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Developing Key Performance Indicators for Buildings Maintenance Management

A Thesis Submitted to the Council of the College of Engineering University of Diyala in Partial Fulfillment of the Requirements for the Degree of Master of Science in Engineering

By

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بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ

﴿ قَالُواْ سُبْحَٰنَكَ لَا عِلْمَ لَنَآ إِلَّا مَا عَلَّمْتَنَآ ۖ إِنَّكَ أَنتَ ٱلْعَلِيمُ ٱلْحَكِيمُ ﴾

صدق الله العظيم

سورة البقرة

اية-32

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We certify that the thesis entitled **"Developing Key Performance Indicators for Buildings Maintenance Management"** presented by **"Suror Hameed Ramadan"** was prepared under our supervision in the Civil Engineering Department, The University of Diyala, in partial fulfillment of the Requirement for the Degree of Master of Science in Civil Engineering.

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SCIENTIFIC AMENDMENT

I certify that this thesis entitled **"Developing Key Performance Indicators for Buildings Maintenance Management"** presented by **"Suror Hameed Ramadan"** has been evaluated scientifically, therefore, it is suitable for debate by the examining committee.

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We certify that we have read the thesis titled **(Developing Key Performance Indicators for Buildings Maintenance Management)** and we have examined the student **(Suror Hameed Ramadan)** in its content and what is related to it, and in our opinion, it is adequate as a thesis for the degree in Master of Science in Civil Engineering.

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DEDICATION

To my role model in life and the symbol of struggle, patience, and success (my beloved father).

To the light of my eyes... and the source of kindness and tenderness, to the most wonderful woman in existence (my beloved mother).

To my brothers and sisters and everyone who supported me even with a word.

I dedicated this work, hoping that they will always be proud of me.

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ABSTRACT

Developing Key Performance Indicators for Buildings Maintenance Management

By

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Supervised by: **Co- supervisor:**

Asst. Prof. Ali Hussein Hameed **Prof. Dr. Waleed Mustafa Khammas**

Maintenance management key performance indicators (KPIs) are essential for many construction projects. Structural buildings, public government buildings, need a regular Assessment of maintenance performance, which contributes to the success of the organization through continuous improvement of performance. As a result, performance indicators among the ways to evaluate the success of organizational performance and to demonstrate the organization's effectiveness in achieving its goals through its strategy. The purpose of this research is to identify an appropriate set of key performance indicators for maintenance management in construction projects.

A preliminary questionnaire was prepared, and it was distributed to a group of engineers, specialists, and experts in various governmental departments, to assess the state of maintenance performance in construction projects. The results showed that there is no periodic follow-up of the building’s condition, as well as the absence of professional development of employees and their training through a training course, in addition to the lack of consideration during the design and construction phase of how maintenance is performed.

According to the reality of maintenance performance, a second questionnaire was prepared to know and identify the main performance indicators for maintenance. Then the questionnaire was distributed to

experienced engineers in a number of public buildings. Next, the relative importance indicator method was used to find weights for each perspective and its indicators. The questionnaire analysis obtained (16) key performance indicators for the maintenance of buildings divided into four views, financial, customers, learning and growth, and internal business. The results indicate that the measurement of the performance of buildings is not only dependent on financial indicators. On this basis, it is recommended to use financial and non-financial indicators of building as a key factor for measurement and continuous improvement.

Finally, to obtain more accurate and realistic data, the final list of indicators was applied in case studies that included (5) maintenance projects for government buildings. Through the analysis of the results of the case studies, it became clear that despite the importance of these indicators, there was a significant weakness in the application of these indicators in the construction projects. Weights were calculated for the extent of the indicators' importance as well as the extent of the indicators' application. These indicators were the basis for developing a computer system for maintenance management using indicators. Through the proposed system, it was possible to develop the reality of maintenance performance in construction projects.

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List of Abbreviations and Symbols

The Abbreviations	Description
BPE	Building Performance Assessment
BSC	Balanced Scorecard
CSFs	Critical Success Factors
EFQM	European Foundation for Quality Management
IEQ	Indoor Environmental Quality
KPIs	Key Performance Indicators
MPIs	Maintenance Performance Indicators
MPM	Maintenance Performance Measurement
PIs	Performance Indicators
PM	Performance Measurement
PMI	Performance Measurement Importance
RII	Relative Importance Index
SPSS	Statistical Package for Social Sciences
S.D	Standard Deviation
ACD	Age Coefficient
DC	Density Coefficient
AME	Annual Maintenance Expenditure
MSR	Maintenance Sources Ratio
MEI	Maintenance Efficiency Indicator
MSC	Managerial Span of Control

Chapter One

Introduction

1.1 Background

Building maintenance is a vital program for developing infrastructure long-term survival. Buildings have traditionally been regarded as one of a country's most significant assets, providing people with homes, workplace comforts, and leisure activities. Building maintenance becomes more important as time passes in terms of preserving a structure's worth and condition. Therefore, the maintenance of buildings plays an integral role in the design and construction process of buildings. Moreover, building maintenance personnel should be concerned about building maintenance achievement performance in order to sustain building performance that contributes to the business as well as its image (Amaratunga and Baldry, 2002). The effectiveness of building maintenance management and government asset management is a critical aspect in ensuring that all government entities are operating in the public interest (Adenuga, 2012). Building performance can be a good indicator of how well a building is maintained in all aspects of its operation and maintenance. (Lee, H. et al., 2008).

Because the concept of performance is significant in business management, interest in it is growing by the day. Performance is also the most significant factor in an organization's long-term viability. Given the importance of indicators from the financial (economic) and non-financial aspects of internal business, as well as environmental, learning and growth

aspects, a methodology that includes several ways to measure performance, such as the balanced scorecard methodology, is required. When reviewing performance, shareholders, customers, internal procedures, learning, and growth are all taken into account. Failure to apply maintenance indicators on construction projects, on the other hand, has resulted in a decrease in performance. If these indicators are present, organizations will be encouraged to enhance their performance.

1.2 Research Justification

There are a number of reasons that contributed to the creation of this study, including the following:

1. Poor performance of workers to carry out the maintenance work.
2. Measuring the performance of maintenance in Iraq is still regarded ordinary job that receives no attention from the top management of the organizations, in addition to the lack of a developed system for evaluating performance.
3. The lack of planning to manage the financial resources provided for building maintenance, therefore financial resource management must be carefully planned to meet the desired purpose and invested for building maintenance as assigned.
4. The reliance on traditional methods for measuring maintenance performance, such as relying only on financial indicators without looking at the rest of the indicators.

1.3 Research Aims and Objectives

This research aims to (develop key performance indicators for maintenance management in construction projects).

The objectives are as follows:

1. Knowing and evaluating the status of maintenance performance in construction projects, detecting defects, and attempting to correct them.
2. Identifying a set of maintenance key performance indicators capable of diagnosing, evaluating, and treating problems to make them work to achieve their goals.
3. Developing a computer system for maintenance management using key performance indicators.

1.4 Limitations and Scope of the Research

1. The research focused mainly on the key performance indicators and finding the importance of these indicators in the construction projects
2. Case study: Within the borders of Diyala Governorate
3. Temporal limitations: Limited-time period (2021-2022).

1.5 Research Methodology

The methodology includes several steps, as shown in fig (1-1):

1- According to previous studies on the scope of the study, including book and, journals, websites, and thesis, a questionnaire was prepared to evaluate the status of maintenance performance in construction projects and set the final touches on it after the judgment of the supervisor and the expert.

2- The questionnaire was then distributed to a group of engineers with experience of no less than five years, in various disciplines related to building

maintenance in construction projects, and working in different departments in Iraq, in addition to academic professors in engineering disciplines.

3- From the data obtained from the literature review, after assessing the status of maintenance performance, a set of indicators were recommended, and then another questionnaire was prepared to find the key performance indicators of high importance according to the average data collection.

4- The relative importance index was applied to find the relative weight of each indicators.

5- The results were then applied to case studies to obtain more accurate and realistic data.

6- Finally, a computer system was designed for maintenance management using key performance indicators.

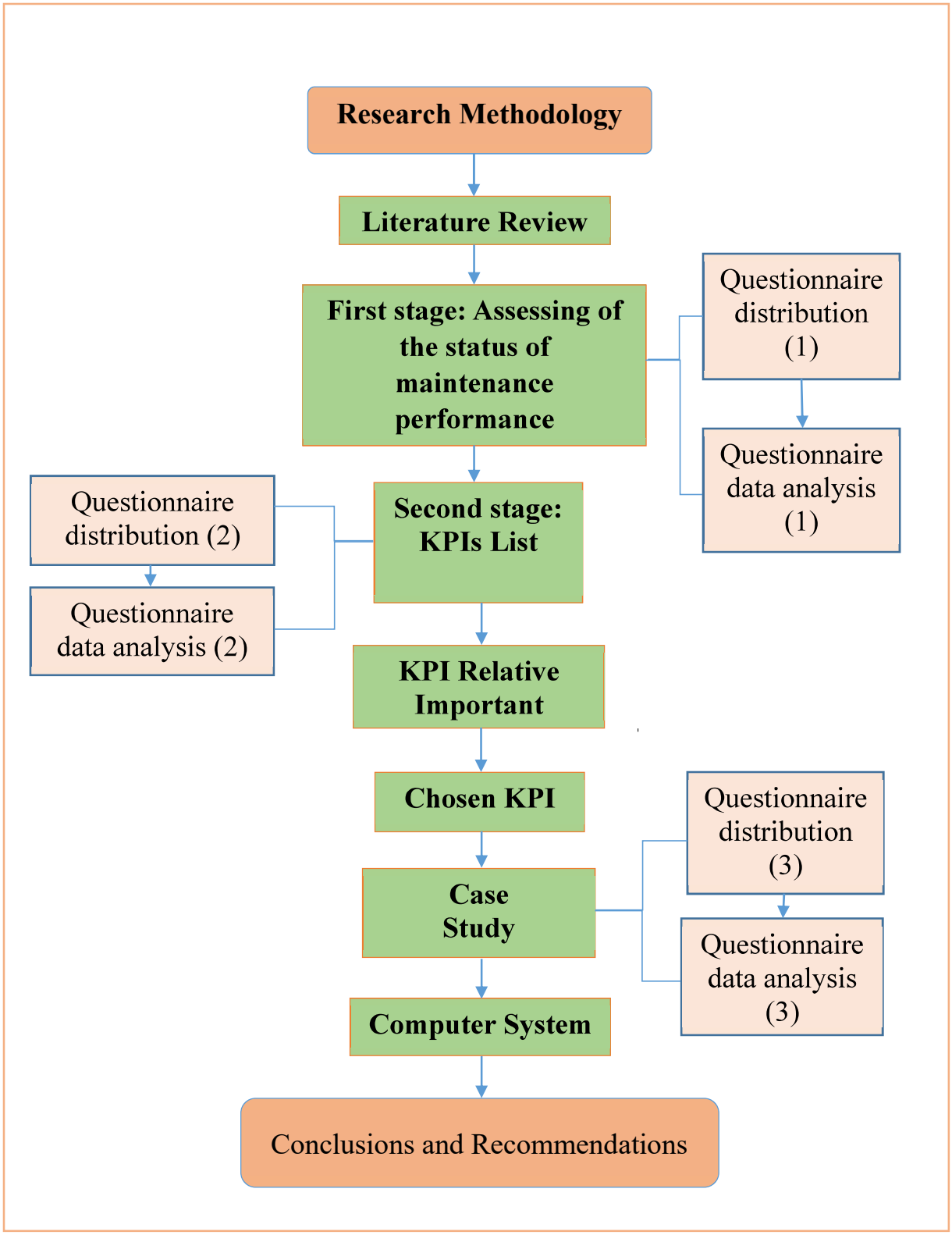

Figure (1-1): Flow chart of Research Methodology

1.6 Research Structure

The chapters of thesis are divided into five chapters, and these chapters are:

1-Chapter One: It is an introductory chapter that includes a background to the research, research justifications, research objectives, study limitations, research methodology, and some previous studies that focus on the key performance indicators for maintenance.

2-Chapter Two: This chapter presents a set of definitions of maintenance, its types, objectives, and maintenance management. In addition to measuring performance in general and measuring maintenance performance in particular, the chapter mentions also definitions related to performance. In addition indicators classification.

3-Chapter Three: It includes data collection, questionnaire design and distribution, questionnaire analysis using the statistical program (IBM SPSS-V21), Assessment of the maintenance performance status in government buildings, identification of key performance indicators, and finding their weight using the relative importance index, and analyzing case studies to determine importance of the main performance indicators for measuring maintenance performance, also applicability of these indicators in construction projects.

4-Chapter Four: This chapter describes the development of a computer program for maintenance management using key performance indicators to solve problems.

5-Chapter Five: This chapter includes the most important conclusions of the research and recommendations to improve maintenance performance.

1.7 Previous Studies

A group of previous studies that are similar to the current study, either in terms of the study's objective or the methodologies used, were mentioned to compare them with the current study, as shown in Table (1-1).

Table 1-1: Previous Studies

No	Author	Title/Study/ Result/Indicators
1	Jawad, Z. A. (2021). In Baghdad	**Title:** A Conceptual Approach for Buildings Maintenance Performance by Using Stakeholder Theory. **Study:** The goal of this study is to determine the reality of maintenance performed in the government building projects, find flaws and try to fix them, and identify the variables and criteria that influence the success of building maintenance performance measurement. It also intends to establish a conceptual approach that leads to the construction of a computer program to measure the performance of government building maintenance (public) using one of the stakeholders' theories and methodologies (balanced and triple scorecard). **Result:** According to the findings, the most important factors influencing the measurement of maintenance performance are the project manager's competencies, correct and frequent communication with

		stakeholders, the existence of a strategy for dealing with stakeholders, the age and quality of construction, the quality of work, and its environmental impact, and financial performance. **Indicators:** The performance indicators are designed into three categories: (Economic Indicators, Social Indicators, and Environmental Indicators)
2	Tofan, 2019) in Baghdad.	**Title:** Development of Blueprint Key Performance Indicators for Construction Companies in Iraq (Public Sector Companies as a Case Study). **Study:** The study's main goal is to find a set of key performance indicators. In addition, the study has other secondary objectives, including discovering and assessing the reality of performance measurement in public construction contracting companies, as well as the reasons for their failure and inability to achieve their strategic objectives despite financial and moral support from the public sector. **Result:** The findings show that financial measures are not the only way to gauge a construction company's performance. Construction companies should employ financial and non-financial metrics as a key factor for performance measurement and continuous improvement in this basic. Profitability, Cash flow,

		completion of work within a budget, business efficiency, effectiveness of planning, safety, quality control, quality of service and work, external customer satisfaction, internal customer satisfaction, motivation **Indicators:** The performance indicators are designed into five categories: 1-Financial indicators (Profitability, Financial stability, Completion within Budget,) 2-Customer indicators (Quality of service and work Competitive price, External customer satisfaction, Internal customer satisfaction) 3-Social and Environmental indicators (Policy or law of government, Risk control, Competitors) 4-Internal business indicators (Business efficiency, Meeting technical specifications, Effectiveness of planning, Safety, Quality control and rework) 5-Learning and Growth Indicators (Company's reputation, Continuous improvement, Motivation, Human resource training).
3	Shohte & Nobili, (2017) in the Zionist entity	**Title:** Application of Key Performance Indicators for Maintenance Management of Clinics Facilities. **Study:** The objective of this study is to the implementation of previously defined key performance indicators (KPIs) in a 42 clinic sample to

		assess facility maintenance performance, intra- and inter- benchmark the performance and efficiency, establish a policy for the strategic and tactical maintenance management, and set priorities in the maintenance plan. **Result:** The results showed that when the KPIs were applied to a sample of clinics, it was discovered that only 55% of them were operating at the intended level of efficiency and level that low performance was associated with both poor maintenance management and low overall performance of building system. **Indictors:** Age coefficient (ACD) of building, Density coefficient (DCy) of the clinic's patients, Building performance indicator (BPI), Annual maintenance expenditure (AMEy), Maintenance sources ratio (MSR), Maintenance efficiency indicator (MEI), Managerial span of control (MSC).
4	Omer, M. & Ibrahim, F. & Omer, W. (2016), in Perlis, Malaysia.	**Title:** An Assessment of the Maintenance Management Effectiveness of Public Hospital Building Through Key Performance Indicators. **Study:** The purpose of this research is to identify key performance indicators (KPIs) in order to find the best maintenance management strategy.

		Result: The result shows that monitoring and supervision, work planning and scheduling, and a computerized maintenance management system (CMMS) are important factors, indicating that the maintenance manager is a key figure who is responsible for ensuring that maintenance services run smoothly. **Indicators:** This study suggests three primary components as indicators for the effectiveness of maintenance management for the public hospital building: 1-The Individual Factors (monitoring and supervision, task planning and scheduling, and computerized maintenance management system (CMMS)). 2-Maintenance Aspects (maintenance approach, spare pert management, and outsource strategy). 3-Administration and organization factors (human resources, financial and continuous improvement.)
5	Enshassi & EI Shorafa, (2015). In the Gaza strip.	**Title:** Key performance indicators for the maintenance of public hospital buildings in the Gaze Strip. **Study:** The development and Assessment of key performance indicators (KPIs) for Gaza's public hospital building maintenance is the aim of this study. **Result:** According to the results, the European Gaza

		hospital had the highest BPI score (81.66), while the Dorra hospital received the lowest (68.26). According to the statistics, the average AME for all hospitals was $13.8/m2, which is regarded to be below the industry standard. The MEI for a public hospital building in Gaza was determined to be 0.3, indicating a low level of maintenance spending. **Indicators:** Building performance indicators (BPI), maintenance efficiency indicators (MEI), annual maintenance expenditure (AME), and an urgent repair request indicator.
6	Goncalves & Dias & Machado, (2015). In Portugal	**Title:** Multi-Criteria Decision Methodology for Selecting Maintenance Key Performance Indicators. **Study:** This study proposes a novel methodology for picking relevant maintenance KPIs based on the original ELECTREI, a multi-criteria decision-making process. The proposed methodology, which incorporates the decision marker preferences, generates a ranking of feasible options after evaluating them against key criteria **Result:** The finding demonstrates that this methodology is a useful tool for assisting maintenance managers in performing appropriate KPIs selection tacks based on maintenance goals and strategies. The

		proposed technique clarifies, rationalizes, and streamlines the decision-making process. **Indicators:** Average response time to emergency calls (incidents), Average time to replacement of functionality, Availability related to maintenance, Availability due to planned and scheduled maintenance, Maintenance quality index, Maintenance performance index, Rate of planned work (planning intensity), Quality of planning.
7	Yahya & Ibrahim, (2012) in Malaysia	**Title:** Building Maintenance Achievement in High Rise Commercial Building: A study in Klang Valley, Malaysia. **Study:** The purpose of this research is to create a maintenance achievement index (MAI) to compare the performance of building maintenance across a variety of key performance indicators (KPIs). Eleven high-rise office buildings in Malaysia's Klang Vallery were investigated at random. **Result:** According to the study's findings, building maintenance practitioners believe that quality, safety, time, cost, functionality, and friendliness can be used as key performance indicators (KPIs) for building maintenance activities.

		Indicators: Quality, Safety, Time, Cost, Functionality, Environmental, Friendliness.

Current Study: As explained above, there are many researchers in different countries who studied the key performance indicators and touched on the most important quantitative and qualitative indicators for improving performance. The lack of research to clarify the most important key performance indicators for building maintenance in Iraq.

This study aims to identify a set of key performance indicators (qualitative indicators) for maintenance management in construction projects in order to increase the effectiveness of the organization in achieving its goals.