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QFD & SCORECARD ANALYSIS IN PAVEMENT MANAGEMENT

BY

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ABSTRACT

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Title: QFD & SCORECARD ANALYSIS IN PAVEMENT MANAGEMENT

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Pavement management is a set of tools used to evaluate and maintain pavements so it can be used safely over a certain period of time. Many traditional methods were and are still being used by entities related to pavement management in order to increase efficiency of management in decision-making and in coordinating the different activities that have direct impact on pavement system. There were no exact method focusing on analyzing the different pavement perspectives in order to prioritize objectives based on pavement financial goals. Lately, most of pavement management entities are driven by optimization models that allows optimization of single objective. The aim of this thesis is to provide the pavement management sector with a new methodology in order to prioritize the various pavement perspectives goals based on the prioritization of the financial perspective goals, which will lead to optimization of multiple goals based on their priorities. The scorecard and the quality function deployment: were adopted and modified in order to fit the subject and main goal of the thesis. Implementation of pavement goals based on their priority related to financial goals will help in achieving the ultimate goal of understanding the requirements and allocate the required funds for the top priority objectives.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

1.1 Background

With the rise in the modern consumerism there is an ever increase demand in the proper products which could satisfy the needs of the customers to as much as possible and at the same time it is also important that the companies remain profitable and it is only possible when the company addresses the key financial perspectives that are related to the project. In the case of the pavement management project, this becomes more important. In this respect, QFD (Quality Function Deployment) and balanced score tools are the important tools which can help the pavement management companies to address the issues faced by the public and also incorporate the financial perspective so that the company remain profitable (Akao, 2004). QFD is a method which is mostly used by the engineers so that the consumer's demands and quality features could be incorporated into the design of the product. On the other hand, the Balanced Score Card (BSC) tool is a process which helps to translate the objectives of the company into the various measures for the performance and also helps to develop a framework which could further provide direction to the strategic mission of the organization. The balanced score tool is used for measuring the financial perspective of the project. There are four key perspectives used in the balanced scorecard tool which is related to the main financial perspective; firstly, in the manner in which the company will present the project to the stakeholders, secondly, how the company should be able to address the demands of the customers, thirdly what internal processes that the company must excel are and fourthly the manner in which the organizations can learn and develop. In the case of the QFD approach it is divided into the multiple numerical analyses (Hunt and Killen, 2004). Through the QFD, it would be possible for the researchers to design the system in a systematic approach which is in turn based on the close awareness of the desires of the customers, coupled with the integration of the corporate functional groups. The main aim of the QFD is to translate the most subjective criteria into the objective ones which could be easily quantified and measured and they could be used for the designing and the manufacturing of the products. This is a complementary process which is helpful in determining how and where the priorities of the product have to be assigned for the development of the product (Lal, 2008). The main intent of utilizing this process is to employ the objective procedures in increasing the detail throughout the product development.

There are three main goals for which the QFD approach is generally used for a project; prioritizing the spoken or the unspoken needs and wants of the customers, translating the needs into the technical characteristics and specifications and building and delivering a quality product or the service through focusing the on the needs of all kinds of customer's satisfaction.

The aim of this thesis is to provide the pavement management sector with a new methodology in order to prioritize the various pavement perspectives goals based on the prioritization of the financial perspective goals that will lead to optimization of multiple goals based on their priorities. The scorecard and the quality function deployment were adopted and modified in order to fit with the subject and main goal of the thesis. Implementation of pavement goals based on their priority related to financial goals will help in achieving the ultimate goal of understanding the requirements and allocate the required funds for the top priority objectives.

1.2 Research Objectives

The main research objectives for this research study are illustrated as follows:

- To integrate the application of the QFD in the pavement management
- To integrate the application of the balanced score card tools in the pavement management.
- To identify the priorities of pavement management.
- To identify the financial perspective of the organizations indulged in the pavement management projects.
- To identify the important factors by integrating the QFD and balanced score tools to address the financial perspective.

1.3 Research Significance

The main significance of this research study is that with the increase in the consumerism in the 21st century it has become important for the organizations to come out with new solutions which can help to address the issues of the consumers as properly as possible. This could be possible only when the multiple tools are incorporated into a single system. In the case of the pavement management it becomes more important to address the benefits to the public as they will utilize the system but at the same time, the organization has to keep a look on the financial perspective of the project so that the project is financially feasible. Hence this study proposes the application of the pavement management utilizing the quality function deployment and the balanced scorecard

tools.

1.4 Research Methodology

The research methodology that was utilized by the researcher for this study has been highlighted below:

i) Stage 1: In the first stage of the research study, the aims and objectives of the research were identified.

ii) Stage 2: In the second stage of the research, study has identified the methods that must be followed by the researcher so that the research aims and objectives could be addressed.

iii) Stage 3: The third stage is related to the reviewing of the literature.

iv) Stage 4: The fourth stage of the research study is to do data collection through the survey method.

v) Stage 5: In the case of the fifth stage, the researcher has analyzed the data utilizing the statistical tools and found out the important factors which could help the researchers to understand the factors that make the application of the pavement management utilizing the QFD and the BSC.

vi) Stage 6: In the sixth stage, the main findings and conclusion of the research study were summarized.

1.5 Structure of the Research

This research study has been segmented into the following six chapters:

i) Chapter 1: The Chapter 1 will be the introduction chapter which will generally present the background of the research topic, the problem statement for the research study, the main significance for conducting the research study and brief information regarding the methodology that will be adopted by the researcher for conducting the research on the topic.

ii) Chapter 2: The Chapter 2 is related to the reviewing of the literature which is associated with the similar theme as that of the research topic. In the case of this research study, the research has analyzed several kinds of literature, journals, articles, research reports, conference proceedings and relevant websites related to the pavement management applications with the help of the QFD and the BSC.

iii) Chapter 3: The Chapter 3 is related to the research methodology, whereby the researcher has

provided a complete description of the different processes that has been followed by the researcher during the entire course of the research study so that the pre-determined aims and objectives of this study could be addressed in a proper manner.

iv) Chapter 4: The Chapter 4 is concerned with the data analysis whereby the researcher will utilize the different statistical tools to analyze the data which has been collected by the researcher.

v) Chapter 5: The Chapter 5 is the final chapter whereby the study will present the main findings of the data analysis and will discuss how the findings addressed the objectives of this research study. In this chapter, the researcher has also presented the future scope and recommendations for the future studies to carry out research on the similar theme.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction:

The literature review has been conducted in order to collect the information regarding the pavement management functions and tools, such as the quality development tools, which are generally used for the purpose of the pavement function in the local areas. The performance of the pavement is generally described through the change in their condition and the function of the pavements with respect to their age. It is important to analyze the performance of the pavement over a period of time as it will show the ability of the pavement to carry the intended traffic and also simultaneously satisfy the environment during the design life, both functionally and structurally (Bardeesi and Attallah, 2015). In order to ensure that the optimal outcome of the pavements of the construction organizations has to function optimally from an organizational perspective, this will ensure that the tools for the management of the pavement are utilized on an optimal basis. The balanced scorecard and quality deployment functions are tools that can be used to prioritize the activities in order to achieve the financial goals which will also, in turn, enable the optimization of multiple goals based on their priorities.

2.2 Pavement management:

With the rise in the economic and the development activities in Australia, it can be seen that there is a multifold rise in the traffic on roads in the last few decades. This has caused stress on the road network in the country. The development of higher stress leads to the failure of the pavements (Bardeesi and Attallah, 2015). In case the pavements fail to carry the design loads satisfactorily, then it can be said that the failure of the pavement is of structural type. Whereas in case the pavement is not able to provide a smooth riding surface, it can be stated that the failure of the pavement is of the functional type. The unevenness in the surface of the roads not only causes discomfort to the riders but it also significantly raises the vehicle operating cost (VOC) which then leads to a rise in the overall transportation cost (Creative Industries research institute, 2017).

The structural and the functional conditions of the pavement change with respect to time due to different effects, like that of the structural adequacy, volume, composition of the traffic, loading characteristics of the traffic, local environment, conditions in the surrounding and the maintenance that has been provided to the pavement over a duration of time. One of the major reasons that are

directed towards the failure of the pavement are traffic loads which are put on the pavement in an operational environment over a period of time and this is not an abrupt phenomenon (Dennis and Spulber, 2016). The deterioration of the pavement can be expressed in terms of the accumulation of the damage and the failure of the pavement has reached the limiting stage beyond which it cannot be serviced. It has been found that though the construction techniques of the pavements vary from location to location, the pattern of the failure of the pavement is almost the same.

Causes behind the failure of pavements:

There are different causes which lead to the deterioration of the pavements over a period of time. The main structural failures comprise of cracking, potholes, rutting along the wheel paths and the high roughness on the surface of the road. The internal damages such as cracking, rutting and potholes physically manifest themselves in the form of distress (Dennis and Spulber, 2016). There are different ways in which the distress could be classified, which are illustrated as follows:

i) Cracking due to fatigue: This can be caused due to the load related cracking, thermal; cracking, longitudinal cracking which happens at the edges due to the movement of the moisture and the cracking due to the deflections in the pavement structure over a period of time.

ii) Load related distortion of the pavement: This type of distress is of two types. One is the transverse distortion or rutting and the second one is the longitudinal distortions or roughness.

iii) Non-load related distortions in the pavement due to movement in the foundations.

iv) Distress that is caused due to the various disintegration factors like that of raveling, stripping, potholing etc. (KASAHARA, 2005).

Evaluation of the pavement performance:

In order to ensure that the roads are more durable, it is extremely important that the pavements and the materials that are used for the building of the pavements do the intended work under repetitive heavy loads. There is slow deterioration in the pavements in the initial years of the construction but as the construction reaches its last stages, the deterioration process increases. In the process of performance evaluations, there are studies conducted on different factors like that of the subgrade support, composition of the pavement, thickness of the pavement, loading of traffic and the conditions in the surrounding environment (KASAHARA, 2005). The evaluation of the pavement is generally classified as structural evaluation and the functional evaluation of the pavements. The evaluation of the pavement is generally comprised of four different areas of evaluation. These areas are the roughness of the pavement, the distresses in the pavement, the pavement deflection

and the resistance to skid.

Pavement condition survey:

As pavements age with time and their performance deteriorate gradually due to the environmental factors, traffic loadings and the various other factors. It becomes highly important that the resources that are used for the maintenance and repairing of the roads are managed effectively so that the money which is being spent on the maintenance is utilized at the right place at the right time. For this, it is important that the current location of the pavement network is identified and the rate of deterioration of the pavement (Luhr and Rydholm, 2015). The government agencies in Australia have found that by conducting regular pavement surveys it is possible to evaluate the conditions of the pavements and accordingly allocate the funds for the maintenance and construction works.

The acquiring of the data for the pavement condition for the management of the pavement is time consuming and costly process. Thus, it becomes highly important that the pavement survey method which is being used by the agencies closely matches the resources that are available (Luhr and Rydholm, 2015). The process for the collection of the pavement distress data can be either measured or its process of estimation can be gathered using the automated and manual methods. The different types of processes for the collection of the pavement distress data are illustrated below:

i) Measured pavement condition data: In this process, the distress information is quantified and the ratings for the conditions are calculated which are based on the measured quantities of the specific types of distress like that of cracking, rutting or potholes and then they are measured on the basis of their severity like that of high, low or medium. In this process, a sophisticated structure is used for the identification of the different distress types and the severity of the distress which has been identified that are supported through specific measurements (Luhr and Rydholm, 2015).

ii) Estimated pavement condition data: The distress quantities are generally for an overall rating which is generally assigned on the basis of the judgment of the rater. The condition of the pavement is generally observed and the pavement sections are accordingly rated on the basis of their overall condition without making estimations of the specific distress.

iii) Manual collection of data: In this process, the pavement condition data is generally collected through the procedure where the people are involved directly in the observation or the management of the pavement surveys (MACTEC Engineering and Consulting, Inc., 2011). In the case of the

manual surveys, the distress is generally measured from a moving vehicle or by walking on pavement sections.

iv) Automated collection of data: In the process for the automated collection of data, imaging technologies and sensors are used. It has been found that the devices like the profiling devices are generally used for this purpose. These technologies are generally integrated into a mobile van or on trailers of a vehicle (MACTEC Engineering and Consulting, Inc., 2011).

The economics of pavement management:

In the last few years, the pavement management practitioners have found various benefits of the pavement management system. These benefits generally comprise of the ability of the system to document the condition of the pavement network, ability of the pavement management systems to predict the future condition of the pavement on the basis of the given variable budget and it also helps to increase the credibility of the stakeholders who are involved in the construction and maintenance of the pavement. There are various methods that are used for the economic analysis of the pavement; one of such methods is the Life Cycle Cost (LCC) analysis. This method is generally utilized in all the projects (Santos, Ferreira and Flintsch, 2014). In the case of the pavement, the LCC is generally used during the initial stages of designing the pavement, implementation, user costs and the cost of retirement. There are also mathematical algorithms that are used for the purpose of the economic analysis of the pavements. This process is generally based on the five pavement characteristics so that the process could be executed in a successful manner. The five characteristics are the total budget that is available for the maintenance, alternative to the maintenance and treatment, M&R (Maintenance and rehabilitation) equivalent uniform annual cost (EUAC), annual benefit and the initial costs that are related to M&R alternatives.

Apart from the financial analysis of the pavement M&R activities, it is also found that the management focuses on the specific perspective in order to have a direct impact on the pavement management functions (Santos, Ferreira and Flintsch, 2014). Hence, it is important that the management is able to prioritize the various goals related to the pavement management which will, in turn, help the management of the construction organization to prioritize the financial perspective of the total pavement management. This research study will focus on balanced scorecard and the quality function deployment as a tool for prioritizing the financial perspectives that are related to the pavement management function.

2.3 Balanced Scorecard process:

The balanced scorecard is generally a strategic planning and management system which is used extensively in the business organization, government agencies and the other organizations throughout the world in order to align the vision of the organization with the strategic goals of the organization (SEMBADA, 2006). It is also used for improving the internal communications in the organizations and also monitoring the performance of the organization against the strategic goals of the organization. This process was developed by Robert Kaplan and David Norton. The balanced scorecard suggests that the organization is viewed from four different perspectives so that the development metrics could be developed accordingly, data could be collected and the growth of the organization or the project could be analyzed on the basis of these perspectives (SEMBADA, 2006). The four perspectives which are associated with the organization or a project are learning and growth perspective, business process perspective, the customer's perspective and the financial perspective. In this research study, we will focus only on the financial perspective which is related to the management of the pavement system.

As per Kaplan and Norton, the financial perspective is very important for the viability of a project or an organization. Timely and accurate funding of the projects should always be the priority of the management in the organization and the managers had to do whatever possible to do it. The corporate databases are a way to handle and process the lots of financial data. The financial perspective of the Balanced scorecard could be used for focusing on the objectives like that of the enhancing the revenues, improving the cost and productivity, increasing the resource utilization and also simultaneous reduction of the risks. It is important that balanced scorecard is designed in such a manner that it is able to reflect the strategy which has to be followed by the organization (SEMBADA, 2006). Thus, the designing of properly balanced scorecard is based on three important principles which link the measures to the strategy, like that of the cause-and-effect relationships, performance drivers and the linkage to the financials. These principles are illustrated as follows:

i) Cause and effect relationships: All the measures which are selected for the balanced scorecard is associated with the link of the cause and effect relationship which shows the strategy that has to be adopted by the organization.

ii) Outcomes and the performance drivers: It is important that the proper balanced scorecard should have the appropriate mix of the outcomes, i.e. the lagging indicators and the performance drivers

i.e. leading indicators which have been customized as per the needs of the project or the organization.

iii) Linkage to the financials: The cause and effect relationships from the all the measures in the scorecard have to be linked to the financial objectives (SEMBADA, 2006).

In the pavement management, it can be said that the Balanced score card could include the performance metrics which generally evaluates short-term metrics like that of the customer satisfaction, riding quality, resistance to skid etc. (Wolters and Zimmerman, 2011). These metrics will be balanced with the long-term metrics like that of the remaining service life and the lowest overall lifecycle cost of the methods and treatments that have been performed for the pavement management.

2.4 Quality Function Deployment

The quality function deployment is a method which is developed in Japan in around 1966 in order to help the organizations to transform the voice of customers into the engineering characteristics of the product (Uhlmeyer, Luhr and Rydholm, 2016). In the QFD process the needs of the customer is identified first, then in the next step these needs are classified and accordingly the importance of those needs are identified, then all the engineering characteristics which are relevant to those desires are identified and finally a correlation is developed between the needs of the customers and the engineering characteristics. It also allows for the verification of these correlations. In the case of the pavement management, the quality function deployment is used to indicate the level of the data quality by identifying the decision makers' requirements. In the QFD process, the design quality of the product is obtained by identifying the relationship between the demands and the quality characteristics utilizing the charts and the metrics tracking the customers' needs, evaluation of the quantitative importance and the multi-discipline team in stepwise manner utilizing the top-down approach (Uhlmeyer, Luhr and Rydholm, 2016). The house of QFD generally comprises of six basic functions which are interlinked between the customer needs and the goal of the designer. These six basic functions are illustrated as follows:

i) Voice of customer: It addresses the needs of customers and a list is presented for the customers to rate their importance.

ii) Voice of organization: It generally addresses how the organization will put the resources to meet the needs of customers.

iii) Relation matrix: It shows the relationship between the voice of customer and the voice of organization.
iv) Correlation matrix: It shows the relationships that exist between the different voices of the organization.
v) Competitive analytics: It is used to compare the current system with that followed by the competitors in order to present a relative importance of the system.
vi) Design target: In this function the technical assessment of a system or a product is concluded (Woldesenbet and Jeong, 2014).

2.5 Development of QFD based balanced scorecard:

As it has been discussed that the balanced scorecard which was first developed by Kaplan and Norton gives strategic framework where there are four different perspectives; financial, customer, internal processes and learning and growth. In the construction industry, the balanced scorecard is generally used as it is successful in developing a proper cause and effect relationship by linking the financial performance of the construction projects to the various measures that are related to the project. In order to construct a balanced scorecard for the construction projects especially for the purpose of the pavement management, researchers have suggested utilizing the top down approach. In this top-down approach, firstly the financial performances are used which are then followed by the cross-perspective routes which lead to these performances. In the construction projects, the strategic maps are generally referred to as the set of assumptions which are set up after continuous revisions and testing which have been done by the construction company that adopts the system for particular construction projects. Further in order make a justification of the various casual relationships between the particular performances which have to be monitored, the selection of the performances has to be done as per the hypotheses which are generally defined by the enterprise strategy.

In the past few years, there has been several authors which have expressed the need to set up the guidelines which could be used for the construction of the balanced scorecard map and the detailed method for the selection of the different performance measures. As per Hudson et al. (2001), through the balanced scorecard method, it is possible to cover all the dimensions of the construction project's performance but there is no proper mechanism which could be used for building and maintaining the relevance of the defined measures. According to Goulian and

Mersereau (2000), the basic guidelines for the selection of the performance measures that are related to an enterprise to be fit into the balanced scorecard map is required. At present, such guidelines are generally proposed in terms of the structured methodological approaches which are based on the Quality Function Deployment (QFD). This technique could be used in a proper manner to represent a design frame for the construction of the performance measures that links the four perspectives of the balanced scorecard.

It has been found in the recent surveys in the UK that the application of the quality function deployment is a relatively very new concept in the construction industry. In the survey, it was found that there are only 18% of the total 72 respondents who are generally aware of the concept for the QFD (Delgado-Hernandez and Aspinwall, 2007). These results were slightly better than the similar kind of a survey which was conducted in the year 2001 which showed that there are just 7% of the respondents who were surveyed who have actually known the concept of the QFD in the construction industry (Pheng and Yeap, 2001). In the year 1990, Shino and Nishihar examined the concept of the QFD in the construction industry (Shino and Nishihara 1990). After two years in the year 1992, it was found by Oswald and Burati (1992) in the US that the apple-action forth QFD process in the construction industry could be useful in improving the project definition process and the estimation of the requirements of the customers and also simultaneously reducing the cycle time and improving the cross-functional communication. In the year 1993, this concept was used by Mallon and Mulligan (1993) in the US in the case of the hypothetical renovation project. Huovila et al. (1997) applied this methodology in the construction of the flat, restaurant and in the construction and development of the industrial building and found that though there is extra work is involved in this process, but even if it is implemented in a partial manner there are lots of benefits that could be obtained from the application of this methodology like that of the better designs of the buildings, better safety features especially in case of the industrial buildings and better communication with the customers. Kamara et al. (2000) also applied this same methodology in UK and found that this methodology is extremely useful in the processing of the customer requirements in case of the early stages of the project and also provided a hypothetical example in order to depict how this tool could be used for the construction of a family house. They also later developed the software which could be helpful in the encouragement of the application of the QFD in the construction process (Hudson, M., Smart, A. and Bourne, M. 2001). The potential benefits which could be obtained from the application of their methodology were as

follows; helping the clients to depict their vision of their house or the facility which has to be developed, enhancing the communication between the clients and those people who generally collect the requirements from the client, as the client needs are properly defined thus this process also encourage the design creativity and this methodology also provides a structure for the requirement management during the process of construction. further, Ahmed et al. (2003) also utilized the QFD process in the construction of the sewage treatment plant project in the Hong Kong in order to establish the trade-offs which would allow the consideration of the new requirements without sacrificing the important requirements like that of the capacity of the sewage works. The main benefits as stated by the researcher are as follows; it helps to keep the track of the customers' needs, it helps to break down the project barriers like that of the communication barriers between the various stakeholders of the project, it provides a means which could be used for the evaluation of the different alternatives to project and the also simultaneously establish the specific performance targets that are related to the project and could be quantified in a simple manner.

QFD is generally developed as a methodology for the product quality design methodology whose main purpose is to extract the needs of the customer and then those needs are translated into the technical characteristics of the product, engineering parameters and finally into the production or manufacturing system. As it has been stated earlier, this approach is generally comprised of four successive stages or matrices which are generally described as follows: matrix for the overall customer requirement, the matrix for the final product characteristics deployment, process plans and the charts for quality control and lastly the operating instructions. The house of quality (HOQ) maps the WHATs that represents the attributes of the product which are generally desired by the consumer and then relate them to HOWs of the technical characteristics which are generally viewed by the research and development staff of the enterprise. As developed according to the QFD concept, the main influence of the operational decision on the needs of the consumer generally crosses the intermediary domains like that of the process plans and the technical characteristics of the product. In of each of these translations a matrix is used which generally models the strength of every relationship, like that of the feature of the product which is desired by the consumer and the product technical feature which is important for the intended fulfillment of the needs of the customer (Hudson, M., Smart, A. and Bourne, M. 2001). Thus, it can be said that the each of the quality deployment matrices could be viewed in terms of the WHATs (Matrix

rows) and the HOWs (Matrix columns). With the help of the detailed strength of the relation it can be stated how well a particular column (a HOW) could be related to a certain row (a WHAT). Though initially there were just three levels for the identifying the strength of the relationship between the WHATs and HOWs, which were; strong, medium and weak, though in the later stages some authors started preferring to assess the relationship on the Likert Scale to get a better picture of the relationship.

In the figure 1 below, it has been shown how the Quality function deployment could be used for the development of the structured performance system for the balanced scorecard map. In the given balanced scorecard map, the researcher has assumed that the learning perspectives influences the financial perspective through the two intermediary perspectives which are; the internal processes and the perspective of the customer.

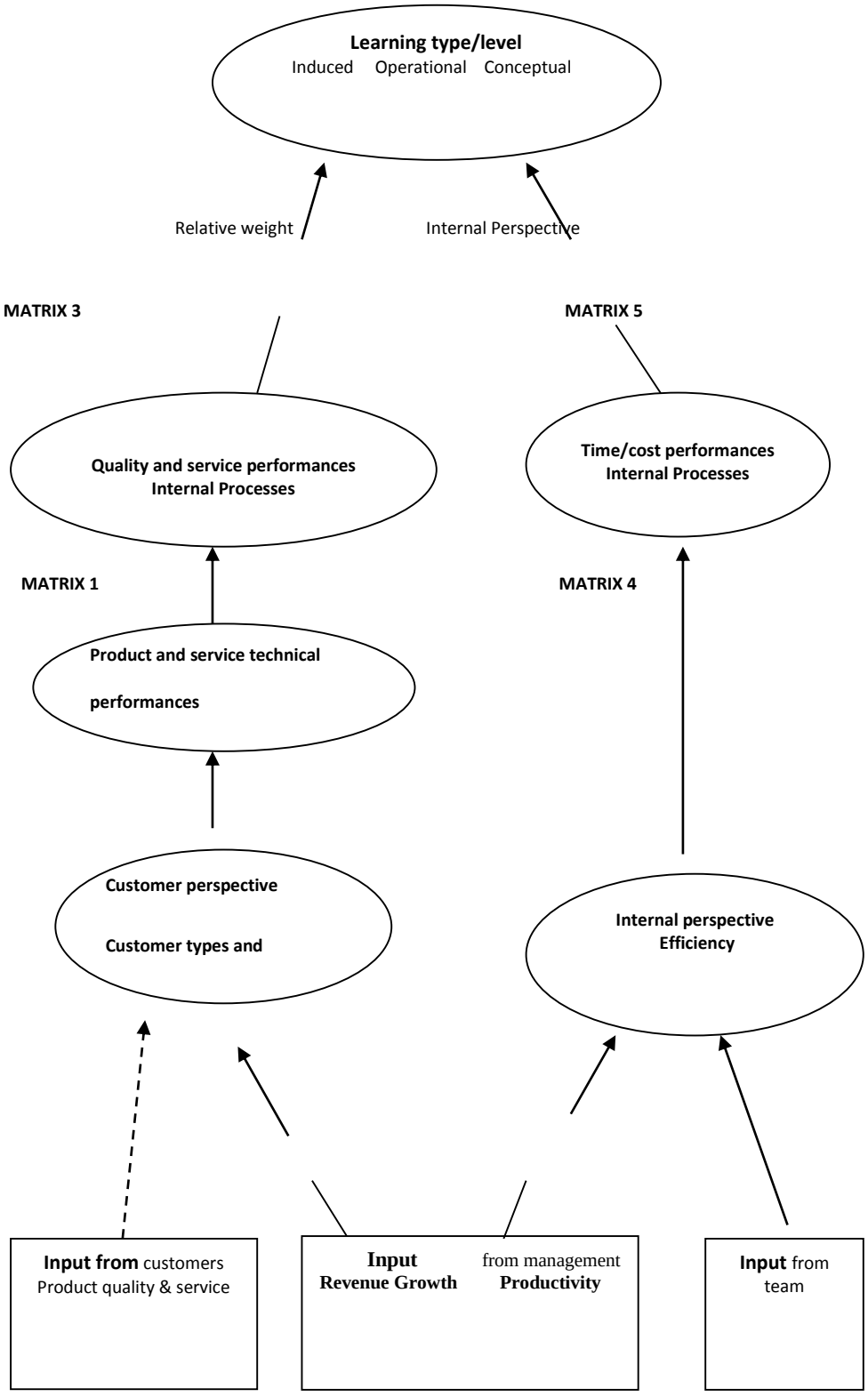


Figure 1. Balanced Scorecard with Five perspectives of QFD

In figure 1, it can be seen that the overview which has been provided depicts a Balanced Score Card (QFD) which shows the linkages between the five matrices of the QFD which have been developed in this case. In this case, it is important to mention that for the development of the above scorecard map the basic structure of the QFD has been freely adapted in order to fit the principles of the balanced scorecard map.

In the figure 1, the matrix 1 is generally used for the translation of the desired improvements that are done in the financial performances as generally viewed by the managers to the relative importance of the perspectives of the customer along with that of the relative importance of that of the internal perspectives (Kaplan, R. S. and Norton D.P., 2001). In this matrix, the input is generally supplied through the management generally after the discussions that are taken in the managerial team. In the above diagram, it could be easily seen that the output of the matrix 1 is fed as the input in the matrix 2 and matrix 4. But we could see that each of these matrices i.e. matrix 2 and matrix 4 will also receive their individual inputs. Thus, this feature somewhat makes it different from the 'classical QFD' structure.

In the matrix 2 there are two major inputs which are; relative weights or the importance of the various customers as per their types and the benefits which are viewed by the manager which generally the output that has been obtained from the matrix 1 and the importance of the describes which has been shown to the customer regarding the quality of the product. These inbput5s are received directly from the customers. The translation of the desired benefits of the customer into the relative weights of the products and the service technical performance then, these two inputs are generally blended in the matrix 2.

In the matrix 3, the output of the matrix 2 is interpreted into the relevant quality/ performance of the services of the internal processes. In this again the outputs are normalized which is presented as the relative importance of weights. Like the matrix 2, the matrix 4 also gets inputs from the two different sources. The inputs that are obtained from the matrix 1 are generally in the form of the relative weights of the internal perspectives with respect to the complete financial perspective. The second input is generally related to more particular performances related to the internal perspectives like that of the cost per unit and the rate of construction and their relative importance (Kaplan, R. S. and Norton D.P., 2001). As it has been shown in the above diagram, it is important that such inputs are generally received from the special teams more preferably a cross-functional

team. In the matrix 4, these inputs are generally transformed into the relevant time/cost performances of the internal processes. When the output of the matrix 4 is presented in the normalized format, the input which is received from the matrix 1 is not relevant, but only for the development of the input for the matrix 5.

The inputs that are used in case of the matrix 5 are generally obtained through the process of integration of the outputs that are obtained from the matrices 3 and matrices 4. These two outs generally represent the related quality/service and the time/cost performance respectively of the internal processes. Through the application of the relative weights that has been supplied by the matrix 1, the inputs that are used in the matrix 5 could be estimated in a very simple process from the outputs that are obtained from the matrix 3 and matrix 4. The main aim of the matrix 5 is to do the translation of the integrated input which depicts the relative importance o0f quality, cost, time and responses based performance measures of the internal processes into the learning oriented performance measures. There are several guidelines that have been provided by the various researchers like that of Muckerjee et al., 1998 and Li and Rajagopalan, 1998, where the performances are structured with respect to domains of learning. In first there are three types/ levels of the learning which are described as; induced, operational and conceptual. The induced learning is generally interpreted as the training at the individual level and the development/enhancement of the information and technology systems (Kaplan, R. S. and Norton D.P., 2001). The operational learning and the conceptual learning are basically viewed as the combinations of the organizational structures and the tools that are used for the purpose of improvement. Teams are involved in both the operational learning and that of the conceptual learning. The operational learning is generally achieved by the means of the local teams utilizing the basic tools like that of the seven basic graphical tools or the SPC. There is a wider scope for the conceptual learning and it has to be dependent upon the cross-functional teams when the more sophisticated tool is applied like that of the general purpose QFD and the advanced statistical tools.

Implications of utilizing the above methodology:

There are several implications of utilizing the above methodology, which are illustrated as follows:

- With the help of the QFD matrices, it is possible that all the financial performances that are identified by the organization or an enterprise are directly linked with the set of performances measures in the relevant domains which will have eventual an influence on the results in the future.

- With the help of the QFD matrices, it is possible for the organization to determine the priorities which are important for improving the performances measures in all the domains.
- With the help of the QFD, it can be ensured that the proposed learning actions are in conjugation with the financial outcomes that are obtained at the end by the company.
- With the help of the systematic approach of QFD, it is possible to organize the balanced scorecard in a proper manner which helps in the continuous improvement for achieving the strategic goals.

In order to design the product in the proper manner, it is important that the design team understands what is they are designing. The same goes for the pavement construction. It is important for the pavement developers to understand what the end users will expect from it. Through the QFD, it would be possible for the researchers to design the systematic approach which is in turn based on the close awareness of the desires of the customers, coupled with the integration of the corporate functional groups. The main aim of the QFD is to translate the most subjective criteria into the objective ones which could be easily quantified and measured and they could be used for the designing and the manufacturing of the products. This is a complementary process which is helpful in determining how and where the priorities of the product have to be assigned for the development of the product. The main intent of utilizing this process is to employ the objective procedures in increasing the detail throughout the product development. There are three main goals for which the QFD approach is generally used for a project; prioritizing the spoken or the unspoken needs and wants of the customers, translating the needs into the technical characteristics and specifications and building and delivering a quality product or the service through focusing the on the needs of all kinds of customer's satisfaction. From the days of the early inception of this approach, this approach has been beneficial in many different kinds of enterprises in planning new products for the consumers, designing requirements for the product, determining the process characteristics, controlling the process of manufacturing and documenting the already existing product characteristics.

Since the conception of QFD approach in over more than forty years, the application of the QFD approach has been mostly related to the manufacturing industry and the construction has not adopted this approach in a large way though there are many potential benefits for this approach if used in the construction projects. It has been identified that the QFD approach could be very well used for the evaluation purpose for fulfilling the needs and demands of the customers. It is also found that the integration of the QFD in the process of contracting could be beneficial for both the

customers and the contractors. In the year Akao (1990) provided a model for QFD which is the first model for the QFD that could be used for the construction projects. Akao (1990) also provided a description of the application of the approach by the Taisei Pre-Fab Construction Company development of the various family housing projects over a time period of ten years. It was found by the researcher that over the time the company has been successful in continuously improve the quality of the projects and the company was also able to maintain a subsequent balance between the construction and quality. In the year 1994, Mallon and Mulligan utilized this same technology for the redesigning of the computer room. It was found by them that though the QFD will not be able to reduce the costs and the time that are associated with the initial design of the project but by eliminating the redesign, the costs associated with the construction and delays shall be reduced.

There are certain principles of the Concurrent Engineering which are being used in the QFD, whereby the cross-sectional teams are generally involved in the different phases for the development of the product. In all the four phases of the QFD process, there are is the utilization of a matrix for translating the requirements of the customers for the initial planning stages through the control of the production. In each of the phase or the matrix, a more specific aspect related to the product requirements is presented. Relationships between the elements are evaluated for each phase. Only those aspects which are very important from each phase are generally deployed for the next matrix. The different phases of the product development using QFD approach are illustrated as follows:

i) Phase1- Product Planning: In this phase, the house of quality is developed. This step is generally led by the marketing department. The phase 1 or the product planning stage is also referred to as the House of Quality. In many organizations, only this phase is followed for a product passing through the QFD process. In phase 1, the customer's requirements are generally documented, data for warranty, competitive opportunities, measurements of the product, measures of the competitive product measures and the technical ability or capacity of the enterprise to meet all the expectations of the customer with satisfaction. For the success of the complete QFD approach it is very much important that good data is collected from the customers during the phase 1 of the process.

ii) Phase 2- Product Design: The phase 2 of the QFD process is generally led by the Engineering department. In the designing of the product, there is a need for creativity and innovative team ideas. The product concepts are generally created during this phase and the specifications of the different parts are also documented during this process. Those parts which are considered to be the

most important by the engineering department and the management of the enterprise on the basis of providing the maximum satisfaction to the customers are then deployed in the planning or the phase 3.

iii) Phase 3- Process Planning: The next phase is the product planning which is generally led by the manufacturing or the production department of the enterprise. During this stage of the QFD process the process planning, manufacturing processes or development processes are expressed in the flowchart and the different parameters that are associated with the processes for the development of the final product are generally documented.

iv) Phase 4- Process Control: In the final stages of the Process control, the indicators for the performances are developed and they are monitored by a specific team during the production process, maintenance schedules and the training of the skills of the various operators, staff and workers. Another important decision that is taken during this process is that of making an assessment of which process possess the maximum risk to the entire process and subsequently additional controls are put in place in order to prevent the additional failures of the process. This phase is generally led by the quality assurance department of enterprise in conjugation with the manufacturing department of the enterprise.

Conjoined BSC and QFD:

A very important strategic tool is obtained by combining the BSC and the QFD together. In the year 1998, Koo combined both the tools, i.e. BSC and QFD and found that the factors in the QFD like that of 'HOWs and WHATs', could be expressed as the four perspectives which are related to the model of BSC. A similar kind of framework was provided in the year 2000 by Lee and Lo0 and for the formulation of the strategy on the issue of vocational education by creating a link between the different factors of SWOT matrix (i.e. strengths, weaknesses, opportunities and threats) so that the four vital perspectives could be established and it could also be possible to examine the quality of the business education in the graduation level. Also in the year 2000, Lee and SainOnKo came out with a new method in which corporate business strategies are developed and implemented. There were two steps in the framework. In the first step, the SWOT matrix was combined with that of the BSC so that it is possible to develop such a strategic management system which is systematic and also holistic in nature. The researchers used the QFD method with different features of the BSC model whereby the 'WHATs' were presented on the vertical axis and

the "HOWs' on the horizontal axis. Further, in the year 2004 Tan et al. also developed a framework for the planning e-business which was associated with the strategic management and the operations management by applying the QFDS approach. They had utilized the QFD approach in order to define the objectives and also to make sure that that initiative that was taken for the e-business approach are basically aligned with the vision and the objectives of the business. In the year 2004, Ip and Koo came out with an approach which was based on combining both the QFD and BSC so that the vague strategies could be translated into action. For the purpose of delineating the above-mentioned strategy, they utilized the case study.

Quality in construction:

There is no single standard which could be used to determine the quality within the construction industry. What is considered as a good quality in the warehouse construction project might be a substandard process in the pavement construction process or in the construction of a microchip manufacturing plant. Thus, it can be said that in the construction industry, different projects have their own quality standards which are generally based on the engineering analysis, requirements of the users and the special needs of the project. There are many decisions that are related to the standards of quality and the requirements of the customers which are basically made during the early construction process and the more often during the project conceptualization phase or the phase for the preliminary design. By properly identifying the needs of the customers mostly the expected and the unspoken desires it could be possible for the project team to focus on the priorities of the customers through the process of design. It could say there are basically three essential elements related to quality, which is illustrated as follows:

i) Quality characteristics: This generally refers to the one or more of the product properties which defines the nature of the product for the purpose of the quality control of the project. The quality characteristics generally comprise of dimensions, color, strength etc.

ii) The quality of design: When the design of the product is developed, engineers generally specify not just the quality characteristics of the raw materials that are to be used in the development of the product, but they also define the acceptable; variance from the values of raw material quality characteristics that has been specified. In case there are too high standards for the raw materials that are to be used in the product development or in case the tolerances are too tight then there are high chances that it could lead to the rise in the product development costs and could also end up

in delays due to the rework. Similarly, is the quality standards of the raw materials are considered as too low standards and very loose tolerances are provided then it could result in the failure of the materials being used in the project and the poor workmanship which could increase the long-term costs for maintenance and repair of the project. Thus, the quality design is generally described as the one in which the standards that are specified are most economical and they are functional for the project and they should also conform to the minimum quality standards that are essential for the project.

iii) The quality of conformance: When the design of the project is completed, the quality conformance could be referred to as the degree to which the physical work generally conforms to the design of the project.

In the construction industry, the projects are generally managed through the time schedules and the budgets have been allocated to the projects. In order to manage the projects within the constraints of time and cost, there are chances that the contractors will compromise with the quality of the raw materials and the other resources and will select the minimally acceptable standards for the quality of the materials in order to reduce the costs and also staying on schedule by accepting the minimum standards in workmanship. In most of the cases, the substandard quality of work is not identified till the project is completed and this generally results in the reworking of the project which lowers the expected performance and it generally causes the dissatisfaction by the owners. This has generally resulted in the rise of the impression that the generally of the quality activity is decreasing and this has increased the use of lawsuits and court cases against the contractors. It has been identified that the problem is that the construction process is not according to what has been demanded by the customer for developing the project. There are five main attributes that are related to this problem and which could be resolved by taking quality-based approach. These attributes are as follows:

- Poor up front definition of the needs and requirements of the customer.
- Incomplete and inappropriate evaluation criteria used for awarding the contract.
- Poor planning of the activities that are related to the project.
- Poor assimilation of necessary midstream changes in the projects which are generally driven by the various problems that are encountered once the project is actually started.

Different metrics that are being used by the corporations for rewards which could drive to the bad performance.

Financial reporting using BSC:

The tangible assets of the company are generally reported on the balance sheets of the company in a separate manner such that the raw materials, land and the equipment and their historic costs in the manner of the conventional methods for the financial accounting. This method was generally favorable of the companies which were operating during the industrial age which were mostly successful in converting their tangible assets into products and the value of the tangible resources helped to increase their acquisitions and the costs of the production (Wolters and Zimmerman, 2011). The conventions of the financial accounting they were related to their depreciation and the cost of goods that were sold allowed an income statement to measure how much value has been generated beyond the costs that were incurred for the transformation and the acquisition of the tangible assets of the finished goods and products. The balanced scorecard has been introduced to provide a new framework in order to describe the strategies for the creation of values which link the tangible and intangible assets. Through the help of the scorecard, it is possible to measure the tangible assets of the company in a form other than currency. With the help of the balanced score, it is possible to describe how the intangible asset gets combined with the other intangible and tangible assets to develop a value proposition for the customer (Wolters and Zimmerman, 2011).

The prices of most of the fixed income securities are generally expressed in the form of the different rates of interest and the yields related to them and to understand the fixed income pricing it will be important to properly understand the interest rate behavior. It is important that the term structure of the interest rate is properly understood so as to analyses the fixed income securities and the behavior of interest rate. The duration is generally referred to as the sensitivity of the price to the changes in the rate of interest (Murira and Sierra, 2016). One of such duration measure for estimating the duration of a mortgage-backed security is the empirical duration. The empirical duration is a duration which is estimated statistically utilizing the observed market prices.

In their research work, Ambastha et al. (2010) gave a proper description about the relationship between the analytical and the empirical duration of the corporate bonds. As per the researchers there can differences in the measures with the deterioration in the quality of the credit and the spreads widen? In this research study, the authors have first updated their earlier research data with the new credit crisis data and gave several reasons for the differences in the sensitivity of interest rate between the investment grade and high-yield bonds. In order to properly explain the relationship between the analytical duration and the empirical duration, the authors have presented

a theoretical model expression for all duration (Ambastha et al., 2010). Each of the duration has been tested by them using regressions and an empirical hedge ratio was established. In their research work, the authors had utilized a combination of the regression approach and a model based approach to find out hedge ratios by utilizing the credit rating for the Barclays Capital's U.S. Investment-Grade Corporate and the high yield indices of US Corporate. From their analysis, the authors found that the relative spread volatility is almost same in the credit ratings. They also found that the hedge ratios which are obtained from the two approaches can be compared and there is a significant reduction in hedge ratios from the high-quality ratings to the low-quality ratings. There was a clear difference in hedge ratios among the investment grade and high-yield bonds. At the time of the credit crisis, there was a clear deviation in the hedge ratios from the expectations of the investment managers. In their research work, the authors rejected the hypothesis that the segmentation was mainly due to the different conventions for pricing and for this the authors conducted three tests. In the first test, the authors used the trading volume in place of liquidity and showed that the sale pricing can be attributed for the separation in the hedge ratio. In the second test, the researchers changed the data on a frequent basis to exclude the sale prices but they got the same result (Ambastha et al., 2010). Finally, an event study was conducted by the authors and it was observed that the separation is still the same which led them to conclude that the data aggregation is not the main reason behind the separation. Thus, the authors determined that the main reason behind the market segmentation between the investment grade and high-yield bonds could be due to the conventions that have been used to measure the performance. The excess return over the treasuries is used for the evaluation of the investment grade bond by the managers and the total risk and default risk is utilized for the high-yield bond by the managers. This could be the main reason behind the sensitivity of the interest rate movements in case of the high yield bonds (Ambastha et al., 2010).

Pavement Management Systems (PMS) are generally utilized by the construction agencies to help them estimating the cost-effective strategies for the preservation of the pavement network and for understanding the level of funding which is necessary in order to address the desire goals of the construction agencies. In the past few years, the construction agencies found that the pavement management systems are very efficient tools for the management of the huge network of pavement systems. The activities that are required to assess the funding required for pavement management generally utilizes pavement inventory information and the pavement condition information which

re-recorded in the pavement management database and models for pavement analysis. The models for pavement analysis comprise of pavement deterioration models, rules for treatment and models for costing. The pavement management system could be for analyzing the various strategies that are related to pavement rehabilitation, maintenance of pavement and pavement preservation. The pavement management systems could estimate the impact of above-mentioned strategies on the future condition of the network of the pavement on the basis of the different level of budget.

As discussed earlier the pavement management systems have been found to be a very effective tool by the government agencies and large construction agencies in the management of huge pavement networks. However, in case of smaller construction organizations, it has been found that many of them have not implemented the pavement management systems despite having similar operation and organizational requirements like those of larger construction agencies. There are several reasons for the above facts like those of not having proper resources to set up the primary database and the initial systems or lack of technical expertise to install the program. Despite the above mention reasons, it is important for the smaller construction agencies to properly manage the different aspects of pavement network (Kasahara, 2005).

With the passage of the time, there is ageing of the pavements and the condition of the pavement generally deteriorates. Thus, surveys are conducted to determine the condition of the survey. The different survey methodologies are illustrated below:

i) Pavement Condition Index (PCI) survey:

The US army corps of engineers could be credited for the development of the Pavement Condition Index survey which was also utilized by the American Public Works Association along with ASTM International. The PCI approach is the type of rating system which generally estimates the integrity of the pavement and the surface operational condition on the basis of the 100-point rating scale. In this approach, the pavement network is divided into branches, sections and sample inspection units. These kinds of surveys are generally carried out on the small sample units. A sample unit could be defined as the specific segment of the pavement which is small in dimensions and could be taken to a laboratory for a detailed inspection of the section. Like the sample units in the pavements which have asphalt surfaces generally, have the size of 2500 square feet which can be either reduced or increased by 1000 square feet. Also, a similar percentage of the sample units are randomly selected from the different location of the pavement. For the purpose of the detailed pavement condition surveys, it is important to estimate the type of distress and the amount of the

every kind of distress which exist in the samples that are collected. There are basically 39 different types of distresses that have been found on the pavement. Of these 20 types of distresses are generally part of the asphalt pavements and the remaining 19 types of distresses are part of the concrete pavements. For each combination of the type of distress, severity of the distress and the extent of distress, there is a deduct value which is related to it, which is established from the available graphs for the various kinds of distress. That distress which can cause more damage to the pavement condition generally have the higher value of deducting points for a sample unit. This value is then adjusted depending upon the number of distresses that has been utilized. In order to determine the PCI for a particular sample unit, the value of deducting is subtracted from 100. To present the condition of the pavement, a weighted average of the entire PCIs determined for the samples that are collected is determined (Wolters and Zimmerman, 2011). There are several pavement management system software programs which could be able to calculate the PCI value on the basis of the distress inputs which are fed into the software.

Estimated Survey methodologies:

i) Condition Rating Survey (CRS):

The IDOT generally utilize the condition rating survey method to analyze the condition of the pavement. The value of the rating system generally ranges from 1.0 to 9.0 with a normal increment of the value 1.0. If there is a condition rating survey value of 1.0, then it shows that there is a total failure of the pavement and the condition rating survey showing the value of 9.0 depicts that the pavement has been constructed newly. The summary of the condition rating survey could be described as follows. In case the condition rating survey value is from 1.0 to 4.5 then it can be said that the value obtained from the rating is poor and there is a critical deficiency in the pavement and the pavement needs immediate improvement (KASAHARA, 2005). In case the condition rating survey value is from 4.6 to 7.5 then it can be said that the value obtained from the rating could be said to be fair and it can be said that the condition of the pavement is in acceptable condition in case of the lower end of the value and in good condition in case of the higher end of the value and there is no need of immediate improvement on the pavement surface. In case the condition rating survey value is from 7.6 to 9.0 then it can be said that the value obtained from the rating is excellent, which in turn signifies that the pavement is in excellent condition which is mainly found when the pavement is newly constructed. The manual for the condition rating survey

was first developed in the year 2004 and there are several images of the distress ratings which are presented in the manual which could be utilized as a reference to the condition of the pavements. It will also be important to point out towards the fact that the condition rating survey methodology which has been developed by the IDOT is generally for the state roads and is taken as the measured survey. There have been several algorithms that have been developed by IDOT which takes into account some of the measured distresses like that of roughness and rutting and incorporates it into the analysis of the pavement performance calculations. But most of these algorithms are basically meant for the state road infrastructure and they are not related to the roads which are developed by the local agencies. The condition rating survey is generally utilized by the local agencies as a methodology for the estimation of the condition of the pavements as the manual for the CRS also contains photographs of the different conditions of the pavement which are associated with the rating value that is followed in the CRS. Thus, it can be said that the CRS could be utilized by the state agencies for the purpose of measured and calculated rating but in the case of the local agencies, the CRS could be mostly used as a way for estimating the condition of the local road network.

ii) Pavement surface evaluation and rating survey:

The system of pavement surface evaluation and the rating survey could be explained as the system which could be used as a visual rating system for the assessment of the condition of the surface of the pavement and the assessment is done on a scale of 1 to 10. In this scale rating, the value of 1.0 denotes that the pavement is in the failed condition whereas the value of the 10 on the rating scale shows that the pavement is in excellent condition. The methodology that is followed in the process of Pavement surface evaluation and the rating survey (PASER) is based on the set of photographs and the description regarding the different categories of rating which is followed in this methodology. These photographs in conjugation with the rating scale and rating description is utilized by the raters to rate and make an assessment of the condition of the single section of pavement. In this process, firstly the general condition of the roadways is determined. In the next stage, the distresses in the pavement are evaluated by the raters in a subjective manner and then the rater selects the most appropriate rating from the description that is provided in the PASER manual. The PASER rating scale generally depicts the various conditions for maintenance. These are illustrated as follows. When the rating that is obtained from the PASER rating scale is 1 or 2 then it can be said that the pavement system requires reconstruction. When the rating that is

obtained from the PASER rating scale is 3 and 4 then it can be said that the pavement system requires structural improvement and levelling. When the rating that is obtained from the PASER rating scale is 5 and 6 then it can be said that the pavement system requires preservative treatments. Further when the rating that is obtained from the PASER rating scale is 7 then it can be said that the pavement system requires routine maintenance, sealing of the cracks in the pavement and the minor works for patching. Also, when the rating that is obtained from the PASER rating scale is 8, then it can be said that the pavement system requires very little and no maintenance. Finally, if the rating that is obtained from the PASER rating scale is 9 and 10 then it can be said that the pavement system requires no maintenance and the pavement is in excellent condition (KASAHARA, 2005). It is important that the periodic evaluation is carried out so that the current and useful evaluation of the data could be done. It is important that the PASER ratings are updated on a two-year basis.

2.6 Summary:

From literature review, it was found that the concept of QFD in the construction industry is a relatively new concept and there are researchers who have shed the light on the application of the QFD for developing the balanced scorecard map. In the case of the pavement management, the acquiring of the data for the pavement condition for the management of the pavement is a time-consuming and costly process. Thus, it becomes highly important that the pavement survey method which is being used by the agencies closely matches the resources that are available. The process for the collection of the pavement distress data can be either measured or its process of estimation can be gathered using the automated and manual methods. QFD is generally developed as a methodology for the product quality design methodology whose main purpose is to extract the needs of the customer and then those needs are translated into the technical characteristics of the product, engineering parameters and finally into the production or manufacturing system.

It could be added that the QFD as a management tool could be extremely helpful in assisting the project managers to identify the requirements of the customers and they also emphasized on those requirements through the process of the project delivery. It was found by them that though the QFD will not be able to reduce the costs and the time that are associated with the initial design of the project but by eliminating the redesign, the costs associated with the construction and delays shall be reduced. Through QFD approach is a systematic means for the translations of the customer

preferences into the technical descriptions in the different stages of the project development. Thereby meeting or exceeding the needs of the customers will require that they maintain or improving the performance of the product. It will require the development of the products which will delight the customers and will be able to fulfil the unarticulated needs of the customers. It can be readily said that the companies which will grow in the 21st century will be the ones which will foster the required innovation for the creation of new markets.

The scorecard and the quality function deployment were adopted and modified in order to fit with the subject and main goal of the thesis. Implementation of pavement goals based on their priority related to financial goals will help in achieving the ultimate goal of understanding the requirements and allocate the required funds for the top priority objectives.

CHAPTER 3: RESEARCH METHODOLOGY

3.1 Introduction:

This chapter will present the research methodology that has been adopted by the researcher for this particular research study. This chapter explains the research strategy and the research approach.

3.2 Methodology:

The proposed methodology that has been adopted by the author for this particular research study is based upon the cascading approach. In the proposed approach that has been adopted by the researcher the upper part of the complete matrix is defined as the House of Quality of the QFD (quality function deployment), which shows the interrelationships between the different financial objectives of the pavement management. The vertical and horizontal matrix out-layers are derived from the modified scorecard which includes the four different dimensions of the pavement management, where the financial requirements serve as the vertical part and the scheduling, public authorities', innovational and operational requirements serve as the horizontal part of the QFD. Accordingly, the sub-dimensions are translated into the determinants. The determinants are general indexes of the main areas which are basically associated with the sub-dimensions. Like the index for the future prospects may generally comprise of the index for innovation index, learning index, improvement index and projection index. In the present stage of the first matrix there no advantage in the ranking or weighing the importance of the different sub-dimensions. In the case of the third matrix, the determinants are translated into the measures. In order to consider all the measures that are relevant, it is important to ask the question "what could be measured that may be associated with a particular perspective" (Uhlmeyer, Luhr and Rydholm, 2016). There are different versions for different perspectives in the different organizations. Thus, it is important to carry out some analysis in order to determine the measures that will be utilized. Though the measures that are related to productivity are generally simple in nature but the measures that are associated with the various other dimensions and perspectives are generally complex in nature. There are several aspects that are associated with the designing of the measures. In order to design the product in the proper manner, it is important that the design team understands what is they are designing. The same goes for the pavement management. It is important for the pavement developers to understand what the end users will expect from it. Through the Quality Function Deployment, it

would be possible for the researchers to design in a systematic approach which is in turn based on the close awareness of the desires of the customers, coupled with the integration of the corporate functional groups. The main aim of the QFD is to translate the most subjective criteria into the objective ones which could be easily quantified and measured and they could be used for the designing and the manufacturing and execution. This is a complementary process which is helpful in determining how and where the priorities of the product have to be assigned to the development of the product (Uhlmeyer, Luhr and Rydholm, 2016). The main intent of utilizing this process is to employ the objective procedures in increasing the detail throughout the product development. It has to be ensured that the measures are not only attainable but they should also be easy to perform. In certain cases, certain measurement might not correspond to certain factors and they might be rather unclear and might be general indicators of the several factors. For each of the measurement, a particular person has to be assigned so that he is able to take the responsibility to collect the accurate data in a proper manner. In most of the cases, it has been found that there is a need to add the measurement system as there is a need for the data and there is no present method through data could be supplied.

3.3 Research Philosophy:

It can be stated that the research philosophy that is generally taken by the researcher forms the main basis for the entire researcher study. It generally forms the basis for the collection of the data, analysis of the data and the application of the both primary as well as the secondary data which is accumulated during the entire research. The research philosophy that is generally chosen by the author helps to set up the association between the data which has been collected by the researchers during the entire course of the research study and the information that was already established. The different research philosophies that are generally followed by the researchers generally comprise of pragmatism, positivism, interpretivism, and realism. In this research study, the researcher has adopted a hybrid research methodology of positivism and interpretivism so that the researcher is able to address all the concerns objectives of this research study. With the help of the positivism research philosophy, the researcher is able to establish a realistic viewpoint which focuses on the relation between the various findings of the research study. One thing that is very important in the positivism research philosophy is that the effectiveness of the positivism research philosophy generally depends upon the degree of correctness of the data that has been collected

by the researcher from the different empirical observations. In this research philosophy, the participants in the research study are considered as an important factor in the proper development of the rationale so those conclusions derived from the research study are appropriate. Also, the data which obtained for the research study will be both qualitative and quantitative in nature as it will help in analyzing the effectiveness of the approach that has been proposed by the researcher for the pavement management. Interpretivism known as humanistic qualitative method starts from the position of knowing the reality including the domain of human action. With the interpretivism methodology, the researcher was able to rely upon the human subject as an instrument to measure some observations by involving interviews with various population that was the source of data collected in order to come up with the different methodologies and analysis used in this research paper.

Realism research methodology is based on facts and reality independent from the human mind, which is not applicable is this case because all data collected is based on human opinions and previous studies

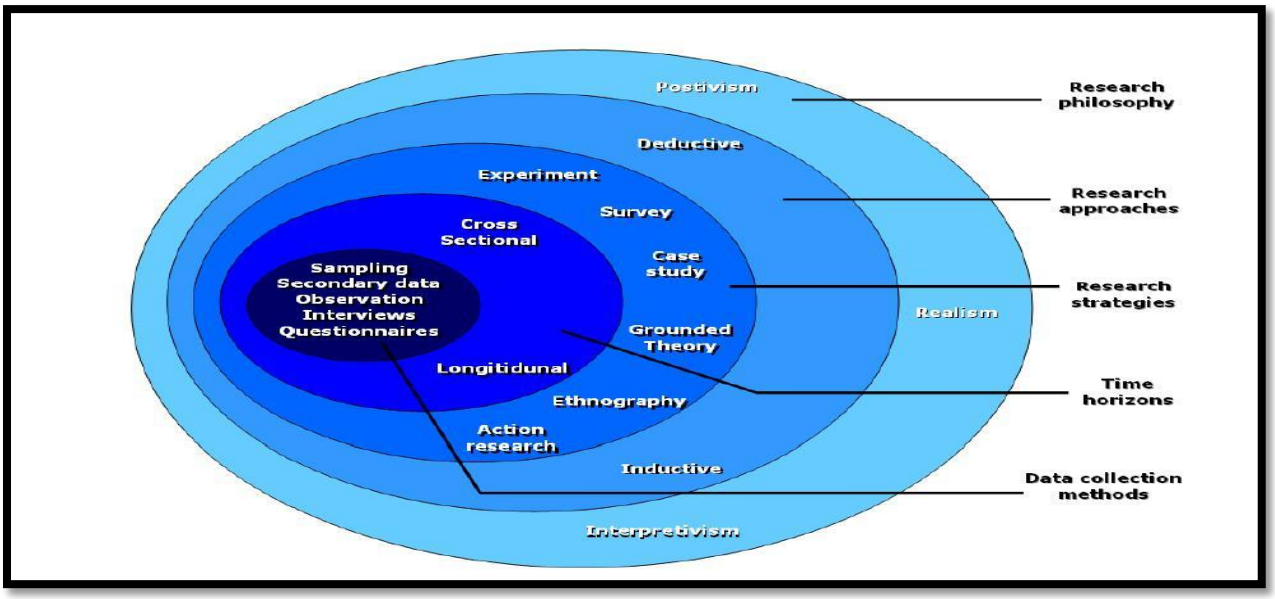


Figure 2. The Research Onion *Sources: (Bryman and Bell, 2011)*

3.4 Research design:

The research design that has been adopted by the researcher could be explained as a tangible approach that is taken by the researcher so as to integrate the various elements of the research in a proper manner such that the objectives of the research study could be attained in a proper manner.

The research designs are generally categorized as the investigative research design and the demonstrative research design. This research design could be extended to a casual and descriptive research design. Further, the descriptive research design is sub-divided as the cross-sectional research design and the longitudinal research design. These different research designs are based on the manner in which the various features of the research study are incorporated together. After taking into account the different complexities that are associated with the development of a new approach for the pavement management utilizing the balanced scorecard tools and the QFD, the researcher has found that the best research design for this study will be descriptive research design. This will help the researcher to elaborate upon a particular point of view, which in this case is the relationships between the financial perspectives and the three other perspectives (public authorities, scheduling, innovational and operational perspectives) of pavement management, leading in prioritizing the three different horizontal perspectives based on the importance of the financial perspectives.

3.5 Research Approach:

The research approach helps the researcher to address the pre-established aims and objectives of the research study. The two main research approaches that are generally followed by the researchers are the inductive and the deductive research approach. Sanders et al. (2003) were the first to identify these two research approaches that are mostly adopted by the researchers. But Blaikie (2009) has been able to explain these research approaches in a much better manner. The research studies which are based on the inductive approach generally comprise of collection or gathering the information by analyzing the different philosophies and applying them and also searching for the various prototypes in the different kinds of literature. In such a scenario, it has been found that the schemes come out to be generality and the associations of the sweeping statement are found to be as a hypothesis (McGinty, 2015). This approach generally comprises of generalization and the development of the support to further substantiate the claims that are made by the researcher. The models which are basically utilized in case of the inductive approach are generally restricted to the description of the abstract and for their mathematical representation. In the earlier part, there is a low level of generalization which also has a network of generalization whereas the second part basically comprises of the mathematical models which are based upon the data that has been gathered (Campbell, 2000). These kinds of modelling generally have the

statistical forms up to the primary level of statistical summaries. In the case of the inductive approach being utilized by the researcher than in that case, the researcher has to make up an intelligent choice from the data analysis so that a proper conclusion of the research study could be obtained. Apart from the several advantages that have been mentioned above, there are also few limitations that are associated with this research approach. The major limitation of this research approach is collecting the required data from a limited population sample size, compromising of 76 participants.

After conducting a thorough analysis of the different needs and objectives of this research study, the researcher has decided to utilize the inductive research approach which will enable the researcher to develop a new approach for the pavement management by utilizing the balanced scorecard tools and QFD. The inductive research approach will also help the researcher to integrate the different bits of information that is associated with the formation of a new approach for the pavement management.

3.6 Sampling Design:

According to Frey, et al., (2000), a sample could be explained as the subgroup of the population. There are two standard methods that exist for the sampling method. The two methods could be explained as the probability sampling method and the second category could be explained as the non-probability sampling method. In certain cases, the probability sampling method is also referred to as the random sampling method whereas the non-probability sampling method is known as the non-random sampling method. For the purpose of this thesis, non-probability sampling will be used. According to Frey, non-probability sampling can be classified as convenience, volunteer, purposive, quota, snowball sampling. Due to the nature of this research, a non-probability purposive method of sampling will be applied. Purposive sampling is selecting a sample "on the basis of your own knowledge of the population, its elements, and the nature of your research aims" (Babbie, 1990). That is the population is “non-randomly selected based on a particular characteristic” (Frey, et al., 2000). The individual characteristics are selected to answer necessary questions about a “certain matter or product” (MacNealy, 1999). The researcher is using a non-probability sampling by selecting specialized sample of population that has pavement management knowledge which will serve the researcher survey in a more constructive and efficient way. As a result, this study will involve people from the staff of the pavement management

companies and pavement users. This sample population will help to generate critical data important for the study.

3.7 Collecting data

According to Kothari (1992), there are two main types of data used in research studies called primary data and the secondary data. Researchers have also found out different methods that could be used for the collection of the data. Primary data is collected as fresh and it is generally said to have the original character because this data is collected for the first time. The secondary data could be referred to as those data which is generally obtained from the various statistical analyses. The secondary data is different from the primary in the respect that the primary data is collected fresh whereas the secondary data could be referred to as the compilation of the work.

3.7.1 Secondary data Collection

For the purpose of this research study, the researcher will utilise the secondary data as they are made available readily by the researchers who are also conducting different research studies on a similar theme but with different research objectives. The secondary data has been collected from different sources like that of the annual reports, journal articles, magazines, research papers, books and articles which are based on the same research theme. These literature are reviewed to a large extent so that valuable information could be retrieved from them which would be able to support the making of the research study, which in our case defining the different four pavement management perspectives and their objectives.

3.7.2 Primary Data Collection

The primary data could be collected either in a quantitative manner or in a qualitative manner. In the case of the qualitative data, information and data are collected which are transformed into the numerical values to be used in the statistical analysis and accordingly the conclusions could be made.

3.7.3 Data Collection:

<u>Questionnaires:</u>

For the purpose of this research study, the researcher will utilise the self-completion questionnaire

whereby the information will be gathered from the staff of the pavement management companies and the users of the pavement. The responses that are provided by the people shall be utilised to understand the perspective of the people regarding the pavement management techniques that has been employed by the researcher. The entire questionnaire to the different respondents shall be provided to the respondents via the internet with the utilisation of the tools like that of the Survey Monkey and e-mail. The main advantage of adopting such an approach is that it increases the range of the questionnaire and privacy of the respondents could be saved in this approach. There are several ways in which the questions were asked to the respondents. The questions were in the form of scaled questions.

3.7.4 Analysis of data:

In order to analyse gathered data, editing and coding will be done. In this research study, data is analysed by using normal excel spreadsheets to find the correlation between variables and their average score weight.

CHAPTER 4: ANALYSIS AND RESULTS

4.1 Balanced Scorecard:

The first analysis used in this research study is the balanced scorecard which allows an organization to translate its vision and strategies by offering a framework that do clarify the various objectives of the organization through the objectives specified by the researcher. The balanced scorecard is an analysis that provides guidance for long term goals. It usually complements the financial perspectives with three other different perspectives. For the purpose of this research study, the original balanced scorecard analysis is modified by the researcher. By collecting the secondary data from different resources and after reviewing many pavement management related literature to a large extent as mentioned earlier in the methodology chapter, the researcher of this study was able to determine the main four pavement management perspectives of the balanced scorecard along with their objectives, as follows:

1- Financial Perspective
2- Public Authorities Perspective
3- Scheduling Perspectives
4- Innovation and Operational Perspective

After an excessive review of information and literature related to pavement management and as a result of a wide research effort, the researcher was able to eliminate many objectives and summarize the most important remaining ones for each perspective, as follows:

4.1.1 Financial Perspective:

Considered as the most important perspective among others, the financial perspective is chosen as the base of the analysis for the QFD. Its major objectives are summarized by the researcher, as follows:

- Reduce resources consumption
- Reduce life cycle cost of pavement
- Reduce or eliminate end users lawsuits due to safety issues
- Reduce cost of data collection

- Reduce overall costs for maintaining and rehabilitating the road network
- Reduce vehicles operating costs
- Work out the least cost solutions considering different alternatives

4.1.2 Public Authorities Perspective:

Instead of the customer perspective included in the original scorecard and for the sake of this research study, the public authorities' perspective is chosen by the researcher for the fact that public authorities are much related to the subject of pavement management. Its objectives are summarized and listed as follows:

- Provide clear inventory of country road network
- Provide proactive maintenance schedule
- Provide pavement scoring system to rate condition of pavement
- Comply with environmental and safety laws and requirements and improve their procedures
- Provide accurate decision making techniques for pavement operations
- Monitor the efficiency and effectiveness of the paved roads
- Evaluate the consequences of delaying or postponing maintenance on future budget needs
- Provide a sound basis for resource allocation and optimal use of funds
- Increase the effectiveness of management and provide savings in expenditure
- Reduce road congestion specially at peak periods

4.1.3 Scheduling Perspective:

This perspective is concerned with the time plan of the pavement management. The fact that pavement management systems are essential tools used for scheduling and planning, this perspective is considered as a mandatory perspective for this research study. Going through a wide review of previous literature, the researcher has chosen scheduling objectives in terms of pavement management as follows:

- Provide on-time future schedule for maintenance activities based on pavement type and condition.

- Provide a proactive operations system to avoid delay in maintenance causing disruption of end users daily activities.
- Provide effective pavement inspection schedule.
- Provide quick conditional scenarios for time-constraint pavement issues based on available funds, available human resources and equipment.
- Identify pavement treatment timing.
- Avoid consequences of delaying or accelerating a pavement treatment.
- Monitor actual outcomes to evaluate whether the results are consistent with what was expected.

4.1.4 Innovation and Operational Perspective

This perspective was chosen as the 4th perspective of pavement management for the fact that pavement management systems are well efficient tools used in achieving innovation and operation goals for pavement management companies. The objectives of this perspectives are listed by the researcher as follows:

- Provide criteria for minimum serviceability, minimum skid, maximum distress, minimum structural adequacy.
- Provide construction quality control.
- Encourage innovation in managing the pavement operations to improve the process of management.
- Provide proper instruments to measure performance and predict failures, materials for construction and repair.
- Use of information systems and models to locate problems, and making in situ repairs and tests.
- Provide objectively based priority program to provide justification for budget requests.
- Provide precise inventory database design and operation.
- Monitor the efficiency and effectiveness of the works carried out.
- Provide a systematic approach to identify current and future road conditions and needs.
- Provide data to communicate agency decision impacts on pavement condition.
- Determine main causes of deterioration for each road.
-

4.2 Quality Function Deployment:

As described earlier by the researcher, the QFD has two main dimensions. Using the above results of defining the four main perspectives of the pavement management and their objectives, the first dimension which is the vertical matrix out-layer is chosen to be the objectives of the financial perspective of the pavement management. The second dimension which is the horizontal out-layer of the QFD is chosen to include all the objectives of the three others pavement management perspectives as defined in the modified balanced scorecard. At this stage of the QFD, there is no ranking or weighting for the importance of the vertical nor the horizontal objectives. The House of Quality, which is the top part of the QFD now is showing the correlation between various objectives of the financial perspective: it shows a relation or no relation.

As a result of the below, the QFD now is ready as shown in Figure 3, Part 1&2:

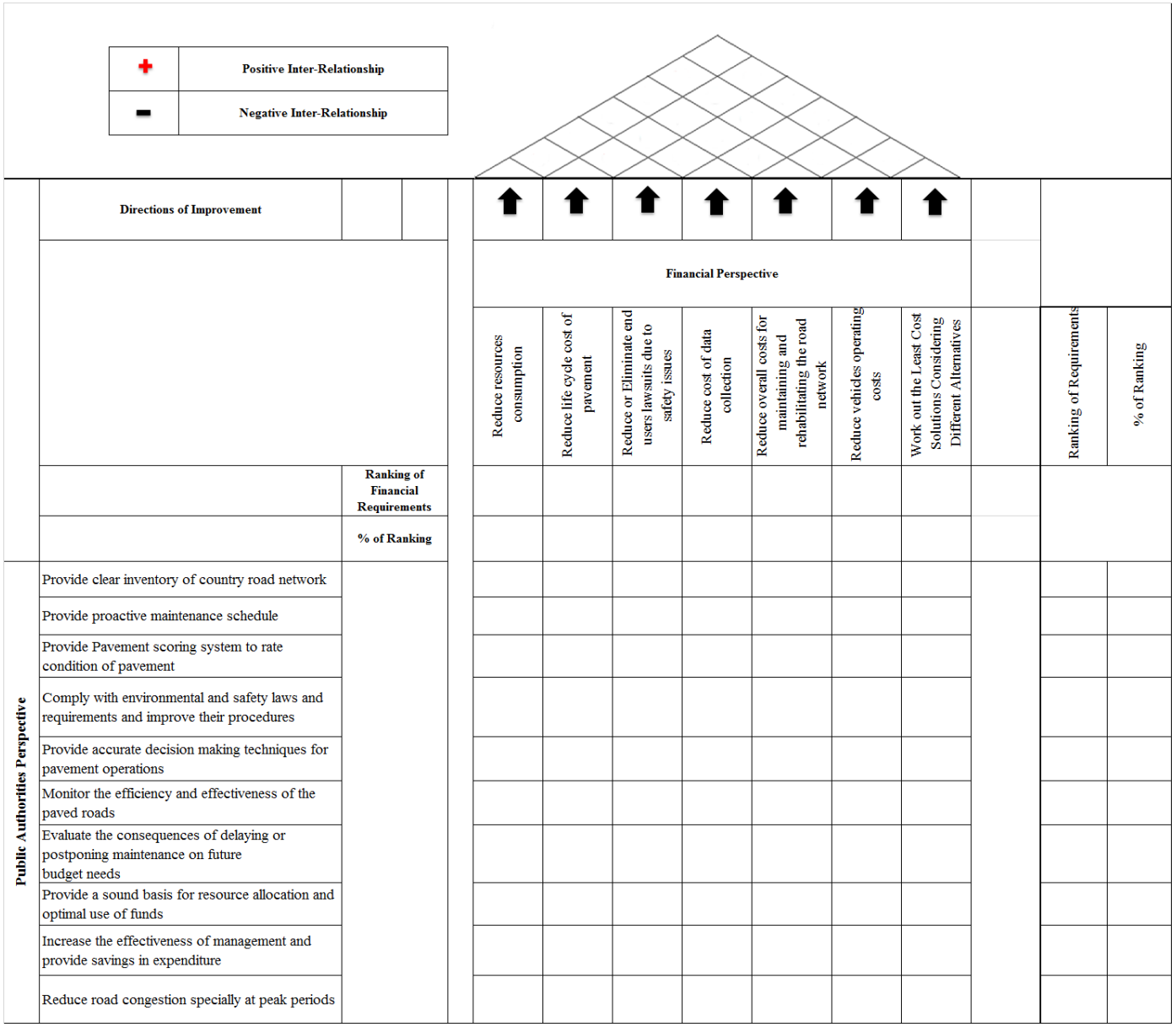


Figure 3. QFD Dimensions filled with Pavement Perspectives *(Part 1)*

Scheduling Perspective	Provide on-time future schedule for maintenance activities based on pavement type and condition.													
	Provide a proactive operations system to avoid delay in maintenance causing disruption of end users daily activities													
	Provide effective pavement inspection schedule													
	Provide quick conditional scenarios for time-constraint pavement issues based on available funds, available human resources and equipments													
	Identify pavement treatment timing													
	Avoid consequences of delaying or accelerating a pavement treatment													
	Monitor outcomes to evaluate whether the results are consistent with what was expected													
Innovation and Operational Perspective	Provide Criteria for minimum serviceability, minimum skid, maximum distress, minimum structural adequacy													
	Provide construction quality control													
	Encourage innovation in managing the pavement operations to improve the process of management													
	Provide instruments to measure performance and predict failures, materials for construction and repair													
	Allow the use of information systems and models to locate problems, and making in situ repairs and tests													
	Provide objectively based priority program to provide justification for budget requests													
	Provide precise inventory database design and operation													
	Monitor the efficiency and effectiveness of the works carried out													
	Provide a more systematic approach to identifying current and future road conditions and needs													
	Provide data to communicate agency decision impacts on pavement condition													
	Determine main causes of deterioration for each road													

Figure 3. QFD Dimensions filled with Pavement Perspectives *(Part 2)*

4.3 Data Collection:

The QFD now is ready to be implemented in terms of a survey using "Survey Monkey" online website that allows to create a survey based on the researchers' inputs. The survey prepared by this study researcher is described as below:

- Questions 1 to 7 are used to determine the importance of the financial perspectives. A Likert scale from 0 to 7 is used by the researcher as shown in below Table 1:

Table 1 – Likert Scale used for Survey Questions no. 1 to 7

Not Important	0
Slightly Important	1
Moderately Important	3
Important	5
Very Important	7

- Questions 8 to 14 are used by the researcher to determine the correlations between the financial perspectives in order to fill the roof matrix (house of quality) of the QFD by just selecting in case of relation and no selection in case of no relation.
- Questions 15, 16 and 17 are in a format of tables to be filled with a certain scale in case of relation and with no input in case of no relation. Likert scale from 1 to 5 was defined by the study researcher as follows in Figure 2:

Table 2 - Likert Scale used for Survey Questions no. 15 to 17

Weak relation	1
Medium relation	3
Strong relation	5

- Question 18 is used in order to define the domain of experience of the population filling the survey by clicking one of the following options:
  Construction – Consultant – Infrastructure/Pavement – Supplier – Others

- Question 19 is used to determine the age groups of the population filling the survey by clicking one of the following options:

21-30 age / 31-40 age / 41-50 age / above 51 age

Various specialized engineers from different engineering contractors, consultants, suppliers, authorities and various engineering professors were asked to complete the survey designed by the researcher of this study related to pavement management. The survey was sent by the researcher supported to by his two professors working with him on this research to industry professionals. 76 respondents completed the survey and the results are as follows:

4.4 Data Analysis:

Starting briefly with the demographic analysis, 21% of the responses were from construction companies while 29% were from infrastructure/pavement specialties and the other 50% were distributed between consultants, suppliers and engineering professors. It is noticed that 38% of the respondents were between 31 and 40 years of age while 28% between 41 and 50 years of age.

The survey results that is used by researcher of this study to fill the QFD are as follows:

Based on the survey results and by applying the Average Score shown in Figure 4, which is calculated by establishing the weighted average, an average resulting from the multiplication of Number of response counts by the factor scale reflecting its importance.

$$\bar{x} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i},$$

which means:

$$\bar{x} = \frac{w_1 x_1 + w_2 x_2 + \cdots + w_n x_n}{w_1 + w_2 + \cdots + w_n}.$$

Figure 4. Average Score Equation

Where W is the response count and X is the question Scale corresponding to each response.

As an example of the above, the researcher will explain how scores are calculated as shown in table 3.

For the "Reduce life cycle cost of pavement", using the survey analytics as shown in Figure 5 and Table 3:

Table 3 – Survey Results of Question no. 2

In pavement management, the reduction of pavement life-cycle cost is:				
Answer Options	**Response Percent**	**Response Count**	**Scale**	**Average Score**
Very Important	48.7%	37	7	
Important	31.6%	24	5	
Moderately Important	15.8%	12	3	**5.47**
Slight Important	1.3%	1	1	
Not Important	2.6%	2	0	
	answered question			**76**
	skipped question			**0**

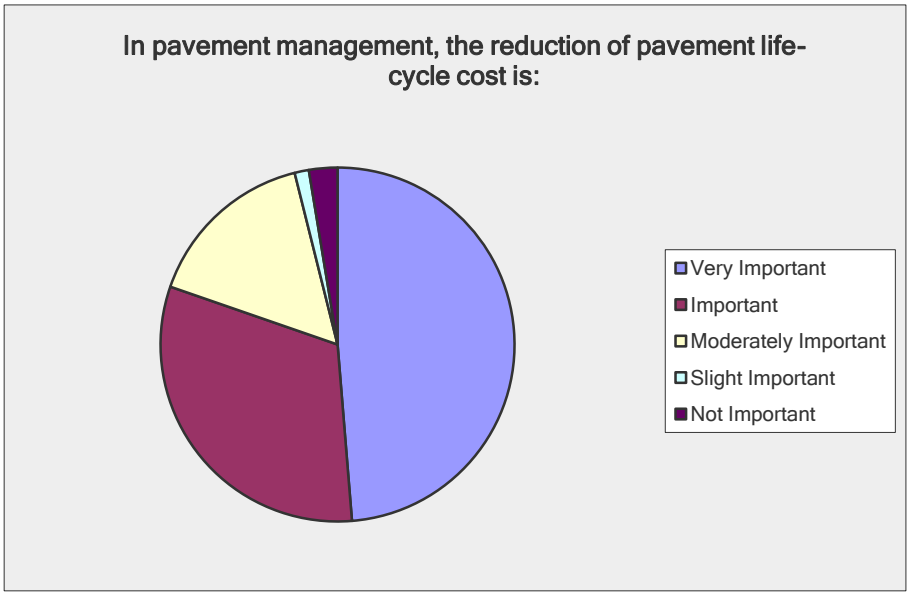


Figure 5. Percentage of responses for Survey Question no. 2

Using the average score equation, the researcher was able to calculate the average score of this particular financial requirement as follows:

{(37*7) + (24*5) + (12*3) + (1*1) + (2*0)} / 76 = 5.47

Using the same calculation, the researcher was able to calculate the average score of all financial requirements as shown in Table 4, which gives at the same time a ranking idea of the financial requirements.

Table 4 – Ranking of Financial Objectives

#	Ranking of Financial Objectives	Calculated Average Score	% of Importance
1	Reduce life cycle cost of pavement	5.47	0.166
2	Reduce resources consumption	5.43	0.165
3	Reduce overall costs for maintaining and rehabilitating the road network	5.28	0.160
4	Reduce or Eliminate end users lawsuits due to safety issues	4.87	0.148
5	Work out the Least Cost Solutions Considering Different Alternatives	4.20	0.127
6	Reduce vehicles operating costs	4.05	0.123
7	Reduce cost of data collection	3.70	0.112
#	Total	**33.00**	**1.000**

The same above Average Score formula is used by the researcher to calculate the average score of the relation between the two different dimensions of the QFD, between the financial objectives and the objectives of three other perspectives listed on the horizontal part of the QFD. As an example of calculation, from question 15 of the survey done, Table 5 shows the answers of the people who did the survey. This question shows the relation between one vertical perspectives along with the horizontal financial ones:

Table 5 - Survey Results of Question no. 15

Kindly specify relationship between financial objectives (columns) and public authorities objectives (rows) please insert (1, 3 or 5) where ("1" weak, "3" medium and "5" strong relation). Important Note: if you leave the answer blank it means there is No relation.				
Reduce consumption of resources				
Answer Options	**1**	**3**	**5**	**Response Count**
Provide clear inventory of country road network	9	26	21	**56**
	answered question			**65**
	skipped question			**11**

Using the same average score equation, the researcher was able to calculate the score of the relation between "provide clear inventory of country road network" from the Public Authorities vertical perspective with "Reduce consumption of resources" from the horizontal Financial Perspectives, as per the following calculation:

{(1*9) + (3*26) + (5x21)} / 65 = 2.95 shown in QFD, Figure 6 as:

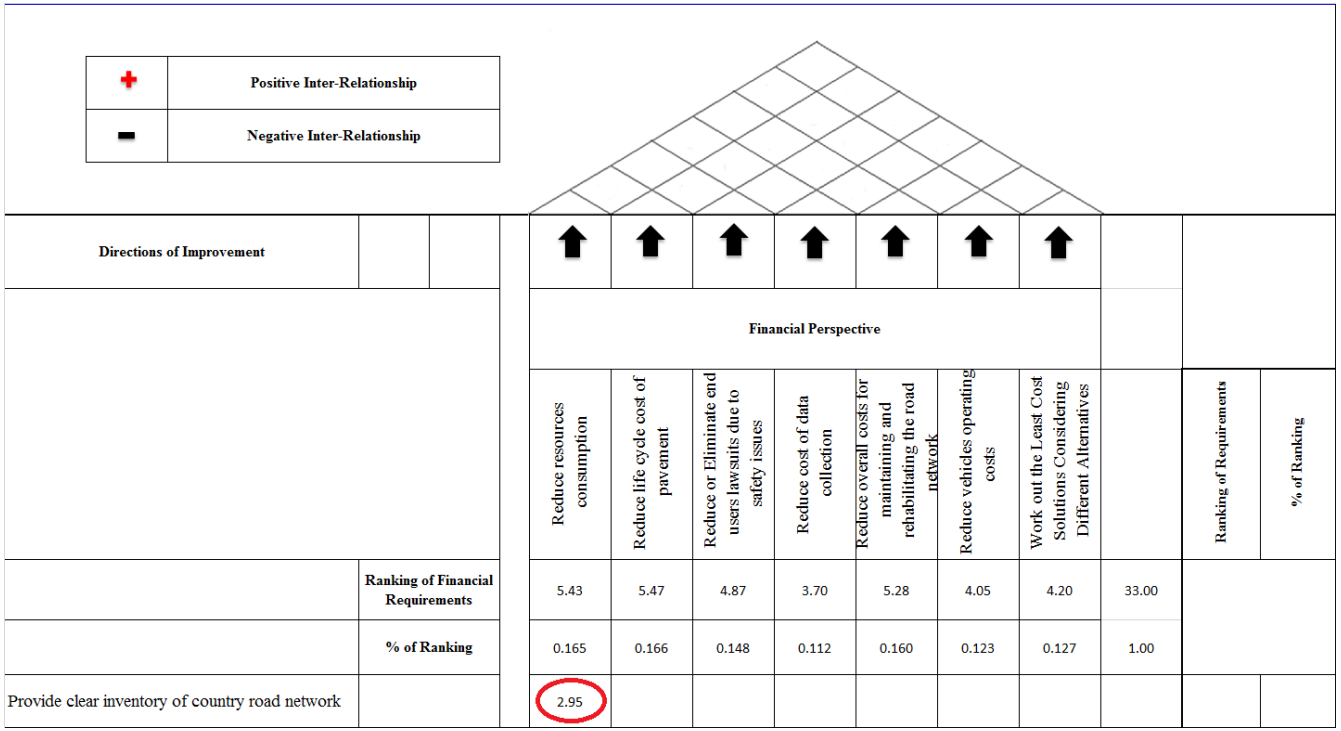
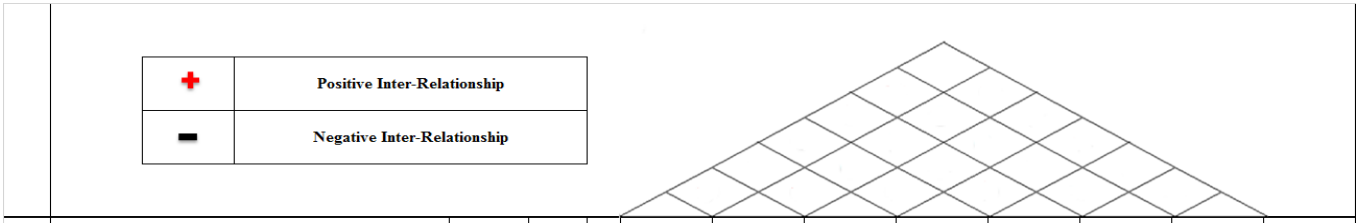


Figure 6. Relation Score Example - QFD

The researcher, doing the same as above for question 15, 16 &17 of the survey, he filled the QFD with number showing the relation between the three vertical perspectives to the horizontal financial perspectives as shown in Figure 7, Part 1&2:



	Directions of Improvement			⬆	⬆	⬆	⬆	⬆	⬆	⬆	
				Financial Perspective							
				Reduce resources consumption	Reduce life cycle cost of pavement	Reduce or Eliminate end users lawsuits due to safety issues	Reduce cost of data collection	Reduce overall costs for maintaining and rehabilitating the road network	Reduce vehicles operating costs	Work out the Least Cost Solutions Considering Different Alternatives	
		Ranking of Financial Requirements		5.43	5.47	4.87	3.70	5.28	4.05	4.20	33.00
		% of Ranking		0.165	0.166	0.148	0.112	0.160	0.123	0.127	1.00
Public Authorities Perspective	Provide clear inventory of country road network			2.95	1.89	1.49	2.29	2.68	1.29	1.03	
	Provide proactive maintenance schedule			2.74	2.72	1.49	1.58	3.46	1.40	1.03	
	Provide Pavement scoring system to rate condition of pavement			2.46	2.52	1.34	1.80	2.97	0.94	0.89	
	Comply with environmental and safety laws and requirements and improve their procedures			2.40	1.60	3.45	1.23	2.12	0.95	0.95	
	Provide accurate decision making techniques for pavement operations			2.94	2.35	1.60	1.68	2.71	1.40	1.11	
	Monitor the efficiency and effectiveness of the paved roads			2.68	2.42	1.80	1.75	2.89	1.31	1.03	
	Evaluate the consequences of delaying or postponing maintenance on future budget needs			2.52	2.42	1.58	1.42	3.38	1.12	0.85	
	Provide a sound basis for resource allocation and optimal use of funds			3.00	2.12	1.08	1.52	2.38	1.02	1.35	
	Increase the effectiveness of management and provide savings in expenditure			3.05	2.32	1.54	1.72	2.46	1.51	1.77	
	Reduce road congestion specially at peak periods			2.51	2.11	1.68	1.23	2.45	2.34	1.09	

Figure 7. QFD filled with perspectives relations scores *(Part 1)*

Scheduling Perspective	Provide on-time future schedule for maintenance activities based on pavement type and condition.			3.24	2.37	1.37	1.65	3.39	1.18	0.74	
	Provide a proactive operations system to avoid delay in maintenance causing disruption of end users daily activities			2.76	1.90	1.52	1.18	2.84	1.50	0.82	
	Provide effective pavement inspection schedule			2.68	1.92	1.66	1.94	2.97	1.03	0.90	
	Provide quick conditional scenarios for time-constraint pavement issues based on available funds, available human resources and equipments			2.94	1.56	1.18	1.76	2.29	1.02	0.95	
	Identify pavement treatment timing			2.58	1.76	1.44	1.63	3.18	1.11	1.05	
	Avoid consequences of delaying or accelerating a pavement treatment			2.32	1.89	2.15	1.31	2.97	0.98	0.79	
	Monitor outcomes to evaluate whether the results are consistent with what was expected			2.65	1.73	0.97	1.69	2.29	0.98	1.11	
Innovation and Operational Perspective	Provide Criteria for minimum serviceability, minimum skid, maximum distress, minimum structural adequacy			3.16	2.30	1.12	1.46	3.63	0.98	0.88	
	Provide construction quality control			3.47	2.04	2.12	1.37	3.04	0.88	0.91	
	Encourage innovation in managing the pavement operations to improve the process of management			3.28	1.98	1.04	1.79	2.93	1.21	1.18	
	Provide instruments to measure performance and predict failures, materials for construction and repair			3.25	2.25	1.58	1.86	3.42	0.98	0.89	
	Allow the use of information systems and models to locate problems, and making in situ repairs and tests			3.25	2.30	1.23	1.58	3.30	1.33	0.88	
	Provide objectively based priority program to provide justification for budget requests			3.47	1.98	0.84	1.68	2.60	0.89	0.79	
	Provide precise inventory database design and operation			3.39	1.95	1.30	1.77	2.86	0.98	0.89	
	Monitor the efficiency and effectiveness of the works carried out			3.16	1.89	1.56	1.77	3.12	0.98	1.04	
	Provide a more systematic approach to identifying current and future road conditions and needs			3.28	2.16	1.56	1.74	3.18	1.09	1.11	
	Provide data to communicate agency decision impacts on pavement condition			2.98	1.75	1.42	1.82	2.67	0.84	0.98	
	Determine main causes of deterioration for each road			3.56	2.40	1.53	1.75	3.61	1.21	1.21	

Figure 7. QFD filled with perspectives relations scores *(Part 2)*

Now, using the QFD calculation, row by row, the researcher was able to calculate a number from which it was possible to show the importance of each vertical perspective. As an example, “providing clear inventory of country road network” perspective, the row results with the financial perspectives are shown in Figure 8:

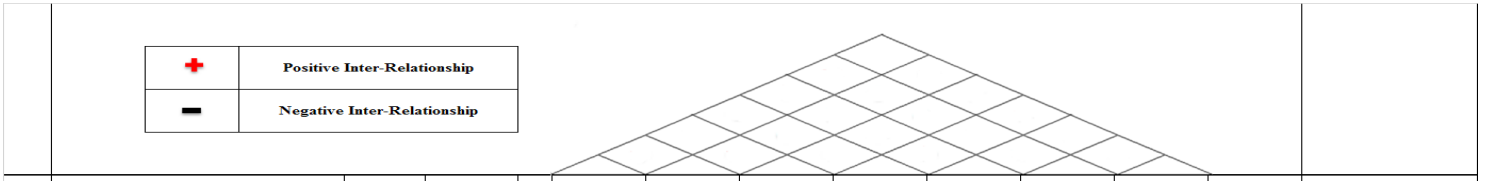
Directions of Improvement				↑	↑	↑	↑	↑	↑	↑		
				Financial Perspective								
				Reduce resources consumption	Reduce life cycle cost of pavement	Reduce or Eliminate end users lawsuits due to safety issues	Reduce cost of data collection	Reduce overall costs for maintaining and rehabilitating th road network	Reduce vehicles operating costs	Work out the Least Cost Solutions Considering Differen Alternatives		Ranking of Requirements / % of Ranking
	Ranking of Financial Requirements			5.43	5.47	4.87	3.70	5.28	4.05	4.20	33.00	
	% of Ranking			0.165	0.166	0.148	0.112	0.160	0.123	0.127	1.00	
Provide clear inventory of country road network				2.95	1.89	1.49	2.29	2.68	1.29	1.03		2.00

Figure 8. Filled QFD with ranking value of an objective

By multiplying the relation number by the percentage ratio of the financial perspectives and summing them:

{(2.95*0.165) + (1.89*0.166) + (1.49*0.148) + (2.29*0.112) + (2.68*0.160) + (1.29*0.123) + (1.03*0.127)} = 2

By doing the same calculation for all the vertical perspectives and calculating their percentage of importance, the researcher was able to complete the QFD as shown in Figure 9, Part 1 &2:



	Directions of Improvement			⬆	⬆	⬆	⬆	⬆	⬆	⬆					
				Financial Perspective											
				Reduce resources consumption	Reduce life cycle cost of pavement	Reduce or Eliminate end users lawsuits due to safety issues	Reduce cost of data collection	Reduce overall costs for maintaining and rehabilitating the road network	Reduce vehicles operating costs	Work out the Least Cost Solutions Considering Different Alternatives		Ranking of Requirements	% of Ranking		
		Ranking of Financial Requirements		5.43	5.47	4.87	3.70	5.28	4.05	4.20	33.00				
		% of Ranking		0.165	0.166	0.148	0.112	0.160	0.123	0.127	1.00				
Public Authorities Perspective	Provide clear inventory of country road network			2.95	1.89	1.49	2.29	2.68	1.29	1.03		2.00	3.60		
	Provide proactive maintenance schedule			2.74	2.72	1.49	1.58	3.46	1.40	1.03		2.16	3.89		
	Provide Pavement scoring system to rate condition of pavement			2.46	2.52	1.34	1.80	2.97	0.94	0.89		1.93	3.48		
	Comply with environmental and safety laws and requirements and improve their procedures			2.40	1.60	3.45	1.23	2.12	0.95	0.95		1.88	3.40		
	Provide accurate decision making techniques for pavement operations			2.94	2.35	1.60	1.68	2.71	1.40	1.11		2.04	3.69		
	Monitor the efficiency and effectiveness of the paved roads			2.68	2.42	1.80	1.75	2.89	1.31	1.03		2.06	3.71		
	Evaluate the consequences of delaying or postponing maintenance on future			2.52	2.42	1.58	1.42	3.38	1.12	0.85		2.00	3.60		
	Provide a sound basis for resource allocation and optimal use of funds			3.00	2.12	1.08	1.52	2.38	1.02	1.35		1.85	3.34		
	Increase the effectiveness of management and provide savings in expenditure			3.05	2.32	1.54	1.72	2.46	1.51	1.77		2.11	3.81		
	Reduce road congestion specially at peak periods			2.51	2.11	1.68	1.23	2.45	2.34	1.09		1.97	3.55		

Figure 9. Filled QFD with ranking values and percentages (*Part 1)*

Scheduling Perspective	Provide on-time future schedule for maintenance activities based on pavement type and condition.			3.24	2.37	1.37	1.65	3.39	1.18	0.74		2.09	3.78
	Provide a proactive operations system to avoid delay in maintenance causing disruption of end users daily activities			2.76	1.90	1.52	1.18	2.84	1.50	0.82		1.87	3.37
	Provide effective pavement inspection schedule			2.68	1.92	1.66	1.94	2.97	1.03	0.90		1.94	3.50
	Provide quick conditional scenarios for time-constraint pavement issues based on available funds, available human resources and equipments			2.94	1.56	1.18	1.76	2.29	1.02	0.95		1.73	3.11
	Identify pavement treatment timing			2.58	1.76	1.44	1.63	3.18	1.11	1.05		1.89	3.41
	Avoid consequences of delaying or accelerating a pavement treatment			2.32	1.89	2.15	1.31	2.97	0.98	0.79		1.85	3.35
	Monitor outcomes to evaluate whether the results are consistent with what was expected			2.65	1.73	0.97	1.69	2.29	0.98	1.11		1.68	3.04
Innovation and Operational Perspective	Provide Criteria for minimum serviceability, minimum skid, maximum distress, minimum structural adequacy			3.16	2.30	1.12	1.46	3.63	0.98	0.88		2.04	3.69
	Provide construction quality control			3.47	2.04	2.12	1.37	3.04	0.88	0.91		2.09	3.76
	Encourage innovation in managing the pavement operations to improve the process of management			3.28	1.98	1.04	1.79	2.93	1.21	1.18		1.99	3.59
	Provide instruments to measure performance and predict failures, materials for construction and repair			3.25	2.25	1.58	1.86	3.42	0.98	0.89		2.13	3.84
	Allow the use of information systems and models to locate problems, and making in situ repairs and tests			3.25	2.30	1.23	1.58	3.30	1.33	0.88		2.08	3.75
	Provide objectively based priority program to provide justification for budget requests			3.47	1.98	0.84	1.68	2.60	0.89	0.79		1.84	3.32
	Provide precise inventory database design and operation			3.39	1.95	1.30	1.77	2.86	0.98	0.89		1.96	3.54
	Monitor the efficiency and effectiveness of the works carried out			3.16	1.89	1.56	1.77	3.12	0.98	1.04		2.01	3.64
	Provide a more systematic approach to identifying current and future road conditions and needs			3.28	2.16	1.56	1.74	3.18	1.09	1.11		2.10	3.80
	Provide data to communicate agency decision impacts on pavement condition			2.98	1.75	1.42	1.82	2.67	0.84	0.98		1.85	3.34
	Determine main causes of deterioration for each road			3.56	2.40	1.53	1.75	3.61	1.21	1.21		2.29	4.13
												55.42	100.00

Figure 9. Filled QFD with ranking values and percentages (*Part 2)*

By calculating the percentage of importance as shown in last column of Figure 9 Part 1&2, the researcher now is able to prioritize and rank the objectives of the second dimension of the QFD, which are the objectives of the Public Authorities, Scheduling and Innovation & Operational perspectives as shown in Table 6:

Table 6 – Objectives Ranking of QFD 2nd dimension

Ranking	Perspectives	Description	% of ranking
1	I&O	Determine main causes of deterioration for each road	4.13
2	P	Provide proactive maintenance schedule	3.89
3	I&O	Provide instruments to measure performance and predict failures, materials for construction and repair	3.84
4	P	Increase the effectiveness of management and provide savings in expenditure	3.81
5	I&O	Provide a more systematic approach to identifying current and future road conditions and needs	3.80
6	S	Provide on-time future schedule for maintenance activities based on pavement type and condition.	3.78
7	I&O	Provide construction quality control	3.76
8	I&O	Allow the use of information systems and models to locate problems, and making in situ repairs and tests	3.75
9	P	Monitor the efficiency and effectiveness of the paved roads	3.71
10	P	Provide accurate decision making techniques for pavement operations	3.69
11	I&O	Provide Criteria for minimum serviceability, minimum skid, maximum distress, minimum structural adequacy	3.69
12	I&O	Monitor the efficiency and effectiveness of the works carried out	3.64
13	P	Evaluate the consequences of delaying or postponing maintenance on future budget needs	3.60

14	P	Provide clear inventory of country road network	3.60
15	I&O	Encourage innovation in managing the pavement operations to improve the process of management	3.59
16	P	Reduce road congestion specially at peak periods	3.55
17	I&O	Provide precise inventory database design and operation	3.54
18	S	Provide effective pavement inspection schedule	3.50
19	P	Provide Pavement scoring system to rate condition of pavement	3.48
20	S	Identify pavement treatment timing	3.41
21	P	Comply with environmental and safety laws and requirements and improve their procedures	3.40
22	S	Provide a proactive operations system to avoid delay in maintenance causing disruption of end users daily activities	3.37
23	S	Avoid consequences of delaying or accelerating a pavement treatment	3.35
24	P	Provide a sound basis for resource allocation and optimal use of funds	3.34
25	I&O	Provide data to communicate agency decision impacts on pavement condition	3.34
26	I&O	Provide objectively based priority program to provide justification for budget requests	3.32
27	S	Provide quick conditional scenarios for time-constraint pavement issues based on available funds, available human resources and equipment	3.11

28	S	Monitor outcomes to evaluate whether the results are consistent with what was expected	3.04

The above ranked outcomes will form the strategic objectives of the balanced scorecard three perspectives based on the importance of the financial perspective objectives of the pavement management. As shown above, the most important objective is to determine the main causes of deterioration for roads with a percentage ranking of 4.13%, which belongs to the Innovation and Operational perspective of pavement management. Focusing on improving and achieving the top objectives as listed above, the company will be able to achieve its financial goals as ranked based on the results of the survey.

Since the researcher has shown using his analysis the importance of the objectives that will lead to achieving the financial objectives as required, the company will be able to set specific initiatives and possible measures of each objective to reach its financial goals as ranked. Milestones for establishing the objectives is not studied in this thesis but it is highly recommended that each company related to pavement management should set time targets to accomplish the required objectives which will have definite frame to be achieved.

As for the house of quality, the top part of the QFD, the researcher has specified survey's questions 8 to 14 to conclude if there is a correlations between the financial perspectives, as per the people doing the survey. Taking the first financial perspective as an example, the survey question show results as per Table 7 & Figure 10:

Table 7 - Survey Results of Question no. 8

In pavement Management, kindly specify if there is a relation between the reduction of consumption of resources and the financial objectives (you may click more than one box):							
Answer Options	Reduction of life-cycle cost	Reduction or elimination of lawsuits due to safety	Reduction of cost of data collection	Reduction of maintenance and rehabilitation costs	Reduction of operating costs of vehicles	working out alternatives for least cost	Response Count
Reduction of consumption of resources	49	23	32	44	25	17	**72**
Relation response percentage	68%	32%	44%	61%	35%	24%	
			answered question				**72**
			skipped question				**4**

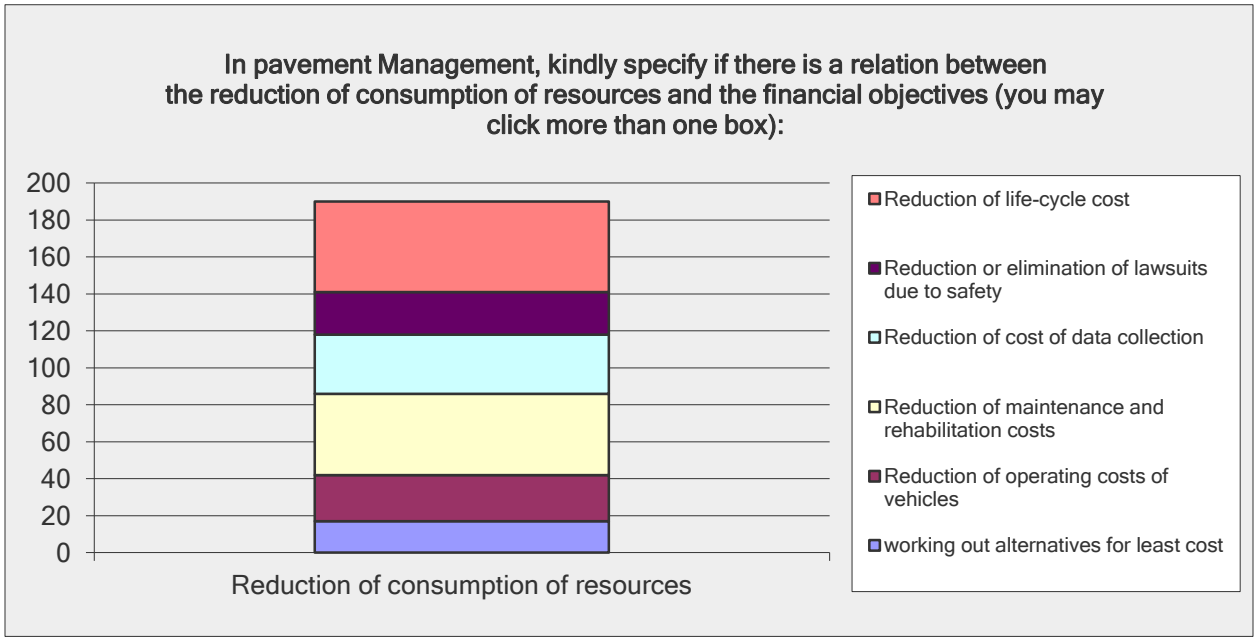


Figure 10. Distribution of responses for Survey Question no. 8

Analysing the results shown in Figure 10 and Table 7, the researcher has found a correlation between first financial perspectives and all remaining, where (49/72) 68% of people who did the survey think that there is a strong relation between "Reduction of consumption of resources" and "Reduction of life-cycle cost". As final result of the survey, people have chosen that there are correlations between all the financial objectives as shown in Figure 11. The reason behind that could be that all financial objectives are having the same direction of Improvement: it is just the result of a survey done by various people. Improving one objective could lead to improving another objective. Thus, the researcher has decided to do a cause-effect analysis to prove this point.

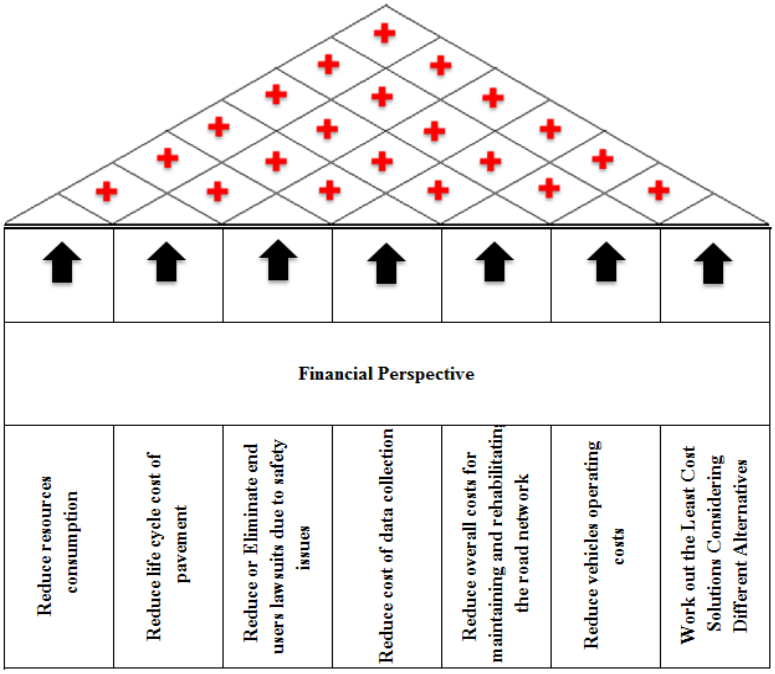


Figure 11. House of Quality with Financial Objectives Correlations

4.5 Cause & Effect Analysis:

It is possible that some objectives are interrelated meaning that the achievement of one objective might help in the achievement of another one. This is realized in the house of quality where we can see that, based on the survey conducted, all financial objectives have correlations and have all the same direction of improvement.

For showing the above purpose, the researcher established a Cause & Effect Relationships between the most important objectives of the four pavement perspectives showing that some objectives from different perspectives also are interrelated, where there accomplishment of one helps in accomplishing another to reach finally in achieving the financial objectives as expected.

To prove this point by analysis not only by common sense, the researcher has decided to show the different objectives in a modified fishbone diagram in order to clearly show that the improvement of a certain objective belonging to the three non-financial perspective can lead to the improvement of a financial objective. This modified fishbone diagram will not

be used to identify the possible causes of a certain problem: it will be modified by the researcher in a way to show some of the cause-effect analysis in a positive way proving that improvement of one objective might lead to the improvement of a major financial objective.

To make it simpler, the researcher has decided to use the four most important objectives of each perspectives as per their importance referred to Table 6. By choosing the top four objectives of each perspective including the financial one, the researcher was able to illustrate the cause-effect analysis by using a fishbone diagram as shown in Figure 12.

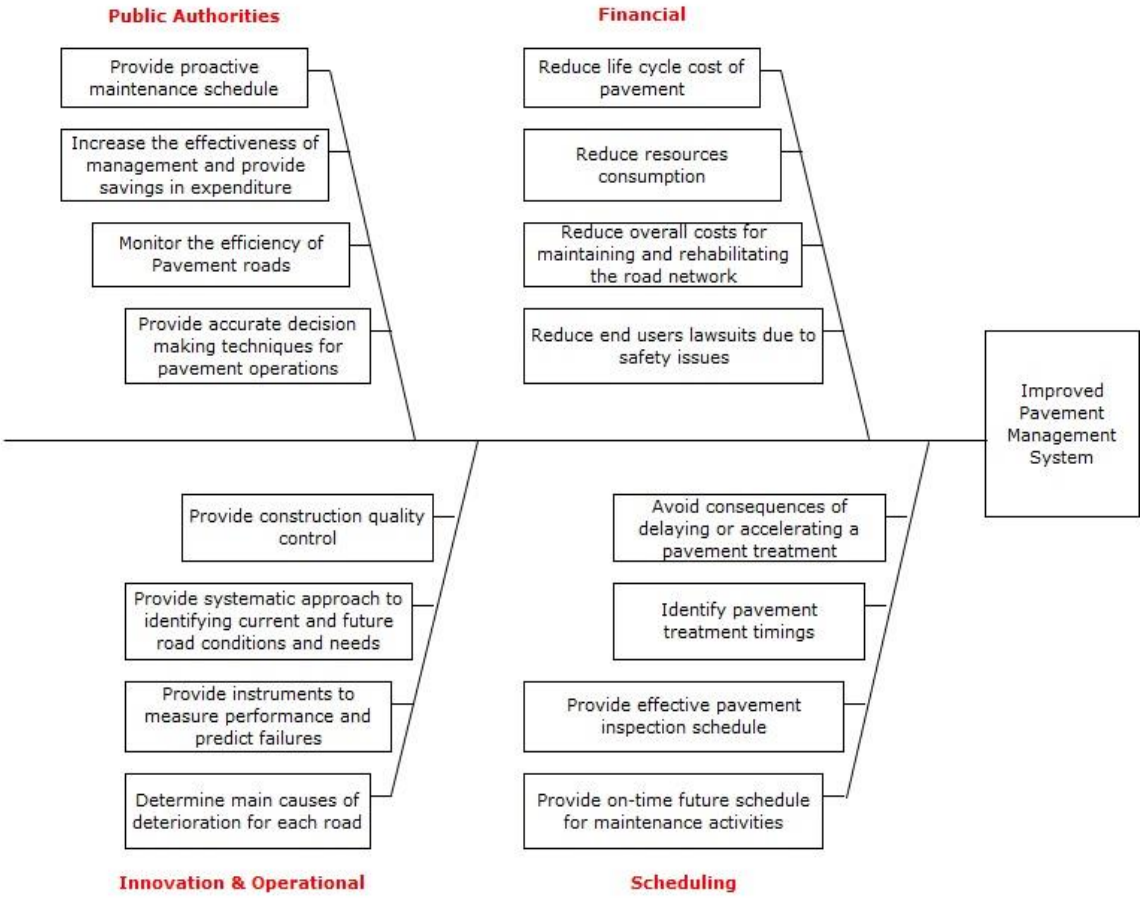


Figure 12. Modified Fishbone diagram with Pavement Management Perspectives & Objectives

To improve the pavement management system, there must be a focus on the top 16 objectives of the four perspectives. This fishbone diagram can be studied in a more detailed analysis to eliminate some of the objectives that are, by improving them, achieving the same results of achieving another objective. To give an example on that, the researcher has translate the fishbone diagram into a more simple modified cause-effect diagram where the researcher has shown the correlations (linkages) between different objectives from different perspectives that are so connected.

Some of those possible Cause & Effect linkages as per the analysis of the researcher, shown in Figure 13:

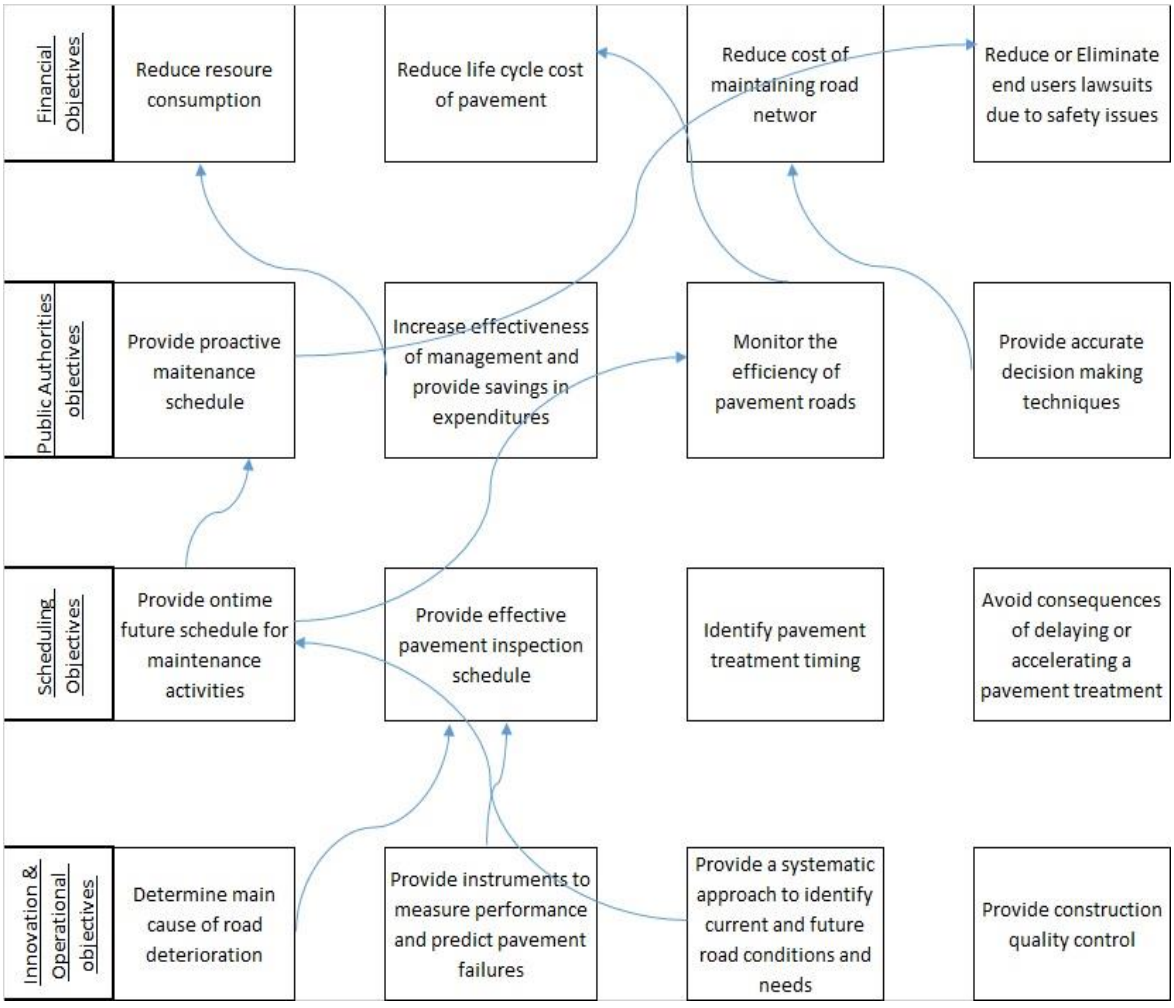


Figure 13. Cause-Effect Diagram showing Pavement Perspectives top ranked objectives

From this cause-effect linkages for example, the researcher can see that achieving the objective of providing a systematic approach to identify current and future road conditions needs will help in achieving the objective of providing ontime future schedule for maintenance activities which will help in achieving the objective of monitoring the efficiency of pavement roads leading to the achievement of the most important objective which is financial, which is reducing life cycle cost of pavement. This can be studied in detailed manner to achieve some eliminations in the objectives but that is not part of this thesis subject.

CHAPTER 5: RECOMMENDATIONS & CONCLUSIONS

5.1 Summary

The objective of this paper was to find a new analysis to be used in pavement management in order to prioritize the different objectives of the four different perspectives of the pavement management by starting with ranking the financial objectives which are considered to be the main achievement in order to achieve a total improved pavement management system. The main challenge was to identify the right objectives of each perspectives and then eliminate them to the maximum possible to make the researcher paper it logical and fruitful. The second challenge was to find a good number of expert people who are working for the pavement or construction industry to fill the survey which was not a simple one due to the load of information related to this paper subject. The analysis of this paper was validated once the researcher has come up with the ranking of all objectives with relation to the ranking of the financial ones as shown in Figure 10. The results are very logical although results are related to the survey which was filled by various people from various fields who have different opinions and answers when it comes to a subject like pavement management.

The results of the research benefits the decision makers working in the pavement management field, whether clients, contractors or consultants, by providing them with a detailed analysis allowing them to focus on certain objectives more than others which will help them achieving their financial goals, which means achieving better profit leading to business growth and expansion. The last analysis used, which is the modified fishbone diagram can be also a great tool to the pavement management industry in finding the main objectives leading to the major achievement of the industry.

5.2 Contribution of current research study to the academic field

Balanced scorecard has been modified and used with the QFD as a methodology in the manufacturing field and in engineering design of structural construction projects but not in

pavement management earlier. It is believed by the researcher that it is the first research where application of modified scorecard and QFD are used as a framework in pavement management to define various perspectives, objectives and rank them based on the most important perspective goals. There have been various studies using a modified scorecard and QFD in other industries like construction of a project as reported in the literature review where scorecard and QFD were modified in a very different way as done by this paper researcher.

5.3 Limitations and Recommendations for future research

This study has its limitations as it is done on a small sample of population. Similar studies need to be undertaken in other countries. A judgmental sample limits the scope of this study. Future research should attempt to utilize our findings and also look into other objectives related to pavement management. The researcher use for QFD was limited to two phases out of the four phases of a normal QFD: the QFD was modified for the sake of this research goal. Another limitation is the main focus on the objectives shown in the scorecard. Measures, targets and initiatives were not studied in this research study. The main goal was to define on the main objectives of the four pavement perspectives in order to prioritize them using the modified methodologies used by the researcher.

This pavement management analysis can still be improved on future versions by working closely from enterprises who are more experts in the pavement management sector that might allow more findings in terms of objectives and perspectives. The purpose of the researcher is not to minimize the significance of any previous work in anyway, but rather to focus the light on the importance of the methodology in ranking and focusing on achieving some objectives over others of different perspectives related to the pavement management. The same analysis can be used in different industries, not necessarily the pavement management. It is an analysis that helps in ranking the different objectives based on the initial objectives ranking of the most important perspective in order to achieve the major goal.

5.4 Last word

The proposed pavement management framework could be an appropriate successful tool and support to companies working in this field to be able in effectively defining, selecting the perspectives and objectives of pavement management, ranking them from most important to least important so that the main goal of the company is clear and focused on prioritizing some goals over others. This framework might also be a right tool in defining the initiative and performance measurements leading in achieving the top important objectives.

References:

Akao, Y. (2004). *Quality function deployment*. 1st ed. Cambridge, Mass.: Productivity Press.

Hunt, R. and Killen, C. (2004). *Best practice quality function deployment (QFD)*. 1st ed. Bradford, England: Emerald Group Publishing.

Lal, H. (2008). *Organizational excellence through total quality management*. 1st ed. New Delhi: New Age International (P) Ltd., Publishers.

Madruga, K. (2001). *Balanced score card perspectives*. 1st ed. Bremen: Univ. Bremen.

Ahmed, S.M., Pui Sang, L. and Torbica, Z.M. (2003) Use of quality function deployment in civil engineering capital project planning. Journal of Construction Engineering and Management, 129(4), 358–68.

Akao, Y. (1990), Quality Function Deployment: Integrating Customer Requirement into Production Design, Productivity Press, Cambridge, MA.

Bardeesi, M. and Attallah, Y. (2015).ECONOMIC AND ENVIRONMENTAL CONSIDERATIONS FOR PAVEMENT MANAGEMENT SYSTEMS. *European Scientific Journal*, 11(29).

Creative Industries research institute, (2017). *http://www.fme.aegean.gr/sites/default/files/cn/quality_function_deployment.pdf*. 1st ed.

Delgado-Hernandez, D.J. and Aspinwall, E.M. (2007) Quality planning improvement methods in the UK and Mexican construction industries. Quality and Reliability Engineering International.

Dennis, E. and Spulber, A. (2016). PERFORMANCE-BASED PLANNING AND PROGRAMMING FOR PAVEMENT MANAGEMENT. *Michigan Department of Transportation*.

Hudson, M., Smart, A. and Bourne, M. (2001). "Theory and practice in SME performance measurement systems", *International Journal of Operations and Production Management*, Vol. 21, No. 8, 1096-1115.

Huovila, P., Lakka, A., Laurikka, P. and Vainio, M. (1997) Involvement of customer requirements in building design,in Alarcon, L. (ed.) Lean Construction, Balkema,Rotterdam, pp. 403–16.

Ip, Y.K. and Koo, L.C. (2004) 'BSQ strategic formulation framework: a hybrid of balanced scorecard, SWOT analysis and quality function deployment', Managerial Auditing Journal', Vol. 19, No. 4, pp.533–543

Kamara, J.M., Anumba, C.J. and Evbuomwan, N.F.O. (2000) Establishing and processing client requirements: a key aspect of concurrent engineering in construction. Engineering, Construction and Architectural Management, 7(1), 15–28.

Kaplan, R. S. and Norton D.P., (2001). "Transforming the balance scorecard from performance

KASAHARA, A. (2005). DEVELOPMENT OF ASSET MANAGEMENT SYSTEMS BASED ON CONCEPT OF PAVEMENT MANAGEMENT SYSTEMS. *JOURNAL OF PAVEMENT ENGINEERING, JSCE*, 10, pp.K1-K4.

Koo, L.C. (1998) 'Building balanced scorecard on the house of quality', The 1st Industrial Engineering and Management (IEM) Symposium Transformational Strategy Towards the 21st Century, Hong Kong.

Lee, S.F. and Lo, K.K. (2000) 'Strategy formulation framework for vocational education: integrating SWOT analysis, balanced scorecard, QFD methodology and MBNQA education criteria', Managerial Auditing Journal, Vol. 15, No. 8, pp.407–423.

Lee, S.F. and SaiOnKo, A. (2000) 'Building balanced scorecard with SWOT analysis, and implementing Sun Tzu's the art of business management strategies on QFD methodology', Managerial Auditing Journal, Vol. 15, Nos. 1/2, pp.68–76.

Leung, L.C., Lam, K.C. and Cao, D. (2006) 'Implementing the balanced scorecard using the analytic hierarchy process and the analytic network process', Journal of the Operational Research Society, Vol. 57, No. 6, pp.682–691.

Li, Y.L., Chin, K.S. and Luo, X.G. (2012) 'Determining the final priority ratings of customer requirements in product planning by MDBM and BSC', Expert Systems with Applications, Vol. 39, No. 1, pp.1243–1255.

Li, Y.L., Huang, M., Chin, K.S., Luo, X.G. and Han, Y. (2011) 'Integrating preference analysis and balanced scorecard to product planning house of quality', Computers & Industrial Engineering, Vol. 60, No. 2, pp.256–268.

Luhr, D. and Rydholm, T. (2015).ECONOMIC EVALUATION OF PAVEMENT MANAGEMENT DECISIONS. In: *9th International Conference on Managing Pavement Assets*. Alexandria.

MACTEC Engineering and Consulting, Inc., (2011). *Pavement Management Practices in State Highway Agencies: Madison, Wisconsin Peer Exchange Results*. Federal Highway Administration.

Mallon, J.C. and Mulligan, D.E. (1993) Quality function deployment: a system for meeting customers' needs. Journal of Construction Engineering and Management, 119(3), 516–31.

measurement to strategic management: Part 1", *Accounting Horizons*, Vol. 15, No.1

Oswald, T.H. and Burati, J. (1992) Identifying Customer Requirements through Quality Function Deployment: Phase I: Feasibility Study, Construction Industry Institute, Austin, TX.

Pheng, L.S. and Yeap, L. (2001) Quality function deployment in design/build projects. Journal of Architectural Engineering, 7(2), 30–9.

SaiOnKo, A. and Lee, S.F. (2000) 'Implementing the strategic formulation framework for the banking industry of Hong Kon', Managerial Auditing Journal, Vol. 115, No. 9, pp.469–477.

Santos, J., Ferreira, A. and Flintsch, G. (2014). A life cycle assessment model for pavement management: road pavement construction and management in Portugal. *International Journal of Pavement Engineering*, 16(4), pp.315-336.

SEMBADA, A. (2006). *SCORECARD APPROACH TO PERFORMANCE MANAGEMENT IN A STATE-OWNED TOLL ROAD OPERATOR*.MASTER OF ENGINEERING.NATIONAL UNIVERSITY OF SINGAPORE.

Shino, J. and Nishihara, R. (1990) Quality development in the construction industry, in Akao, Y. (ed.) Quality Function Deployment (QFD): Integrating Customer Requirements into Product Design, Productivity Press,Portland, OR, pp. 263–97.

Tan, B.L., Tang, N.K.H. and Forrester, P.L. (2004) 'Application of QFD for e-business planning', Production Planning & Control, Vol. 15, No. 8, pp.802–818.

Uhlmeyer, J., Luhr, D. and Rydholm, T. (2016). *Pavement Asset Management*.

Woldesenbet, A. and Jeong, H. (2014). Highway Data Quality Report Card (HDQRC): A Conceptual Framework of Pavement Management Data. *Construction Research Congress*.

Wolters, A. and Zimmerman, K. (2011). *IMPLEMENTING PAVEMENT MANAGEMENT SYSTEMS FOR LOCAL AGENCIES - STATE-OF-THE-ART/STATE-OF-THEPRACTICE*.CIVIL ENGINEERING STUDIES.Illinois Center for Transportation.

Bryman, A. and Bell, E. (2011). Business research methods. 1st ed. Cambridge: Oxford University Press.