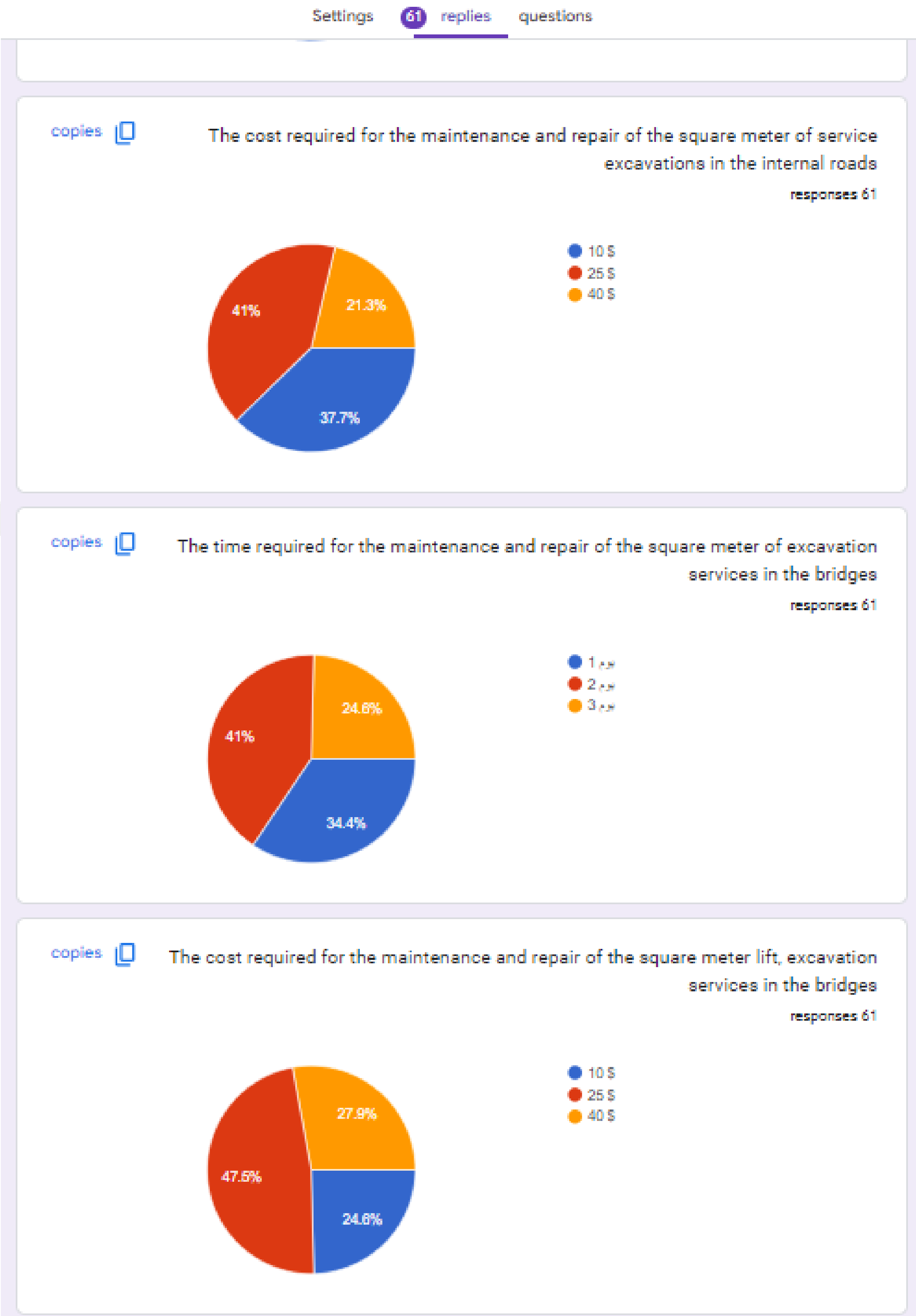

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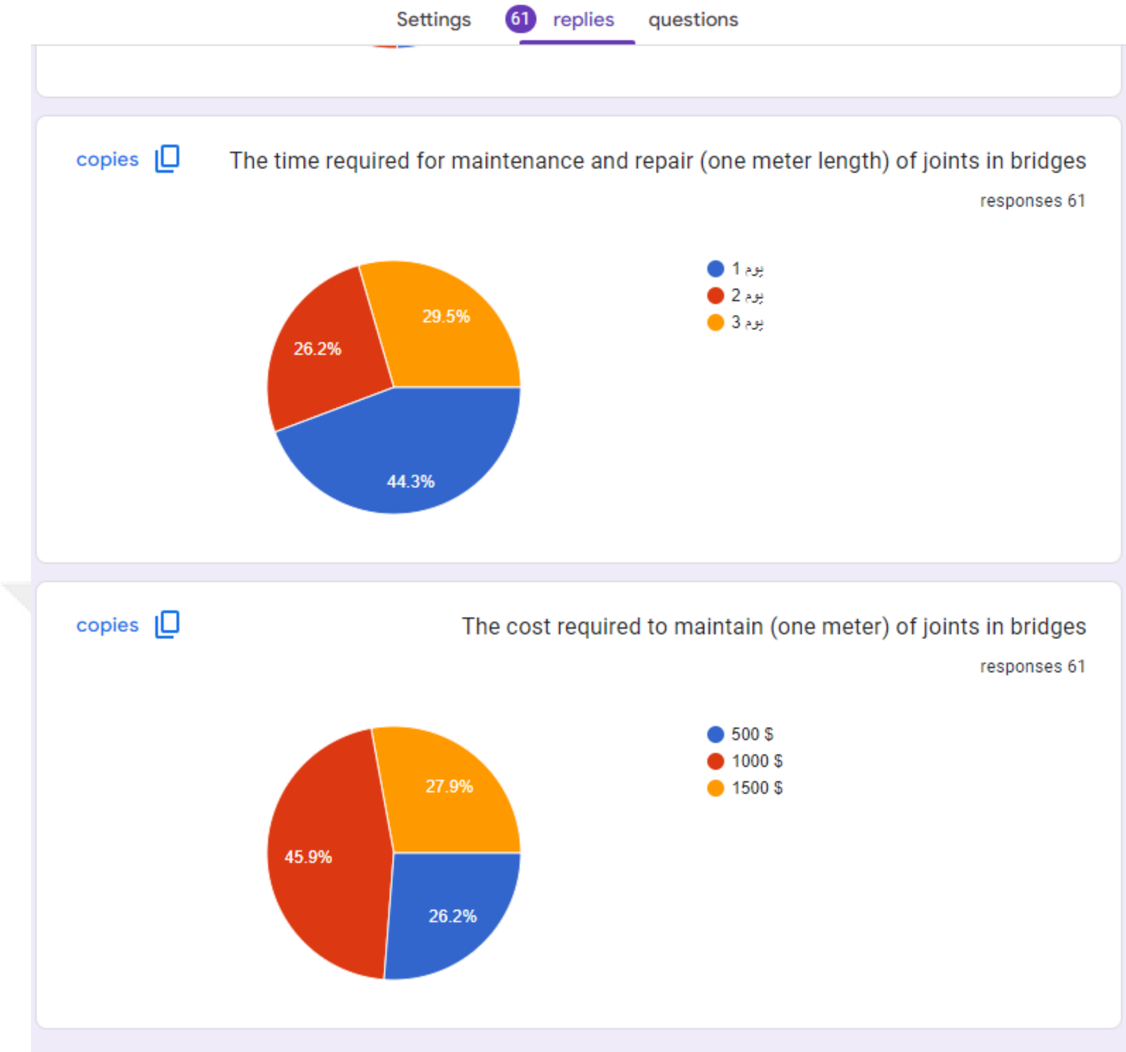

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RESUME

Qutaiba Al-AZZAWI

EDUCATION:

- High School: 2014 graduated from AL-salaam High School
- Bachelor: 2019 graduated from Tikrit University, Faculty of Engineering, Civil Engineering Department.

PROFESSIONAL EXPERIENCE AND REWARDS:

- Executive Engineer White Sea (2019-2020). a project to remove the rubble and build a health clinic in Yathrib district/ Saladin /Iraq (10/2019 to6/2020).
- Executive Engineer in Al-Rafad company contracted with UNDP. renovation project of al sabah primary school in Yathrib district / Saladin /Iraq (6/2020 to 9/2020).
- Field Monitor Stars Orbit Co. contracted with UNDP (2020-2021) the project to clean up the liberated areas and remove the rubble in yathrib district - Saladin - Iraq.
- Project Manager in Al fares Co. of Tilal Shaqlawa residential complex in the city of Tikrit – Saladin – Iraq which consists of 250 housing units (2021).

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