An integrated model for auditing construction projects

A Case study of Oil and Gas projects in Iran

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M.A.SC. Thesis

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In Partial Fulfillments of the Requirements for the Degree of M.A.Sc in

Civil Engineering

Ottawa-Carleton Joint Institute of Engineering Faculty

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ACKNOLEGMENT

First, I am grateful of The Almighty God for providing me this opportunity and granting me the capability to proceed successfully.

I would like to gratefully and sincerely thank my supervisor Dr. Ahmad Jrade for his supports, patience, and advice, and valuable technical comments during the entire work.

Furthermore I would like to thank my mother and father who always encouraged me during my study period.

I would like to give special thanks to my wife for her support, patience, and love that were undeniably the bedrock upon which the past fifteen years of my life have been built.

I would like to thank the Department of Civil Engineering of University of Ottawa especially those members of the committee for their input, valuable discussions, and accessibility.

Also, I like to thank the participants in my research, who have willingly shared their precious time, knowledge, and experience.

Abstract

Nowadays, organizations implement projects for many purposes. Using the project as a strategic success factor for project-oriented companies is continuously increasing. However, most of the time, the results are not the same as planned. Some projects fail to achieve their objectives; others are canceled, whereas on some other cases, companies have to re-plan their strategy. Project-oriented companies know that maintaining an ideal and logical balance between the project's time, cost, and quality constraints can vastly guaranty project success. Therefore, they should switch from traditional project management to modern and advanced project management methodology, which improves project performance and efficiency over its life cycle. One of the most applicable tools used to assess and monitor project performance and thus finding the associated issues is Project Audit, which is a comprehensive and organized assessment of the effectiveness and efficiency of project performance, management, and compliance. In this research, an integrated project audit model is presented that incorporates a detailed design module, which shows the structure of the model, questionnaire module, and a scoring module. The model is developed as an integrated project audit application where the user is easily able to select, plan, implement, and report a project audit. The model's output consists of two parts: 1) a comprehensive report that shows the project situation in five main project processes and nine project functions. This report presents the project's score in a specific function and its related process (i.e., planning cost or closing procurement); 2) useful analytical reports and graphs of the project performance. In this part, the model compares the project's planned and actual time and cost, calculates their variances, and forecasts the final cost and time based on the current performance. The model is validated by using an actual Oil and Gas project to test its workability and capabilities. Three groups will benefit from this model; 1) owners; 2) project managers and

project team; 3) general contractors and construction companies. The model helps project owners to identify problems early on and reduce project waste in terms of time, effort, material and costs. Moreover, it provides owners the opportunity to identify the project performance from the cost and time constraints. Also, after using this model, project managers and project team have a list of findings that need to be addressed to enhance the overall project performance. The various reports of the model not only provide detail information about project constraints (time, cost, and quality) but it also present valuable analysis related to other aspect of the project (i.e. risk, scope, and communication) which are very useful for the project team. Furthermore, the developed lessons learned from the project can be documented with this model, which is very useful for general contractors and construction companies in future projects.

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Glossary

ACWP	Actual Cost of Work Performed
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
CMMI	Capability Maturity Model Integrated
CSF	critical success factors
CV	Cost Variance
EFQM	European Foundation for Quality Management
EVM	Earned Value Method
GPM	German Association Model for Project Management
IPMA	International Project Excellence Award
KPA	Key Performance Area
KPI	Key Performance Indicators
KPM3	Kerzner Project Management Maturity Model
MADM	Multiple Attributes Decision Making
MPP	Measuring Project Performance Tool
OGC	Office of Government Commerce
OPM3	Organizational Project Management Maturity Model
P2MM	Prince2 Maturity Model
P3M3	Portfolio, Programme & Project Management Maturity Model
PD	Process definitions
PEM	Project Excellence Model
PHC	Project Health Check

PHT	Project Health Check Tool
PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
PMO	Project Management Office
PMP	Project Management Professional
PP	Process Practice
PQC	Practice Questionnaire Corporate
SEI	Software Engineering Institute
SPI	Schedule Performance Index
SV	Schedule Variance
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
TQM	Total Quality Management

Chapter One

Introduction

1.1. Background

Nowadays, using the project as a strategic success factor is continuously increasing; this proves the importance of projects. Organizations use projects for many purposes but these projects do not always have the planned results. Some projects fail to achieve their objectives, some projects are cancelled, and in other cases organizations have to re-plan the project strategy. It is rare to find a successful project in which the results are better than what was planned. Lack of efficiency in planning the project deliverable may impose a higher cost and more resources. Poorly-defined quality and specifications result in a low level of project quality. Project-oriented organizations have many challenges to manage projects correctly and to achieve their predetermined objectives. They know that maintaining an ideal logical balance among project constraints such as time, cost, and quality can vastly improve the chances of project success. In order to save time, reduce costs, and improve quality in projects, organizations are aware of the importance of switching from traditional project management methods to modern, scientific, and up-to-date project management methodologies, which improve project performance and efficiency during the whole project life cycle. Using different tools and techniques such as project control methods, risk management methodologies, cost management applications, value engineering techniques, etc., have the potential to aid the critical role of construction management. Because of the huge amount of investment in infrastructural projects (i.e., oil and gas, roads, dams, and buildings) around the world, organizations should not only use valid standards, rules, and

regulations for projects but they must also always assess the outcome of their projects. In this research the focus is on the type of project named “Oil and Gas Projects” in Iran.

One of the most useful tools by which project-oriented organizations can assess their project success, find project’s issues, and monitor its performance is the “Project Audit.” In the literature, an audit is defined as a systematic, integrated, and independent assessment to determine the level of achieving project requirements and progress. A project audit is an assessment of the effectiveness and efficiency of project performance, management, and compliance. A construction project audit is a detailed evaluation of all its functions in order to find the project concerns, issues, and challenges so a set of corrective actions can be provided. A project audit can be formal or informal. Also, it may be quick or comprehensive. It can be done anytime during the project life cycle including the conception stage, the implementation stage, or the closing stage. Finding the reasons for uncomfortable symptoms is the primary purpose of a project audit. This audit may be done by asking the project team simple questions such as:

- Are you being told the truth about the current status of the project?
- Is the project going to deliver something that meets its requirements?
- Is the project management approach being used appropriately?
- Should you believe the project plan?
- Is the project organised appropriately, and are the project processes being fully followed?
- What should be done to improve the project performance?

The output of a project audit should answer these questions. The main achievement of a project audit is the identification of the lessons learned, resulting in a positive impact on project performance. Also, an audit provides an opportunity to improve the performance of future

projects by avoiding repeating the same errors and mistakes. In this case, for project-oriented organizations, project audits are highly beneficial because of the following outcomes:

- Defining project success factors such as being on-time, being on-budget, having acceptable quality, satisfying stakeholder expectations, etc.
- Defining a corrective action plan that may address current problems and enhance the likelihood of success in future projects
- Providing a valuable source for risk management because all issues and concerns mentioned in a project audit report are the project risks
- Identifying the lessons learned on the project, which can be applied in future projects within the organization.
- Providing recommendations to prevent potential problems and challenges.
- Developing documents of the project lessons learned that are beneficial for the organization and its subcontractors.
- Providing a snapshot of the current situation of the project that says whether the project is on-track or off-track.
- Showing the project performance trend, especially for long term projects, such as oil and gas, which take more than 5 years, by doing periodic project audits.
- Identifying both the opportunities and the risks of the project.

1.2. Research Objectives

Because huge amounts of work, time, and money are spent in the construction of projects, it is very important to know that the project meets its predetermined objectives and to ensure its success. Although the term “project audit” may have a negative connotation to it, especially for the project team undergoing it, a project audit will result in a positive outcome, whether a project manager and his/her team passes or fail it. The objectives of this research are based on actual

problems (i.e. delay, over budget, quality, resources, and project management) that face organizations and project team during the project life cycle. The main objective of this research is to develop an integrated project audit model with several modules for construction projects, which can be used as a tool during the project implementation. The proposed model can be applied in any construction project regardless of its location. It reports the status of project processes and project functions, and measures their performance. The sub-objectives of the research are:

- Study and evaluate the different methods (i.e. project maturity model, project measurement performance) used to assess construction projects.
- Identify advantages and disadvantages of current project audit tools and models.
- Determine the critical factors (i.e. process, function, performance indices) which affect construction project results.
- Developing an automated tool, which can be used during construction implementation to assure the quality of project implementation and project management methodology, identify project risks and issues, and document the lessons learned.
- Developing an integrated project audit model that can be used in construction projects despite of the project location, size, and duration.

1.3. Methodology

To accomplish all the above listed objectives the following steps need to be taken:

1.3.1. Literature Review

A review related to construction project processes and functions, project success factors and project management methodology are necessary. Furthermore, a comprehensive review of project audits and project maturity models must be conducted.

1.3.2. Data Collection

Because this integrated project audit model stores and analyses the project's data, collecting accurate and updated data is a very important step for this research. The data was collected from real Oil and Gas construction projects implemented in Iran between 2011 and 2014.

1.3.3. Analysing project audit and improvement models

After reviewing the project audit and improvement models, these will be analysed. This analysis is divided into two parts; 1) identifying the advantages and disadvantages of each model; 2) ranking the models based on their advantages. Then, several advantages and disadvantages have been identified for each model. The advantages will be included in the proposed model while the disadvantages will be excluded.

1.3.4. Model development process

The new project audit model will be developed through three phases: 1) developing the conceptual model; 2) developing the detail model; and 3) developing a scoring system for the model. In the conceptual model, the main structure of the project audit model will be designed. In the detail model, selected aspects (process, function, and progress) of the project are described and categorised for measurement. A scoring model is needed to be designed to calculate the score of the projects after the audit.

1.3.5. Model Validation

To validate the capability and workability of the developed model and its results, a real Oil and Gas project is audited by using the developed model. The project is a Refinery Gas Pars which has a starting date of October 2011 and a finishing date of October 2015.

1.4. Thesis Organization

This thesis consists of six chapters. A brief description of each chapter is provided as follows:

- Chapter Two: This chapter present a comprehensive literature review of the research which is divided into two main parts: 1) construction project management methodology, 2) project audit and improvement models. The first part focuses on project management methodology and related subjects (i.e. project processes, functions, life cycle, project team organization). This part helps us to understand the methodology used to manage construction projects and describes its critical elements. The second part provides a comprehensive review of different project audit and improvement models. This is achieved by identifying the advantages and disadvantages of each model to be considered during the development of the proposed model.

- Chapter Three: This chapter describes the methodology that has been used to develop the proposed project audit model, clarify its components, and show the data flow.

- Chapter Four: This chapter illustrates the development process of the proposed project audit model and shows the main steps that have been followed.

- Chapter Five: In this chapter the capability and workability of the developed project audit model is examined by using a real Oil and Gas project.

- Chapter Six: This chapter consists of the thesis conclusion and the list of recommendations. Also, some future expansions have been suggested as well as limitations of the current research is provided.

Chapter Two

Literature Review

2.1. Introduction

One of the important knowledge areas in project management is performance management, which will be more vital if it is integrated with other sciences (i.e. project performance management). There is lots of research works related to project Key Performance Indicators (KPI) that are only concern about the output of the projects (Atkinson, 1999). However, a project audit provides the opportunity for the project team, especially the project manager and project sponsor, to find the problems, concerns, and challenges that are raised during the project life cycle including design, implementation, and turn over. The audit increases the chance for the project team to uncover what has gone well and what needs to be dealt with as soon as possible to successfully complete the project. Therefore, a deep understanding of the project and its related subjects is a vital factor in implementing the project audit.

The first part of this chapter will focus on construction projects and related literature (i.e. project process, function, life cycle, team, and organization). Also, project management knowledge will be reviewed briefly. Furthermore, earned value technique and its importance to the project during implementation will be checked as well. The second part highlights reviews of the project audit with the concentration on construction projects. Some important models for project audit and improvement will be reviewed from several aspects (i.e. having an understandable process, scoring system, questionnaire) to find the advantages and disadvantages of each model.

2.2. Fundamentals of the Project

A project is “a temporary endeavor undertaken to create a unique product, service, or result” (PMBOK, 2012). According to Spinner (1997), a project has several distinguishing characteristics, which are: 1) well-defined objectives; 2) specified product or result; 3) no repetitive endeavour; and 4) limited sources to consume. There is a significant difference between “project” and other similar words such as “operation.” They may seem similar because both “project” and “operation” are performed by people, use limited resources, and need to be planned, executed, and controlled.

However, according to the Michigan Office of Project Management, there are three specific characteristics for every project: temporary, unique, and progressive elaboration. They are temporary because every project has a finish time. They are unique because the product or service of every project is different from those of others although they may have a similar platform. Progressive elaboration integrates the two prior characteristics and means that the project will be developed step by step and in detail (Woodward, 1997).

Construction projects not only meet the definition of projects but also contain a high degree of risk related to time and cost. Although an oil and gas refinery project may have similar engineering specifications and may need the same types of equipment, during the construction phase, it has specific uncertainties about its constraints, time, cost, and quality. For example, construction projects may require additional technology to install a specific unit (i.e. slug catcher) that needs an additional contract, budget, and schedule (Woodward, 1997).

Moreover, because there is no way to make a prototype for a construction project, the project design needs to be done in the initial step. Because a construction project always has one or more deliverables, such as refinery, dam, highway, etc., the geographical location and the environment of the project’s site must also be considered. In addition, due to the size, complexity, and type of

construction projects, more than one group of individuals such as managers, engineers, technicians, and workers, or more than one organization may be involved.

Project management is the art and skill of achieving project goals through the project implementation while considering available resources and several constraints. Spinner (1997) defines project management in this way: “managing and directing time, materials, personnel/labor, and costs to complete a project in an orderly and economical manner and to meet the established objectives of time, costs, and technical and/or service results”.

Spinner (1997) believes that a project needs three important tasks to be managed; planning, scheduling, and controlling. Therefore, the main goals of managing a project are: 1) requirements identification; 2) consideration of all stakeholders’ concerns and expectations during the project planning and executing, to achieve project objectives; and 3) addressing project constraints such as time, cost, quality, human resources, etc. (Woodward, 1997). Although knowledge areas such as cost, time, quality, procurement, risk, scope, integration, communication, and human resource are common among all types of projects, in construction projects there are some additional areas which also need to be managed such as safety, claim, and environmental effects.

Project management is essential to monitor project constraints during the construction process. For instance, when there is a need to reduce project time, the first reaction should be to increase the project budget. If the project budget is limited, project scope may be affected and changed.

There are five main groups of processes for every project which can also be used for construction projects: 1) Initiating; 2) Planning; 3) Executing; 4) Monitoring and Controlling; and 5) Closing Process Groups as shown in figure 2.1.

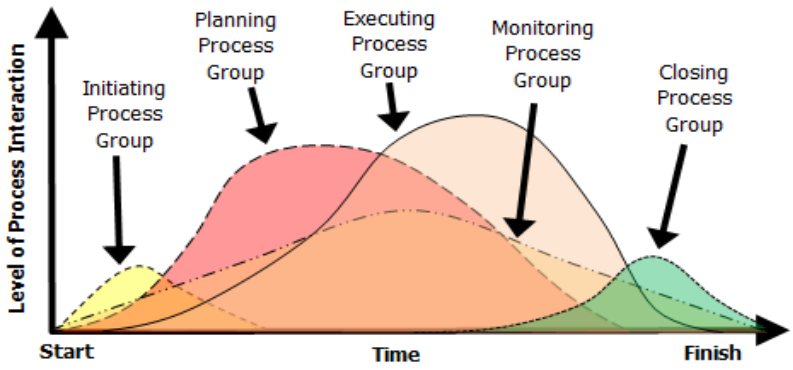


Figure 2.1: Process groups interact in a construction phase or project, Source: Construction Extension of PMBOK (2007)

These processes are sequential activities, but in most projects, especially construction projects, they overlap. Each process has its own outcomes that affect later processes. For instance, when basic design is finished, the client or project sponsor must approve the result and accept the design documents.

2.2.1. Project Functions

A project function includes a set of tasks, concepts, and sometimes definitions making up the project management field. These functions are mostly defined based on few factors: 1) project type (i.e. construction, IT, research and development, etc.); 2) size (i.e. small, medium, or large), and 3) complexity (i.e. simple or complex). However, project functions are relatively similar in every project. Woodward (1997) defined cost, time, scope, and quality as project functions. Spinner (1997) considered integration, risk, procurement, human resources, and communication as project functions in addition to what Woodward already had defined. Three years later, in 2000, the Project Management Institute (PMI) published a guideline, Project Management Body of Knowledge (PMBOK), in which a set of functions were defined as a standard for many projects. Construction Extension of Project Management Body of Knowledge (2007) added

safety, environment, finance, and claim to the other nine functions that Spinner had defined. Figure 2.2 shows the project functions' changes during the two decades.

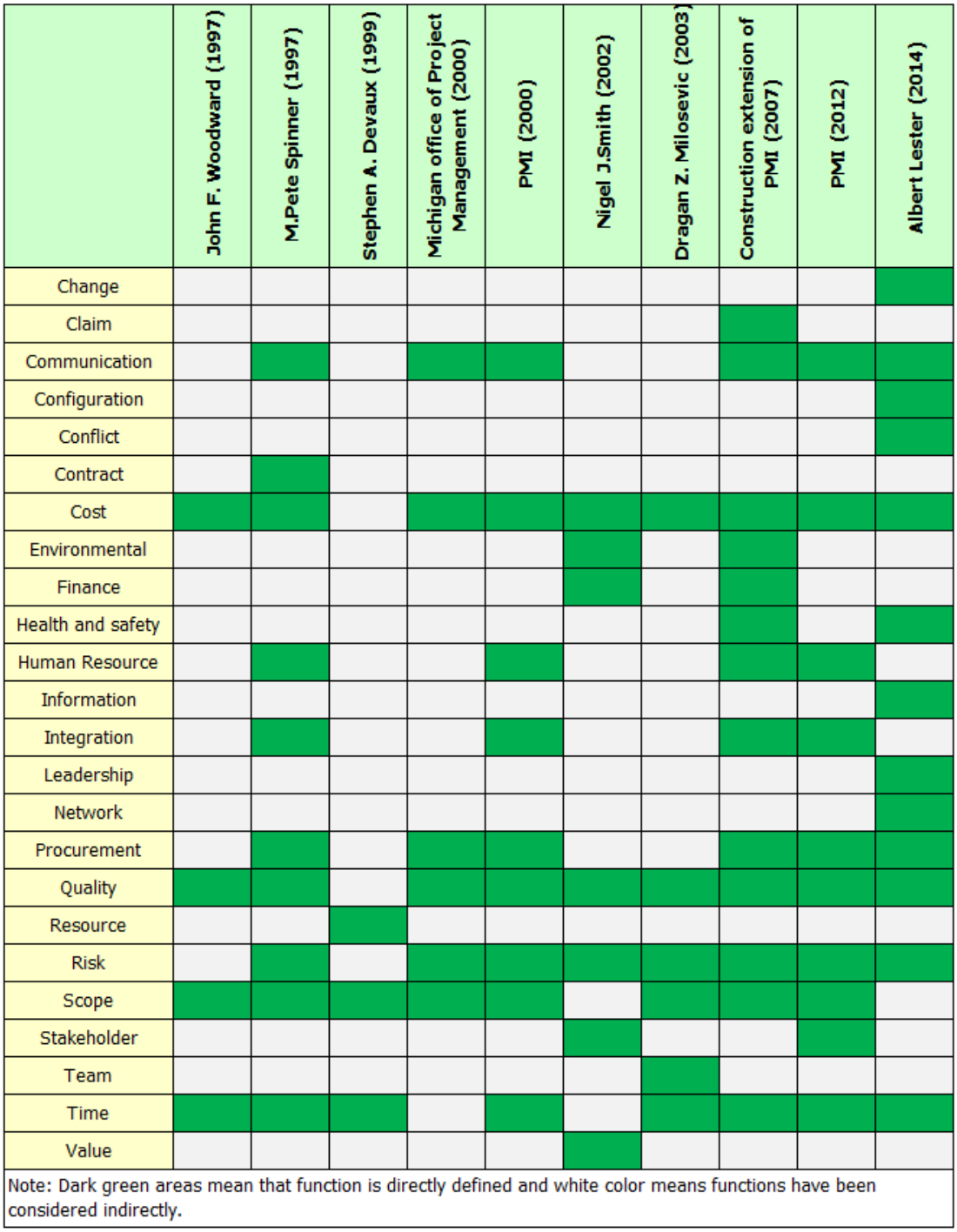


Figure 2.2: Comparing project management functions

2.2.2. Project Team Organization Form

Another aspect of the project that should be reviewed is organizational form of the project. Organizational structure affects a project in two ways: 1) it has a strong effect on resource availability (i.e. human resources); 2) it may influence project implementation approach according to project management authority. There are three main groups of project organizational structures in the project management literature; 1) functional; 2) matrix (weak, balanced, and strong); and 3) projectized. Table 2.1 represents the difference in these groups based on five project characteristics.

In the functional organization, staff members work in a specific group based on their speciality, for example accounting, engineering, or construction, and each group may be divided into some other detail categories such as electrical, process, or pipeline engineering, but they work completely independently of each other. A matrix organization, which is classified as weak, balanced, or strong has a combination of functional organization and project-oriented structure.

Table 2.1: Influence of organizational structures on projects, Source: PMBOK (2012)

Organizational Structure / Project Characteristics	Functional	Matrix			Projectized
		Weak Matrix	Balanced Matrix	Strong Matrix	
Project Manager's Authority	Little or None	Low	Low to Moderate	Moderate to High	High to Almost Total
Resource Availability	Little or None	Low	Low to Moderate	Moderate to High	High to Almost Total
Who manages the project budget	Functional Manager	Functional Manager	Mixed	Project Manager	Project Manager
Project Manager's Role	Part time	Part time	Full Time	Full Time	Full Time
Project Management Administrative Staff	Part time	Part time	Part time	Full Time	Full Time

A weak matrix organization is very similar to functional because it has most of the functional characteristics. There is no real project manager, or project expediter. The project coordinator has the authority to make decisions and he or she reports to a high-level manager. On the other hand, a strong matrix organization is very similar to a projectized organization because it has most project-oriented characteristics. As shown in Table 2.1, a projectized organization gives the maximum authority to project managers and all resources are used to serve projects.

2.3. Construction Project Life cycle

According to Lester (2014), most construction projects pass through a different life cycle based on the project type, complexity, and size. He divided this life cycle into eight main sequences as following:

1. Concept: includes basic ideas, business case, statement of requirements, scope of the project,
2. Feasibility: consists of tests for technical, commercial, and financial viability, technical studies, and investment appraisal,
3. Evaluation: includes application for funds and stating risks,
4. Authorization: includes approvals of permits to start the project, all conditions, project,
5. Implementation: consists of design development, procurement, fabrication, installation, and commissioning,
6. Completion: covers performance tests, handover to client, post-project appraisal,
7. Operation: includes revenue earning period, production, and maintenance of the project, and
8. Termination: includes close-down, decommissioning, and disposal of the project

Construction projects, regardless of their size, type, or complexity, have four main periods in their life cycle: 1) beginning the project, 2) arranging and setting up, 3) carrying out the project work, and 4) finishing the project (Chou, 2012). First, the need to construct a new facility or renovate/improve of an existing facility is determined by the owner. To determine what exactly the project should be and clearly understand its viability and profitability, a basic and detail study is conducted by designers. The study should include some input from the contractor if possible. One important specification of a project life cycle is the cost and staffing level has the lowest level at the beginning of the project, which increases during the project implementation and drop sharply at the closing stage as shown in figure 2.3. For this reason, a project audit will be more efficient and effective if applied as early as the project starts because any change at the starting point does not have significant impact, but it will increase while the project is implemented.

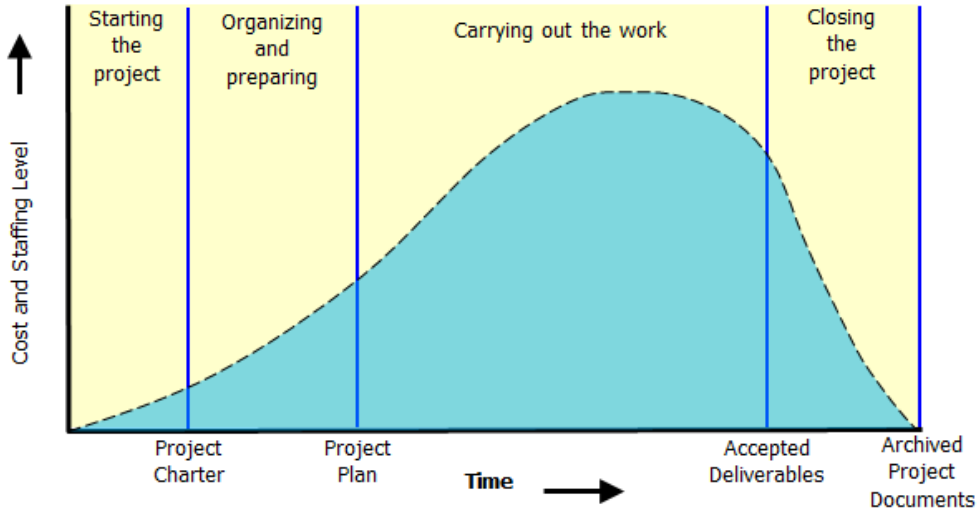


Figure 2.3: Typical Cost and Staffing Levels across a Construction Project Life Cycle Structure, Source: PMBO (2008)

The life cycle of most construction projects can be divided into five main phases; 1) concept; 2) planning; 3) detail design; 4) construction; and 5) turnover. This may sometimes, be shortened to

four for some types of construction. In the first phase, concept, the project is defined by a comprehensive feasibility study. Then, in the planning phase, more explanation and information such as basic design, high level schedule and budget, high level project risks, etc. are provided. Sometimes, the planning phase needs the involvement and approval of the owner. Next, in the detail design, all specifications, equipment, and drawings are prepared. To start the construction phase, it is not necessary to finish the detail design but basic design should be finished. Usually construction starts a short time after the start of the detail design. It is because of the progressive elaboration characteristic of construction projects. After finishing construction, the project should be inspected, which may be followed by turnover to the owner. The number of phases is not constant, it depends on the size and complexity of the project and it can be of any number but each phase needs different time and effort.

There is a big difference between phases and processes of a project. According to ISO10006 “A project may be divided into interdependent processes and into phases as a means of planning and monitoring the realization of objectives and assessing the related risks”. Project processes are important and necessary for two aspects; managing the project and realize the project’s product. Project phases, has other duties, which is dividing the project life cycle into two or more manageable parts such as conception, detail, and development.

2.4. Project Audit

Although the trend of project management in construction projects is growing, the purpose of using project management in many projects is still as document management or knowledge management (Chou and Yang, 2012). However, ineffective project management not only lead to waste in resources (time and cost) but also in many cases it causes project failure. Bassioni et al,

(2004) have suggested that reasons for project failure should be translated into quantitative measurements that can define a corrective action for those failures. In other words, in today's competitive environment, project-oriented organizations cannot focus only on project KPIs to be sure their project is going the right way. Therefore, in the past decade, some related research has been conducted where a model for assessing and correcting construction project health was introduced by Mian et al, (2004); the Project Health Check (PHC) was introduced by Jaafari (2007), and an analysis of project performance methodologies by Nalewaik and Millsb (2014). Since 1993, the Taiwan government has enforced public construction projects to have three-levels of quality management systems to improve the quality of the projects (Wang and Kong, 2012)

According to the National Institute for Further Education of Netherlands (2010), the project audit is "the process of verification of the extent to which the project realisation complied with the rules and principles of project management for the specific project. The project audit has many goals, one of which is to inspect and evaluate the current situation of the project. It also helps the team to find if the project complies with all the defined criteria or not. Moreover, the project audit identifies the points of strength and points of weakness in the project and whether it is moving toward success or not. Furthermore, project issues, challenges, and concerns, which usually happen during project execution, are uncovered by conducting a project audit. It is worthwhile for the project team, manager, and other stakeholders to spend time considering what has gone well in the project and which parts need to be improved to complete the project successfully. If done at the final part of the project, the audit results and experiences will be useful for future projects. This especially helps the project team to avoid repeating mistakes on future projects.

According to Ruskin and Estes (1984) project failure is mostly because of problems in the planning and executing processes which are not corrected. Sometimes, project teams do not notice these problems, or there is no time to fix them. Project audit can truly identify and address these issues. In other words, the chance of project failure is reduced by an on-time project audit. McDonald (2002) believes that the main reasons for a project audit are: 1) to force the project team to develop a reliable project plan which will likely result in a successful project; 2) to increase the possibility of project risks identification; 3) to determine what correction actions should be done to have a project with efficient time, cost, and quality. He also selected the design phase of the project as the best time for a project audit as shown in figure 2.4.

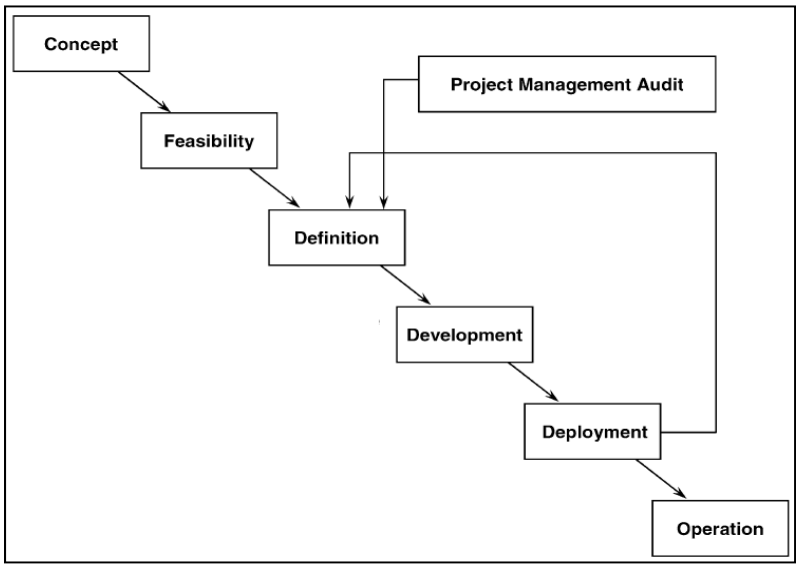


Figure 2.4: Optimal project audit timing, Source: McDonald (2002)

Project performance can be assessed by measuring critical success factors (CSFs). Although lots of researchers have tried to identify the CSFs of a project, it has not been defined specifically for the project management knowledge. Therefore, CSFs may be different from one project to another (Mian, et al, 2004). However, except for research and development projects, projects have some common CSFs (i.e. cost, time, quality). Some other researchers have focused on new

types of CSFs (i.e. productivity, contract disputes, and procurement strategy). Past work by Young and Poon (2013) identifies success factors specifically for the construction process.

Regardless of when the audit is conducted, either in the middle or at the end of the project, audit processes are similar. It is important that a third party, who is a specialist in project management, conducts the project audit. There might be several interviews during a complete audit process that provide the opportunities to the project team to express their opinions and points of view about what has been done in the project. Usually, the process of a project audit consists of the following phases; 1) Development of project success factors; 2) Development of a questionnaire; 3) In-depth investigation; 4) Final report (Bates and Coles, 2012).

First, appropriate success criteria for the project need to be defined. This is usually completed with the collaboration of all stakeholders because the success criteria are extracted from stakeholders' expectations. Next, a questionnaire is developed by the auditors. Questionnaires could be sent to the team directly or they could be answered through interviews. In a complete project audit both methods are used. Then, one or more project site-visits are planned to gain detail information about the project. Also, all project historical data and documents such as the Project Plan, Milestone Report, Team Structure, Business Requirements, Meeting Minutes, Issue Logs, Change Logs, etc., need to be reviewed. Finally, all collected information from interviews, individuals who completed the questionnaire, project documentation review, review of the project quality management, issues, concerns, and challenges, and also the site-visit, are gathered, analysed, and reported.

2.5. Project Audit Success Factors

Although varieties of researches have been conducted, there is no common consensus on a project audit success factors. Different people consider different factors to assess the project

audit success factors. It is commonly known that delivering what the owner wants out of the project is to be on budget, on time, and with defined quality could be considered project success. Although these are real success factors for every project, there are some other factors and ways to achieve a successful outcome; 1) achieving the project's objectives; 2) completing the project with an agreed budget; 3) delivering the project on time; 4) delivering the project with required quality; 5) satisfying stakeholders (i.e. owner, vendor, supplier); and 6) providing value added for all stakeholders. For example, one stakeholder may sacrifice quality for a quicker delivery, and another may want to extend the project time and cost by adding in a new scope to the project work. In both cases, satisfying stakeholders' expectations mean project success although the project is completed over budget and over time. The reality is that only 34% of projects are delivered on time and on budget. Jaafari (2007) believes that project success is influenced by three factors; 1) project resources; 2) capability and managerial approach; and 3) commercial and physical environment. Marques et al (2010) advocate that the risk assessment report is a main part of every project performance measurement system. They believe it is not possible to create a unique and complete checklist for the project assessment that can be used in every project. According to Takim and Akintoye (2002), performance is a contribution of performing a task in order to completing the construction project. Therefore, to determine a construction project performance, all tasks should be measured, analyzed, and prioritised.

2.6. Project Maturity

One factor that is indirectly determined and measured in a project audit is project maturity. The level of maturity can be extracted from the score of all success factors. Project maturity is defined as those capabilities that produce repeatable success in project management.

Kwak and Ibbs (2000) believe that project maturity is the sophistication level of an organisation's current project management practices and processes. Moreover, Bolles (2002) mentions that the current level of project management knowledge and skills in an organisation is project management maturity. In the definition of Kerzner (2004) "Maturity in project management is the implementation of a standard methodology and accompanying processes such that there is a high likelihood of repeated successes". Albrecht and Spang (2014) believe that most of project management maturity models have a similar structure with five level of maturity for a project and each level has its specific requirements to be satisfied.

The appropriate level of maturity will vary for each organization based on specific goals, strategies, resource capabilities, scope, and needs. Furthermore, project maturity translates organizational strategy into success and provides a roadmap for strategic improvement. It allows another way for organizations to find their strengths and weaknesses and enables them to set achievable targets for improvement.

2.7. Project Audit and Improvement Models

In this section, different project audit and improvement models are reviewed. This review enables us to identify the advantages and disadvantages of all 11 models that will be considered in developing the proposed project audit model.

2.7.1. Portfolio, Programme & Project Management Maturity Model (P3M3)

This model has been provided by the Office of Government Commerce (OGC) of the UK, which has conducted lots of research in the field of project management. The P3M3 is based on the Capability Maturity Model Integrated (CMMI) of Carnegie Mellon University and uses a similar approach. Initially, between 1986 and 1991, the Software Engineering Institute (SEI) of Carnegie Mellon University designed a primitive version of the model. Later, because of its weaknesses,

researchers improved it as the P3M3, which is considered as a guideline and a list of instructions for project management, program management, and portfolio management.

The P3M3 model uses critical process areas that contribute to achieving project success. The P3M3 recognizes activities that need to be carried out in project and program levels and also within the organization that is responsible to implement them (UK Office of Government Commerce, 2006).

The P3M3 can be used for any type of organization (i.e. public, private, consultant, and training) because this model does not focus on a specific industry. However, it seems that this model is more compatible with UK industries. According to this model, project-oriented organizations need a set of critical project requirements and they are divided into two groups: Mature and Immature. In a mature organization, there are appropriate and sufficient standard procedures and instructions to keep the project on schedule and on budget with a high quality. Managers monitor and control project progress against the project plan and always consider stakeholders' satisfaction.

As shown in Table 2.2, P3M3 has five levels of maturity: 1) initial process; 2) repeatable process; 3) defined process; 4) managed process; and 5) optimised process. These levels can be considered in developing the proposed project audit model. Table 2.2 present a brief description of these five levels for project, programme, and portfolio maturity.

Table 2.2: Five levels P3M3 model, Source: UK Office of Government Commerce (2006)

Level	Process	Project	Programme	Portfolio
Level 1	**Initial Process**	Does the organisation recognise projects and run them differently from its ongoing business? (Projects may be run informally with no standard process or tracking system.)	Does the organisation recognise programmes and run them differently to projects? (Programmes may be run informally with no standard process or tracking system.)	Does the organisation's Board recognise programmes and projects and run an informal list of its investments in programmes and projects? (There may be no formal tracking and reporting process.)
Level 2	**Repeatable Process**	Does the organisation ensure that each project is run with its own processes and procedures to a minimum specified standard? (There may be limited consistency or co-ordination between projects)	Does the organisation ensure that each programme is run with its own processes and procedures to a minimum specified standard? (There may be limited consistency or co-ordination between programmes)	Does the organisation ensure that each programme and/or project in its portfolio is run with its own processes and procedures to a minimum specified standard? (There may be limited consistency or co-ordination)
Level 3	**Defined Process**	Does the organisation have its own centrally controlled project processes, and can individual projects flex within these processes to suit the particular project?	Does the organisation have its own centrally controlled programme processes and can individual programmes flex within these processes to suit the particular programme?	Does the organisation have its own centrally controlled programme and project processes and can individual programmes and projects flex within these processes to suit particular programmes and/or projects. And does the organisation have its own portfolio management process?
Level 4	**Managed Process**	Does the organisation obtain and retain specific measurements on its project management performance and run a quality management organisation to better predict future performance?	Does the organisation obtain and retain specific measurements on its programme management performance and run a quality management organisation to better predict future programme outcomes?	Does the organisation obtain and retain specific management metrics on its whole portfolio of programmes and projects as a means of predicting future performance? Does it assess its capacity to manage programmes and projects and prioritise them accordingly?
Level 5	**Optimised Process**	Does the organisation run continuous process improvement with proactive problem and technology management for projects in order to improve its ability to depict performance over time and optimise processes?	Does the organisation run continuous process improvement with proactive problem and technology management for programmes in order to improve its ability to depict performance over time and optimise processes?	Does the organisation run continuous process improvement with proactive problem and technology management for the portfolio in order to improve its ability to depict performance over time and optimise processes?

The P3M3 defines related activities for the programme and project through different key process areas in each level. The structure of these process areas consists of functional achievement/process goals, approach, deployment, review, perception, and performance measures (UK Office of Government Commerce, 2006).

2.7.2. Prince2 Maturity Model (P2MM)

Another model developed by the UK Office of Government Commerce (OGC) is the Prince2 Maturity Model (P2MM). This model provides a framework that can access projects which their project management method is Prince2. Because P2MM is derived from P3M3, they have similar structure in managing projects. It has five levels for organizational maturity and seven processes that cover project management aspects (Williams, 2013). The five Maturity Levels are; 1) Level 1 – awareness of process; 2) Level 2 – repeatable process; 3) Level 3 – defined process; 4) Level 4 – managed process; and 5) Level 5 – optimized process. Also, seven processes that P2MM focuses on are; 1) management control; 2) benefits management; 3) financial management; 4) stakeholder engagement; 5) risk management; 6) organizational governance; and 7) resource management. With using P2MM, project oriented organizations can justify investment in project management improvements and recognise their strengths and weaknesses in order to enable those improvements.

Organizations use the P2MM assessment method, which is only conducted by an Accredited Consulting Organizations (ACO) and led by a qualified consultant who already has been trained to do the assessment process. During the assessment they look for KPAs through structured interviews. The numbers of people who are interviewed depend on the size and complexity of the project and organization (Murray, 2006). In this model, organizations plan to improve their level of maturity in project management during the projects implementation and they can track their

progress in maturity. Figure 2.5 shows an example of long-term performance improvements based on P2MM.

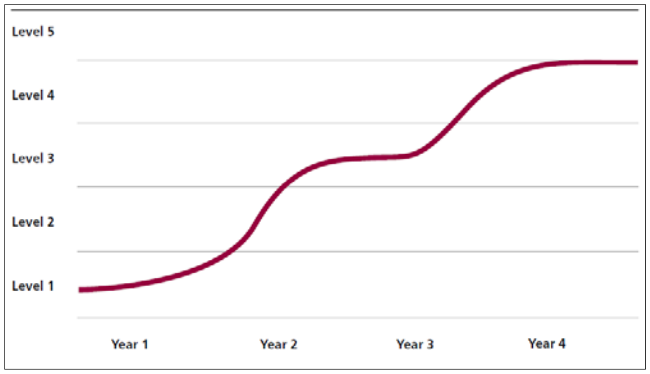


Figure 2.5: An example of long-term performance improvements, Source: P2MM (2013)

2.7.3. Capability Maturity Model Integrated (CMMI)

The CMMI is a suite of maturity models which are all related to software engineering and there are five KPAs specifically for project management. The suite contains the following components:

- CMMI-SW – capability maturity model for software engineering,
- CMMI-SE – capability maturity model for system engineering,
- CMMI-IPPD – integrated product and process development, and
- CMMI-SS – supplier sourcing,

The CMMI models are completely appropriate for those organizations which mostly implement software engineering projects. The evidence shows that this model can improve schedule and budget predictability, cycle time, productivity, quality, customer satisfaction, and can decrease the cost of quality (Murray, 2006). There is no clear information about this model in the literature.

2.7.4. Kerzner Project Management Maturity Model (KPM3)

Dr. Harold Kerzner, developed a model named the Kerzner Project Management Maturity Model (KPM3) in 2001. This model helps project-oriented organizations to achieve a new level of project management excellence and improve its capabilities. Kerzner (2001) believes that this model can describe an appropriate way to achieve excellence in project management on those five levels. Each level represents a required degree of maturity in project management. Figure 2.6 shows the five levels of KPM3.

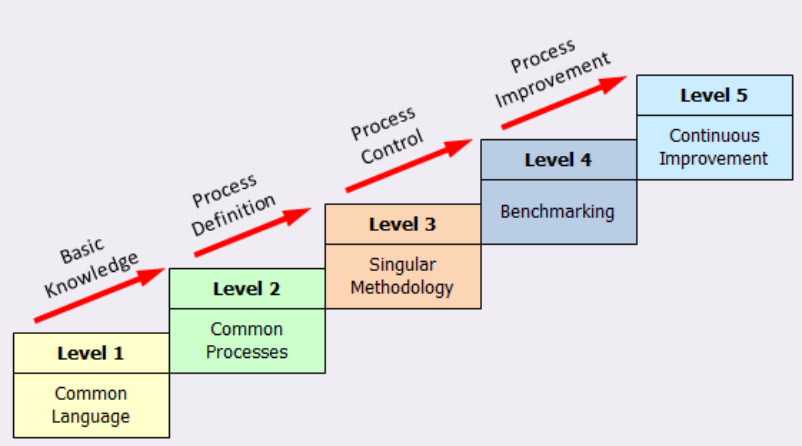


Figure 2.6: The five levels of KPM3, Source: Strategic Planning for Project Management (2001)

By reviewing these levels, only one advantage is identified: they represent organized steps that a project oriented company needs to follow to be successful in its project processes and functions. It would be a good practice to include this advantage in the model that will be developed in this research. As shown in Figure 2.6, there are five levels for maturity and each level represents a specific capability as following:

- **Level 1- Common Language:** Importance and basic knowledge of project management are fully understood in this level. Also, common language and terminology is defined.

- **Level 2- Common Processes:** Definition and development of common project management processes are the main outcomes of this level. For example, a successful approach in one project can be helpful for another. Also, additional information such as application and support of the project management principles may need to be provided.
- **Level 3- Singular Methodology:** In this level, the organization puts project management methodology in the center of all other methodologies which are being used. Combining these methodologies to take advantage of their synergistic effect is the main objective.
- **Level 4- Benchmarking:** The goal of this level is to provide a competitive advantage environment for the company to continuously improve processes. It is important to understand whom and what should be benchmarked.
- **Level 5- Continuous Improvement:** All information obtained through benchmarking is evaluated in this level. A decision should be made whether this information can enhance project management methodology used by the organization or not.

2.7.5. Project Management Process Improvement

Wysocki (2004) developed a model that was published by Artech House publisher. Although the author did not mention a specific industry for his model, it seems that the model is mostly compatible with information technology projects. The model presents ten criteria to project success: 1) executive support; 2) user involvement; 3) experienced project manager; 4) Clear business objectives; 5) minimized scope; 6) standard software infrastructure; 7) firm basic requirements; 8) formal methodology; 9) reliable estimates; 10) skilled staff.

Seven of these criteria are related to the process where the other three of them, which are not the interest of this research, executive support, experienced project manager, and skilled staff, are specifically about the project team members, and the relation between the project objectives and

the organization's goals. The model was designed based on two project management standards; 1) OPM3 and 2) PMBOK. Also, this model considers five maturity levels for projects; 1) initial process; 2) structured process; 3) institutionalized process; 4) managed process; and 5) optimizing process

All other maturity levels assess both the process definitions (PD) and Process Practice (PP) in the organization and its projects. In this way, project team can evaluate only a single process for either PD or PP maturity or both (Wysocki, 2004). He believes that "PD is the documented and standardized processes that drive all project management activity in the organization. The second, and more difficult step, is the adoption of the project management processes. This will be measured by PP. Project managers, especially those who come from other organizations, will bring their own approaches to project management". This model has a complicated process for audit, which is a disadvantage for it.

2.7.6. ISO 10006:2003 Standard for Project Management

ISO 10006 provides guideline specifically applicable in quality management in projects. This standard can be used in all type of projects simple to complex, small to large, short to long duration, soft product such as IT projects to physical product such as oil and gas projects. However, it is very important to tailor the standard before implementation. This model has four main clauses; 1) management responsibility that consists of strategic process; 2) resource management that consists of resource-related and personnel-related processes; 3) product realization that consists of interdependency, scope, time, cost, communication, risk, and purchasing processes; 4) measurement, analysis, and improvement that consist of improvement, measurement, and continuous improvement processes. ISO 10006 has not been developed for managing a project, but it is a very useful guideline for quality in project management processes.

According to the Bureau of Indian Standards (2003), ISO 10006 is an application that provides guideline for quality management in any type of project with different complexity, size, and duration. This model has a specific definition for a project: “unique process, consisting of a set of coordinated and controlled activities with start and finish dates, undertaken to achieve an objective conforming to specific requirements, including the constraints of time, cost and resources (ISO 10006)”. Therefore, ISO10006 can be applied along with a project management methodology and it provides a set of important requirement for project management quality.

2.7.7. Roland Gareis Model

The basis of Roland’s model is analysing the organisational competencies in the project-oriented organizations. These competencies consist of strategies, structures, and cultures of project management that project-oriented organizations use. In 2005, a research was conducted by Project Management Group of Vienna by which they analysed organisational competencies of a project-oriented company by applying Roland’s model.

The model is based on eight important criteria; 1) project management; 2) programme management; 3) assurance of the management quality in a project or programme; 4) assignment of a project or programme; 5) project portfolio coordination and networking; 6) organisational design; 7) personnel management; and 8) process management. Each criterion has a score between 0 and 100 as shown figure 2.7.

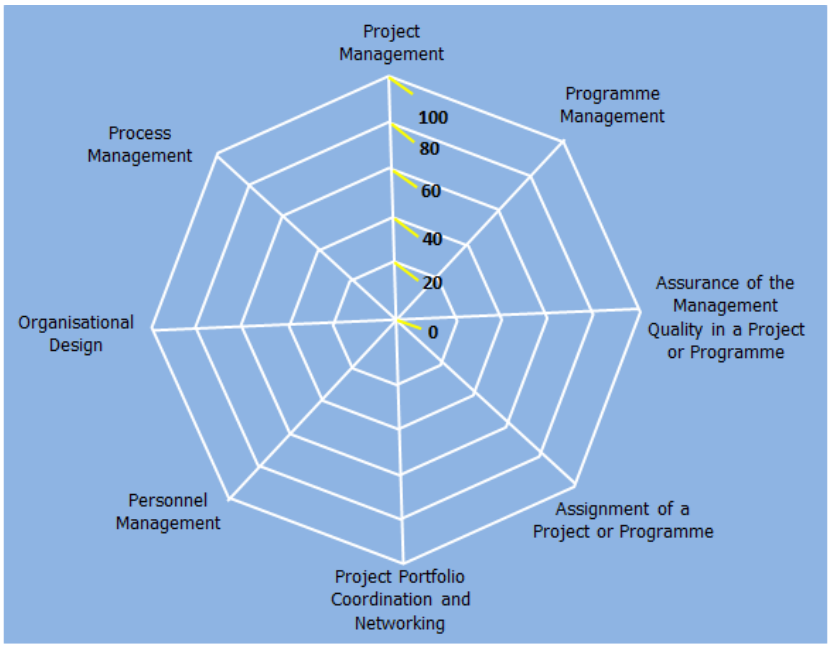


Figure 2.7: Roland's model criteria, Source: Maturities report of project-oriented companies Vienna (2005)

This model has a questionnaire that consists of 74 questions and 35 sub-criteria. All the sub-criteria have the same weight, but each of the eight main criteria has different weights based on their importance. Roland's model focuses on the project management process and its objective is to improve quality of project management and increase project success. It is useful for project-oriented organisations, which have an explicit project management culture and uses "management by projects" as an organisational strategy. These organizations manage various types of projects in a project portfolio.

2.7.8. German Association Model for Project Management (GPM)

German Association Model for Project Management (GPM) audits a project according to three areas; 1) project management and system; 2) training project managers; and 3) providing certification in project management. GPM assesses a project with 19 main criteria as shown in table 2.3. Also, this model has a questionnaire that consists of 300 questions.

Table 2.3: The 19 main project's assessment areas in GPM model (Delta)

• Definition of Objective	• Management of Resources
• Structuring	• Sequencing/Dates/Deadline
• Project Organization	• Multi Project Coordination
• Human Resources Management	• Risk Management
• Contract Management	• Information and Reporting
• Claim Management	• Controlling
• Configuration Management	• Logistics
• Change Management	• Quality Management
• Expenditure Management	• Documentation
• Cost Management	

This model does not have maturity levels. Also, each category mentioned above has a different weight. However, the weights have been hidden in the model. The main objective of the model is to help individual who is going to be a project manager especially in European projects. There are three modules of certificate for GPM; 1) module I (individuals); 2) Module P (Project); and 3) module O (organization). There is limited information about the detailed structure of this model in the literature.

2.7.9. Lynn Craford Maturity Model

Professor Lynn Craford's assessment model was presented by the Human Systems Company in 2005. Her model has three assessment tools. For projects, it has the "Project Health Check Tool (PHT)" and "Measuring Project Performance Tool (MPP)." For organizations, it has the "Practice Questionnaire Corporate (PQC)." The PHT lacks information about maturity levels, the improvement cycle, sub-criteria, and questions. There is not much information about maturity levels, number of questions, and scoring system for this model and only it was mentioned that the model assess the project's maturity in 25 main criteria as listed in table 2.4.

Table 2.4: Lynn Craford maturity model project criteria

• Human Resource	• Cost Control	• Time Planning
• Communication	• Quality Control	• Change Control
• Planning	• Resource Control	• Team Work
• Control	• Time Control	• Project Performance
• Requirements	• Relation with Owner	• Competency
• Risk Planning	• Project Schedule Success	• Performance Success
• Cost Planning	• Rule and Responsibility	• Capability Improvement
• Resource Planning	• Communication Success	
• Culture	• Quality Planning	

There are two groups of questions in Lynn Craford's assessment model; 1) project's product and 2) project's process. As shown in figure 2.8, to answer the questions related to project's product, there are six possible answers; 1) not at all; 2) committed; 3) active ; 4) performing; 5) measuring; and 6) verifying, where "not at all" represents the worst and "verifying" represents the best. For project's process questions, there are four possible answers; 1) none; 2) partially; 3) largely; and 4) fully where "none" represents the worst and "fully" represents the best.

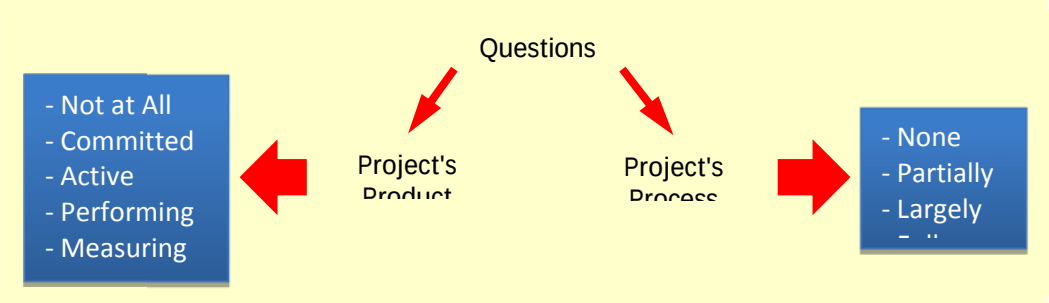


Figure 2.8: Lynn Craford's maturity model types of questions and answers

2.7.10. Project Excellence Model (PEM)

The Project Excellence Model (PEM) is a system to rank projects. PEM was established in 1997 by Roland Ottmann at the German Association for Project Management (GPM) and it is mostly based on the European Foundation for Quality Management (EFQM) model. The model has two

main objectives; 1) evaluation of the project management process and 2) measurement of the results achieved in a project. Two institutes, GPM and International Project Excellence Award (IPMA), designed an award system named the Project Excellence Awards by using the model.

As shown in figure 2.9, PEM has two main criteria for project audit; 1) project management and 2) project results. Project management has five sub criteria; 1) project objectives; 2) leaderships; 3) people; 4) resources; and 5) processes. Project results has four sub criteria; 1) customer results; 2) people results; 3) results of other parties involved; and 4) key performance and project results.

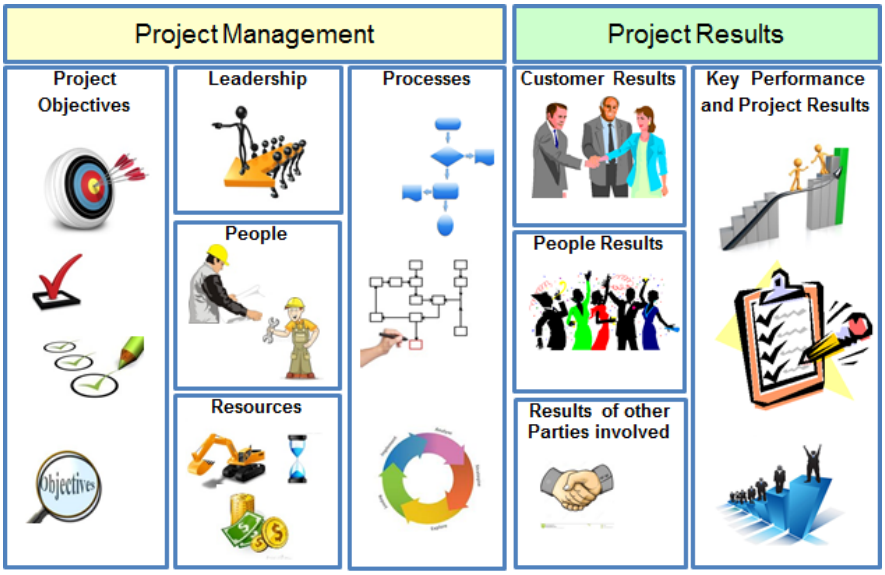


Figure 2.9: Project Excellence Model (PEM) criteria and sub-criteria, Source: Möller (2005)

PEM's sub-criteria have the following definitions:

- **Project Objectives:** The way that the project defines, develops, controls, and realises its objectives according to information about the demands of all involved parties.
- **Leadership:** How project managers move toward "Project Excellence."

- **People:** Project team members approached to be involved in the project.
- **Resources:** Effective and efficient approach to the use of project resources.
- **Processes:** The way that projects' processes are defined, implemented, and controlled.
- **Customer Results:** Customer expectations and satisfaction management.
- **People Satisfaction:** Project team members' expectations and satisfaction management.
- **Results of other Parties involved:** Stakeholders' expectations and satisfaction management.
- **Key Performance and Project Results:** Project achievements and performance.

The philosophy of PEM originates in a quality management model, Total Quality Management (TQM) in which teams try to find strong and weak points of the project. As shown in figure 2.10, PEM divides a project into two main parts; 1) project management (total 500 scores) and 2) project results (total 500 scores).

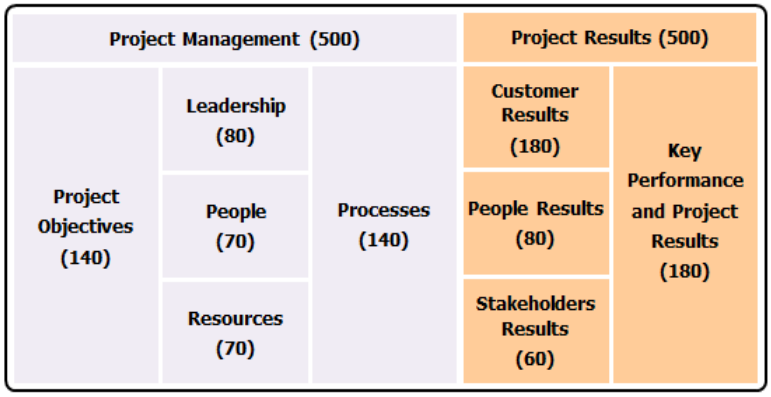


Figure 2.10: Project Excellence Model (PEM) scores, Source: IPMA International Project Excellence Award (2008)

Final score of the project assessment with PEM is computed by project management score plus project results score. For example, if a project achieves 410 scores in project criteria and 360 score in project results criteria, the total score for this project is 770. There is a comprehensive

questionnaire for this model and only trained auditors are allowed to audit projects based on this model. The following steps should be followed to audit a project with PEM:

Step 1: Sending a request letter to the International Project Excellence Award for being audited

Step 2: Project audit by a four-member group of trained auditors

- Each member audits the project based on his or her point of view
- Consensus on the results
- Reporting the assessment result

Step 3: Project site visit (if needed)

Step 4: Final project assessment report

Step 5: Participation in the award competition

2.7.11. Organizational Project Maturity Model (OPM3)

The Organizational Project Management Maturity Model (OPM3) was designed by PMI in 2003. It is a self-assessment project audit model. This model was developed for project-oriented organizations and it assesses them in three levels: 1) project, 2) program, and 3) portfolio. In other word, the OPM3 framework provides an overview of an organization's maturity level of portfolio, program, and project (OPM3, 2008). This model considers everything from the lowest level of a strategic plan which is a project to the highest level which is portfolio. As shown in figure 2.11 OPM3 consists of the three important elements that are connected together; 1) knowledge; 2) assessment; and 3) improvement.

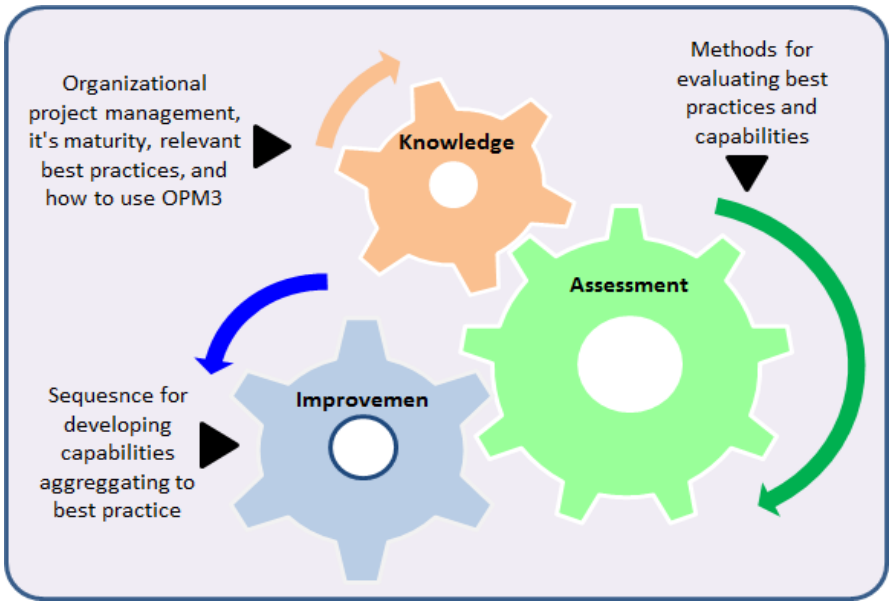


Figure 2.11: three elements of the OPM3, Source: OPM3 (2008)

The structure of OPM3 consists of four components: 1) best practices which consist of 600 recognized approaches that an organization can follow to achieve its projects goals; 2) capabilities that include all steps to achieve a project maturity level; 3) outcomes that consist of results of applying a capability; and 4) KPIs that provide qualitative and quantitative criteria to assess an outcome.

As shown in figure 2.12 each best practice has one or more project management capabilities. When all capabilities achieved, the best practice is attained. Capabilities also need one or more outcomes to be satisfied. OPM3 uses KPI to determine, quantitatively or qualitatively, whether the outcome exists or the degree to which it exists.

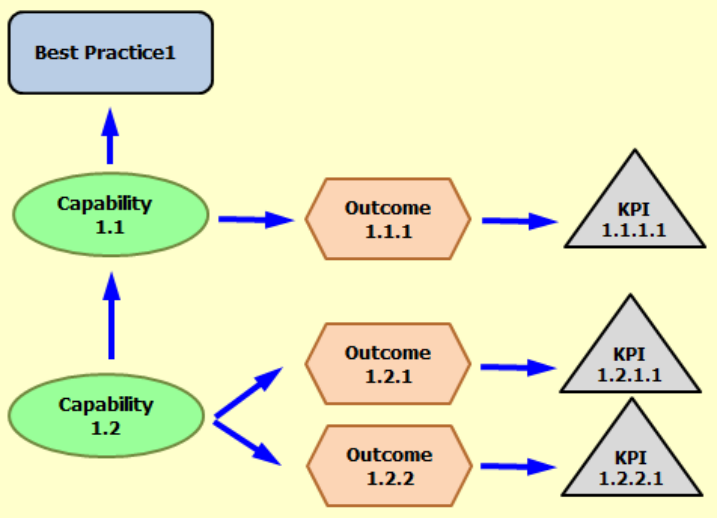


Figure 2.12: Best practice, capability, outcome, and KPI in OPM3 model, Source: OPM3 (2008)

There are four maturity levels in OPM3; 1) standardization; 2) measuring; 3) controlling; and 4) continuous improvement. Also, OPM3 has a questionnaire that contains 151 questions for project audit self-assessment. But the scoring system has been hidden in its software.

2.8. Summary

This chapter reviewed the most important aspects of a project (i.e. process, function, and performance) and project audit and improvement models and methodologies. Discussing the details of these models is out of scope of our research. Also, there are some limitations of accessing related information to some models. The main objective of reviewing these models is to find their advantages and disadvantages so it will be considered in the model proposed in this research. Before doing the project audit the following questions should be answered by whoever has asked for the audit, most of the time, the project sponsor:

1. What is the purpose of this audit: The purpose of a project audit is a key factor that has an impact on the results. Usually, the main reason for a project audit is to determine if the

project is on-track or not. If the answer is yes, what should be done to keep it on-track? What will be the future challenges? And if not, what should be done to fix the situation and bring the project on-track or sometimes cancel it?

2. What is the scope of this project audit: A project audit can be quick or comprehensive. It is important to know which area of the project needs to be audited--processes, functions, or performance--to select an appropriate approach.
3. When is the best time to do the audit: It should be considered that the project audit is not only when the project is in trouble or the client/customer complaints. Sometimes, when a key team member, especially the project manager is changed, a project audit is needed. Also, as mentioned earlier, post-project review is very important to have successful future projects.
4. Who is qualified to be a project auditor: Different people can audit a project such as a PMP certified person, a project manager, a third party construction company, architect, etc. It depends on the two previous questions: what is the purpose of the audit and what should be covered.

To do the project audit, the following steps should be clearly done:

- Having an agreement with key stakeholders especially the project sponsor, owner, and project manager
- Having a detail plan and schedule for the audit to know when it will start and finish. Who is responsible for the audit report? What documents should be provided? What is the level of access to project information? etc.
- Having an appropriate questionnaire and scoring model because there are many questions that can be asked in a project audit

- Having a commitment to implementing the audit as planned and collecting high-quality information
- Reviewing all historical and current documentation related to the project that has valuable information and can indirectly answer questions. For instance, the project charter, scope statement, project plan, risk logs, change logs, meeting minutes, WBS, project organizational chart, etc.
- Having an effective audit report and presentation

Chapter Three

Methodology

3.1. Introduction

This chapter explains the proposed methodology to be used to develop and implement an integrated model for auditing construction projects. The proposed model covers necessary processes and functions that should be audited in a project and includes all related questions. Therefore, before developing the proposed model, the reviewed project audit and improvement models should be analyzed to determine their advantages and disadvantages. Furthermore, in this research, project performance is measured based on the Earned Value method.

3.2. Analysing project audit and improvement models

After reviewing the project audit and improvement models in chapter two, these will be analysed. This analysis is divided into two parts; 1) identifying the advantages and disadvantages of each model; 2) ranking the models based on their advantages.

3.2.1. Identifying the advantages and disadvantages of the reviewed models

For each model, several advantages and disadvantages have been identified and extracted from the project audit and improvement models. The advantages will be included in the proposed model while the disadvantages will be excluded. Table 3.1 and Table 3.2 show the advantages and disadvantages of the reviewed models respectively. In these following tables a "+" means that the model includes the advantage or disadvantage and empty cells mean that the model does not include the advantage or disadvantage.

Table 3.1: Reviewed models advantages

Advantages \ Model	P3M3	P2MM	CMMI	KPM3	PMPI	ISO	Roland	GPM	PHT	PEM	OPM3
applicable for all project stages				+		+					
applicable in construction projects				+							
appropriate for project quality management						+					
compatible with project life cycle				+							+
defines maturity levels	+			+	+		+	+		+	
defines process improvement					+			+			
defines project key process areas		+									
evidences are needed				+		+	+	+	+	+	+
has a questionnaire	+	+		+		+	+	+	+		+
has project success criteria					+					+	+
industry independent	+			+		+	+	+	+	+	+
is easily applicable				+		+			+	+	+
many best practice are available										+	+
scoring model is clear										+	
provides project audit workflow										+	
strong conceptual model			+								
cover all project processes and functions				+			+				+

Table 3.2: Reviewed models disadvantages

Disadvantages \ Model	P3M3	P2MM	CMMI	KPM3	PMPI	ISO	Roland	GPM	PHT	PEM	OPM3
compatible only with specific country	+							+			
compatible only with IT projects			+		+						
does not cover all project functions	+	+			+	+				+	
does not cover all project processes	+	+				+				+	
does not have project audit workflow	+	+	+	+	+	+	+	+	+		
does not have scoring model	+	+				+					
is not easily applicable	+	+	+		+		+	+			
is not evidence base	+		+		+						
needs trained auditor	+			+		+					+
not applicable for all project stages	+	+	+		+		+	+			
questionnaire is not available			+		+						
scoring model is not available			+		+						
scoring model is not clear				+			+		+		+
ambiguous questions											+
specifically applicable in quality management						+					
is mainly conceptual model		+	+								
is not compatible with project life cycle	+	+	+		+	+	+	+	+	+	

3.2.2. Ranking the models

One of the multi-criteria decision analysis methods that clearly consider multiple criteria in decision-making environments is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). In order to rank the project audit and improvement models, TOPSIS has been utilized to rank the models from the highest to the lowest application. Furthermore, it provides a better review of the strong and weak points of each model and helps to develop the proposed project audit model. TOPSIS was originally developed by Hwang and Yoon in 1981. In 1987, Yoon did some more development and improvement for it. The main concept of TOPSIS is that the geometric distance from the positive and negative ideal solutions should be the shortest and longest respectively. According to Kim (1997), TOPSIS is a major MADM technique which has advantages if compared to other MADM techniques (i.e. AHP). TOPSIS advantages are: 1) an understandable logic; 2) considers both the best and worst alternatives simultaneously; 3) a straightforward calculation process; and 4) considers several criteria to rank alternatives. In this method, all alternatives are compared by defined criteria. First, for each criterion a weight is identified. Next, a normalised score for each criterion is calculated. Then, the geometric distance between each alternative and the ideal alternative is computed to find the best score. TOPSIS allows trade-offs between criteria. For example, one criterion which has a poor result can be compensated for by a good result of a positive criterion. This trade-off is the main difference from non-compensatory methods and provides a more realistic result. To apply TOPSIS, the following steps should be implemented:

Step 1: Put A_i as alternatives (i=1, 2 . . . n) and $x_j$as criteria (j=1, 2 . . . m). Create an evaluation matrix consisting of (m) alternatives and (n) criteria, each alternative and criteria is named x_{ij}, therefore a matrix$(x_{ij})_{m\times n}$ is created.

Step 2: Normalize the created matrix in step one by using equation 1. Therefore a normalized matrix named $Y_{m\times n}$ is created.

$$Y = (r_{ij})_{m\times n} = \frac{x_{ij}}{\sqrt{\sum_i (x_{ij})^2}}, i = 1, \dots, m; j = 1, \dots, n \qquad \text{Equation 1}$$

Step 3: Put w_j as weight of criteria j, (j=1, 2 . . . n) and W_j the original weight given to the criteria j. Create the weight matrix W by using equation 2.

$$w_j = {W_j}\Big/{\sum_{j=1}^{n} W_j} \qquad \text{Equation 2}$$

Therefore the matrix $W_{n\times n}$ created.

$$W = \begin{bmatrix} w_1 & 0 & 0 & 0 & 0 \\ 0 & w_2 & 0 & 0 & 0 \\ 0 & 0 & w_3 & 0 & 0 \\ 0 & 0 & 0 & \dots & 0 \\ 0 & 0 & 0 & 0 & w_n \end{bmatrix}_{n\times n}$$

Step 4: Calculate the weighted normalised decision matrix by using equation 3. Therefore matrix $N_{m\times n}$ is created.

$$N = (t_{ij})_{m\times n} = (w_i r_{ij})_{m\times n} \qquad \text{Equation 3}$$

Step 5: Determine the worst alternatives (N^-) by using equation 4 and the best alternatives (N^+) using by equation 5.

$$N^- = \{[\max(t_{ij} | i = 1,2, \dots, m) | j \in J^-]\} \; and \; \{[\min(t_{ij} | i = 1,2, \dots, m) | j \in J^+]\} \qquad \text{Equation 4}$$

$$N^+ = \{[\min(t_{ij} | i = 1,2, \dots, m) | j \in J^-]\} \; and \; \{[\max(t_{ij} | i = 1,2, \dots, m) | j \in J^+]\} \qquad \text{Equation 5}$$

Where,

$J^+ = \{j = 1,2, \dots, n |$ j associated with the criteria having a positive impact, and
$J^- = \{j = 1,2, \dots, n |$ j associated with the criteria having a negative impact.

Step 6: Calculate d^+, the distance between the target alternative i and the best condition N^+ by using equation 6 and d^-, the distance between the target alternative i and the worst condition N^- by using equation 7.

$$d^+ = \sqrt{\sum_j (N_{ij} - N^+)^2} \qquad \text{Equation 6}$$

$$d^- = \sqrt{\sum_j (N_{ij} - N^-)^2} \qquad \text{Equation 7}$$

Step 7: Determine similarities $E_i, (i = 1,2, \dots, m)$ to the best condition by using equation 8. The E_i values present the final score of the alternatives. As shown in equation 8, E_i is a number between 0 (the worst alternative) and 1 (the best alternative).

$$E_i = \frac{d^-}{d^+ + d^-},\ 0 \le E_i \le 1 \qquad \text{Equation 8}$$

Table 3.3 presents all alternatives which are compared with TOPSIS. For simplicity, the alternatives are named from A1 to A11.

Table 3.3: Reviewed project audit and project maturity models (Alternatives)

Alternatives Code	Alternatives Name
A1	Portfolio, Programme & Project Management Maturity Model (P3M3)
A2	Prince 2 Maturity Model (P2MM)
A3	Capability Maturity Model Integrated (CMMI)
A4	Kerzner Project Management Maturity Model (KPM3)
A5	Project Management Process Improvement (PMPI)
A6	Standard ISO 10006
A7	Roland Gareis Management of the project-oriented company
A8	German Association for Project Management (GPM)
A9	Lynn Craford Maturity Model
A10	Project Excellence Model (PEM)
A11	Organizational Project Maturity Model (OPM3)

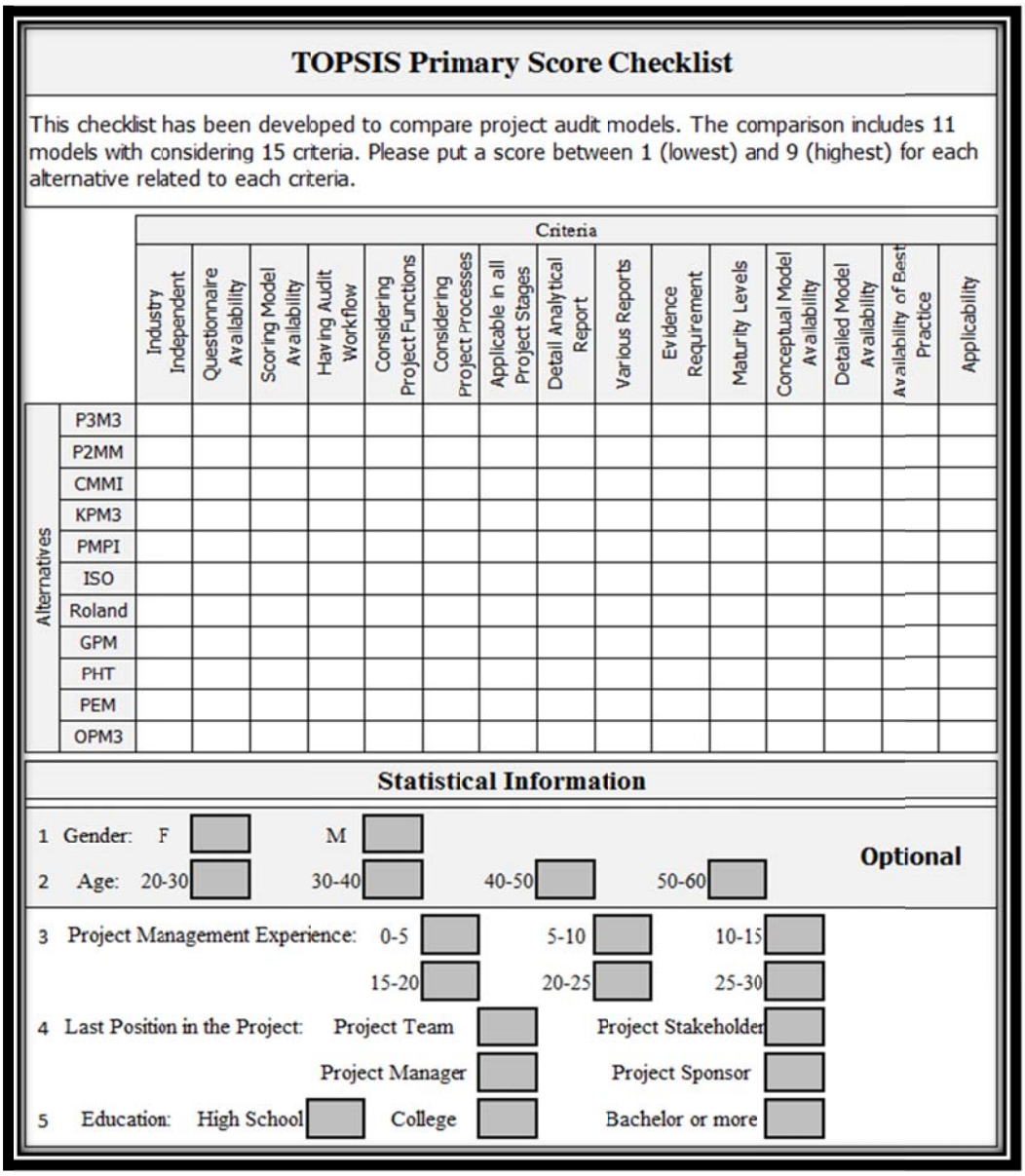
The above alternatives have been compared based on the criteria listed in table 3.4. For simplicity, the criteria are named from X1 to X15. These criteria have been extracted from the models that have been reviewed in chapter two.

Table 3.4: Factors to model comparsion (Criteria)

Criteria Code	Criteria name	Criteria Code	Criteria name
X1	Industry Independent	X9	Various Reports
X2	Questionnaire Availability	X10	Evidence Requirement
X3	Scoring Model Availability	X11	Maturity Levels
X4	Having Audit Workflow	X12	Conceptual Model Availability
X5	Considering Project Functions	X13	Detailed Model Availability
X6	Considering Project Processes	X14	Availability of Best Practice
X7	Applicable in all Project Stages	X15	Applicability
X8	Detail Analytical Report		

To implement TOPSIS technique, the checklist shown in figure 3.1 has been sent to project management specialists, project managers, and project team members who have been working in the Oil and Gas industry in Iran.

The statistical report of participants provides some information; 1) 22.39% of the participants are female while 77.61% are male; 2) 7.46% of the participant are between 20-30 years old, 44.78% are between 30-40 years old, and 47.76% are between 40-50 years old; 3) 19.40% of the participants have experience as a team member, 35.82% have experience as a project manager; 3) 34.33% have experience as a project stakeholder, and 4) 10.45% have experience as a project sponsor; 5) 5.97% of the participants have high school education, 40.30% have college education, and 53.73% have bachelor or higher education; 6) 13.43% of the participants have 0-10 years of work experience, 47.76% have 10-20 years, and 38.81% have 20-30 years.



TOPSIS Primary Score Checklist

This checklist has been developed to compare project audit models. The comparison includes 11 models with considering 15 criteria. Please put a score between 1 (lowest) and 9 (highest) for each alternative related to each criteria.

		Criteria														
		Industry Independent	Questionnaire Availability	Scoring Model Availability	Having Audit Workflow	Considering Project Functions	Considering Project Processes	Applicable in all Project Stages	Detail Analytical Report	Various Reports	Evidence Requirement	Maturity Levels	Conceptual Model Availability	Detailed Model Availability	Availability of Best Practice	Applicability
Alternatives	P3M3															
	P2MM															
	CMMI															
	KPM3															
	PMPI															
	ISO															
	Roland															
	GPM															
	PHT															
	PEM															
	OPM3															

Statistical Information

1 Gender: F ☐ M ☐ **Optional**

2 Age: 20-30 ☐ 30-40 ☐ 40-50 ☐ 50-60 ☐

3 Project Management Experience: 0-5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐ 20-25 ☐ 25-30 ☐

4 Last Position in the Project: Project Team ☐ Project Stakeholder ☐ Project Manager ☐ Project Sponsor ☐

5 Education: High School ☐ College ☐ Bachelor or more ☐

Figure 3.1: TOPSIS primary score checklist

In order to obtain reliable results from TOPSIS, the followings are considered: 1) 85 participants, who have enough qualification, knowledge, and understanding of project management and project audit, were selected to participate in this survey were pre-selected. 2) Two meetings were held to explain the TOPSIS checklist and to provide instructions on how to fill it up. Most the selected participants were familiar with some of the current models (KPM3, ISO, PEM, and

OPM3) because these were already used in their projects. To avoid bias, a presentation was prepared and presented to participants in addition to distributing a brief summary about each model. 3) At all time during the survey, participants had access to the research team either through face to face meeting, emails, or phone calls in order to answer their questions and to provide more explanation whenever was needed. Out of 85 project management specialists including project managers, project team members, project stakeholders, and project sponsors, 67 participated in TOPSIS and returned the checklist. Statistical reports about the participants are shown in figures 3.2 through 3.6.

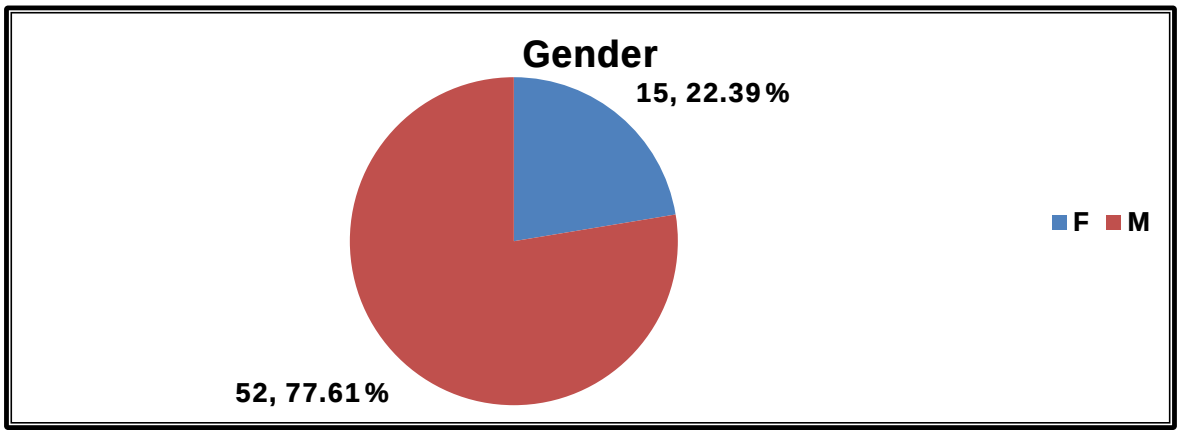


Figure 3.2: TOSIS participants' gender

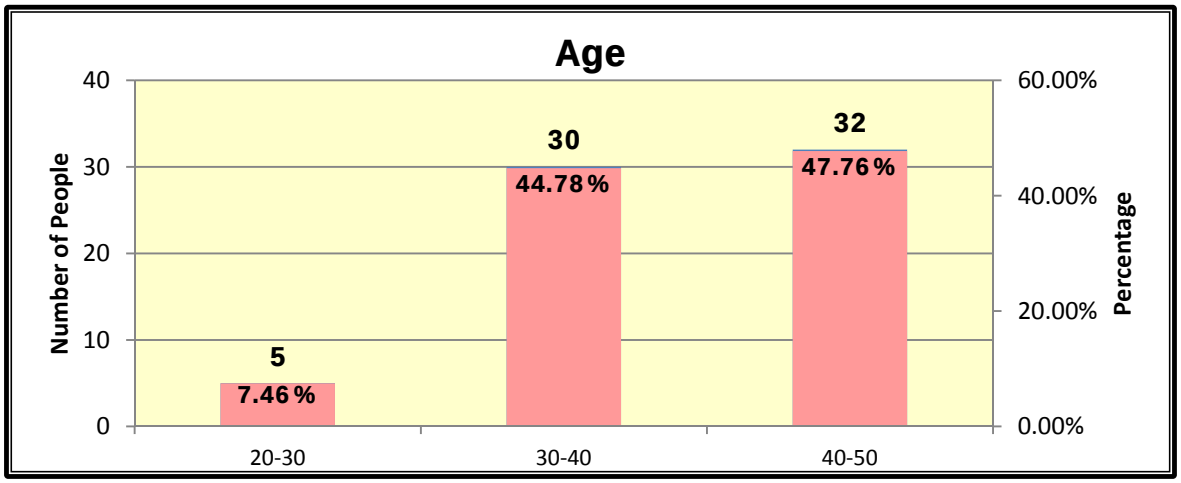


Figure 3.3: TOSIS participants' age

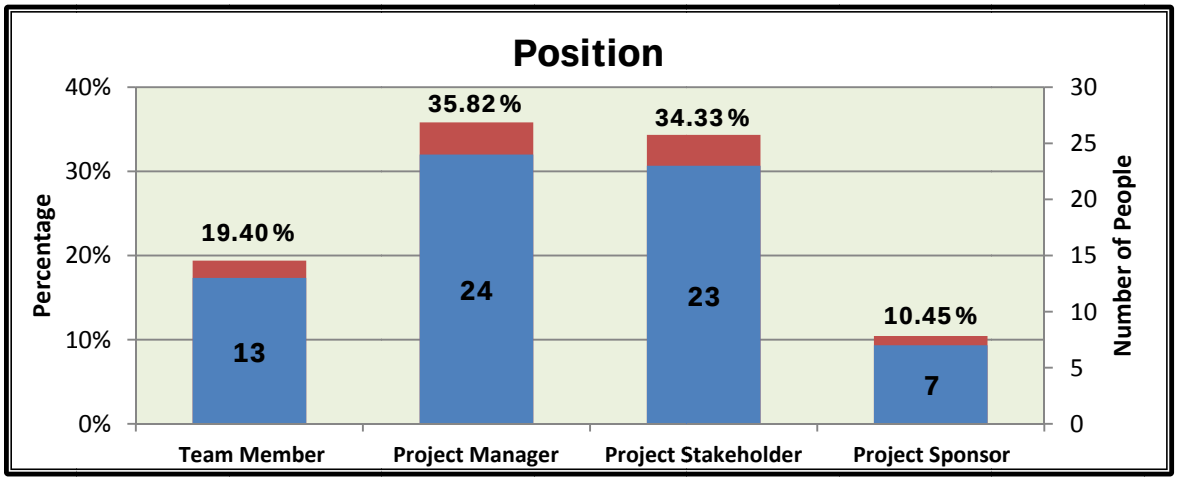


Figure 3.4: TOPSIS participants' working positions

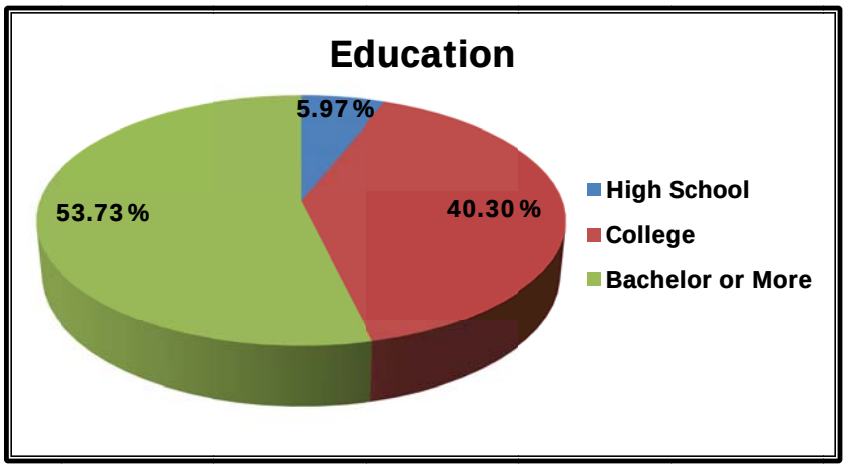


Figure 3.5: TOPSIS participants' education

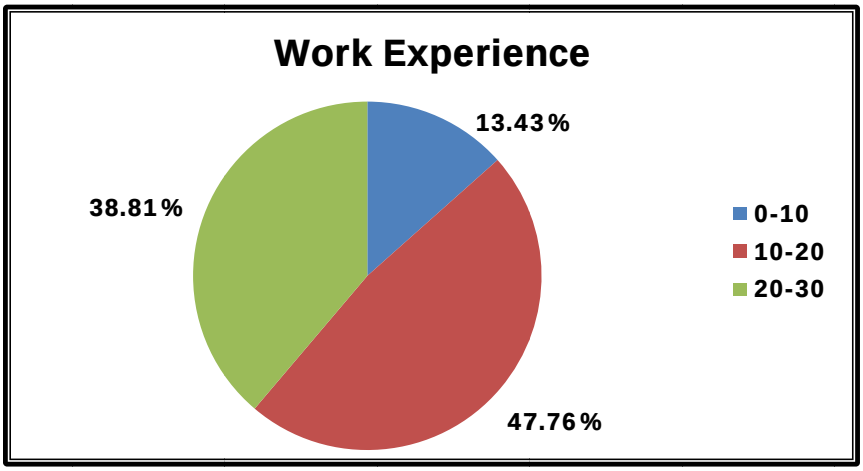


Figure 3.6: TOPSIS participants' work experience

Except the gender and age, which are optional, other statistical reports were helpful in making sure that TOPSIS survey has been completed by qualified project team. As mentioned earlier, all participants have project work experience. Around 94% of the participants have college or university education where 86% of them have more than 10 years project experience.

Table 3.5 shows the evaluation matrix consisting of 11 alternatives and 15 criteria. This matrix has been created directly from the checklist sent to participants. An average of 67 checklists is calculated for all cells as shown in table 3.5. For example cell A1X1=3 is the average of 67 scores that participants wrote for cell A1X1.

Table 3.5: Alternative and criteria matrix

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
A1	3	4	3	1	2	2	2	2	2	2	7	4	2	2	2
A2	4	4	3	1	4	5	4	4	3	3	8	4	3	2	5
A3	2	3	3	1	2	2	2	3	2	2	8	3	3	2	2
A4	7	8	4	5	7	7	4	5	5	6	7	6	6	7	7
A5	3	3	3	2	4	7	3	3	3	5	7	5	4	2	4
A6	7	6	2	4	2	3	8	2	2	9	2	2	3	6	7
A7	6	6	3	2	5	6	5	4	3	6	4	3	4	3	4
A8	6	7	3	2	6	6	4	4	3	5	5	3	5	3	5
A9	8	7	6	4	7	7	5	5	5	6	8	4	7	4	6
A10	8	9	8	6	7	7	6	7	9	9	6	8	8	8	8
A11	6	8	5	4	8	8	4	6	7	7	8	5	7	7	7

Normalized value of the evaluation matrix has been calculated by using equation 1 as shown in table 3.6. For example, cell A1X1= 0.04 is computed by previous value of A1X1=3 divided by square root of the square of all cells which is 67.72, $\sqrt{\sum_i (A_i X_j)^2} = \sqrt{4452}$ = 67.72.

Table 3.6: Normalized alternative and criteria matrix (results of equation 1)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
A1	0.04	0.06	0.04	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.1	0.06	0.03	0.03	0.03
A2	0.06	0.06	0.04	0.01	0.06	0.07	0.06	0.06	0.04	0.04	0.12	0.06	0.04	0.03	0.07
A3	0.03	0.04	0.04	0.01	0.03	0.03	0.03	0.04	0.03	0.03	0.12	0.04	0.04	0.03	0.03
A4	0.1	0.12	0.06	0.07	0.1	0.1	0.06	0.07	0.07	0.09	0.1	0.09	0.09	0.1	0.1
A5	0.04	0.04	0.04	0.03	0.06	0.1	0.04	0.04	0.04	0.07	0.1	0.07	0.06	0.03	0.06
A6	0.1	0.09	0.03	0.06	0.03	0.04	0.12	0.03	0.03	0.13	0.03	0.03	0.04	0.09	0.1
A7	0.09	0.09	0.04	0.03	0.07	0.09	0.07	0.06	0.04	0.09	0.06	0.04	0.06	0.04	0.06
A8	0.09	0.1	0.04	0.03	0.09	0.09	0.06	0.06	0.04	0.07	0.07	0.04	0.07	0.04	0.07
A9	0.12	0.1	0.09	0.06	0.1	0.1	0.07	0.07	0.07	0.09	0.12	0.06	0.1	0.06	0.09
A10	0.12	0.13	0.12	0.09	0.1	0.1	0.09	0.1	0.13	0.13	0.09	0.12	0.12	0.12	0.12
A11	0.09	0.12	0.07	0.06	0.12	0.12	0.06	0.09	0.1	0.1	0.12	0.07	0.1	0.1	0.1

Table 3.7 shows weight matrix. To create matrix W, equation 2 is used as explained earlier. For example, the weigh for cell X1X1 = 0.06 is the average of the normalized weights that was considered for X1 in compare to all criteria.

(0.02+0.01+0.01+0.1+0.02+0.02+0.01+0.14+0.07+0.07+0.1+0.16+0.03+0.08+0.01)/15=0.06

Table 3.7: Weight matrix (results of equation 2)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
X1	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	0
X2	0	0.09	0	0	0	0	0	0	0	0	0	0	0	0	0
X3	0	0	0.08	0	0	0	0	0	0	0	0	0	0	0	0
X4	0	0	0	0.02	0	0	0	0	0	0	0	0	0	0	0
X5	0	0	0	0	0.16	0	0	0	0	0	0	0	0	0	0
X6	0	0	0	0	0	0.13	0	0	0	0	0	0	0	0	0
X7	0	0	0	0	0	0	0.04	0	0	0	0	0	0	0	0
X8	0	0	0	0	0	0	0	0.03	0	0	0	0	0	0	0
X9	0	0	0	0	0	0	0	0	0.01	0	0	0	0	0	0
X10	0	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0
X11	0	0	0	0	0	0	0	0	0	0	0.04	0	0	0	0
X12	0	0	0	0	0	0	0	0	0	0	0	0.06	0	0	0
X13	0	0	0	0	0	0	0	0	0	0	0	0	0.13	0	0
X14	0	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0
X15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.11

Weighted normalised decision matrix is calculated by using equation 3 as shown in table 3.8. For example, cell A1X1=0.003 is computed by 0.04 multiply 0.06.

Table 3.8: Multiplying matrix y and w (results of equation 3)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
A1	0.003	0.006	0.003	0.000	0.005	0.004	0.001	0.001	0.000	0.001	0.004	0.003	0.004	0.001	0.003
A2	0.003	0.006	0.003	0.000	0.010	0.010	0.003	0.002	0.001	0.001	0.005	0.003	0.006	0.001	0.008
A3	0.002	0.004	0.003	0.000	0.005	0.004	0.001	0.001	0.000	0.001	0.005	0.002	0.006	0.001	0.003
A4	0.006	0.011	0.005	0.001	0.017	0.013	0.003	0.002	0.001	0.002	0.004	0.005	0.012	0.002	0.011
A5	0.003	0.004	0.003	0.001	0.010	0.013	0.002	0.001	0.001	0.002	0.004	0.004	0.008	0.001	0.006
A6	0.006	0.009	0.002	0.001	0.005	0.006	0.005	0.001	0.000	0.003	0.001	0.002	0.006	0.002	0.011
A7	0.005	0.009	0.003	0.001	0.012	0.012	0.003	0.002	0.001	0.002	0.002	0.002	0.008	0.001	0.006
A8	0.005	0.010	0.003	0.001	0.015	0.012	0.003	0.002	0.001	0.002	0.003	0.002	0.010	0.001	0.008
A9	0.007	0.010	0.007	0.001	0.017	0.013	0.003	0.002	0.001	0.002	0.005	0.003	0.014	0.001	0.010
A10	0.007	0.013	0.009	0.002	0.017	0.013	0.004	0.003	0.002	0.003	0.004	0.007	0.016	0.002	0.013
A11	0.005	0.011	0.006	0.001	0.020	0.015	0.003	0.003	0.001	0.002	0.005	0.004	0.014	0.002	0.011

Table 3.9 shows the worst alternatives (N^-) and best alternatives (N^+) that are computed by using equation 4 and equation 5. For example, the worst alternatives for X1 in table 3.8 is the minimum value in column X1 that is 0.002 and the best alternatives is the maximum value in column X1 that is 0.007.

Table 3.9: The worst and the best alternatives (results of equation 4 and 5)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15
N^+	0.007	0.013	0.009	0.002	0.020	0.015	0.005	0.003	0.002	0.003	0.005	0.007	0.016	0.002	0.013
N^-	0.002	0.004	0.002	0.000	0.005	0.004	0.001	0.001	0.000	0.001	0.001	0.002	0.004	0.001	0.003

As shown in table 3.10, to calculate d^+, the distance between the target alternative i and the best condition N^+, equation 6 is used. Also, as shown in table 3.11, to calculate d^-, the distance between the target alternative i and the worst condition N^-, equation 7 is used. For example, D+ for A1=0.027 is computed by SQRT[$(0.003-0.007)^2$ +$(0.006-0.013)^2$ +$(0.003-0.009)^2$+$(0.000-0.002)^2$+$(0.005-0.02)^2$+$(0.004-0.015)^2$+$(0.001-0.005)^2$+$(0.001-0.003)^2$+$(0.000-0.002)^2$+$(0.001-0.003)^2$+$(0.004-0.005)^2$+$(0.003-0.007)^2$+$(0.004-0.016)^2$+$(0.001-0.002)^2$+$(0.003-0.013)^2$]=0.0270

Also, D- for A1=0.004 is computed by SQRT[$(0.003-0.002)^2$+$(0.006-0.004)^2$+$(0.003-0.002)^2$+$(0.000-0.000)^2$+$(0.005-0.005)^2$+$(0.004-0.004)^2$+$(0.001-0.001)^2$+$(0.001-0.001)^2$+$(0.000-0.000)^2$+$(0.001-0.001)^2$+$(0.004-0.001)^2$+$(0.003-0.002)^2$+$(0.004-0.004)^2$+$(0.001-0.001)^2$+$(0.003-0.003)^2$]=0.004

Table 3.10: Distances between the target and the best alternative or D+ (results of equation 6)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	D+
A1	0.00002	0.00005	0.00003	0.00000	0.00021	0.00013	0.00001	0.00000	0.00000	0.00001	0.00000	0.00001	0.00014	0.00000	0.00009	0.0270
A2	0.00001	0.00005	0.00003	0.00000	0.00010	0.00003	0.00001	0.00000	0.00000	0.00000	0.00000	0.00001	0.00010	0.00000	0.00002	0.0194
A3	0.00003	0.00007	0.00003	0.00000	0.00021	0.00013	0.00001	0.00000	0.00000	0.00001	0.00000	0.00002	0.00010	0.00000	0.00009	0.0268
A4	0.00000	0.00000	0.00002	0.00000	0.00001	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00000	0.00000	0.0080
A5	0.00002	0.00007	0.00003	0.00000	0.00010	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00001	0.00006	0.00000	0.00004	0.0188
A6	0.00000	0.00002	0.00005	0.00000	0.00021	0.00009	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00010	0.00000	0.00000	0.0228
A7	0.00000	0.00002	0.00003	0.00000	0.00005	0.00001	0.00000	0.00000	0.00000	0.00000	0.00001	0.00002	0.00006	0.00000	0.00004	0.0162
A8	0.00000	0.00001	0.00003	0.00000	0.00002	0.00001	0.00001	0.00000	0.00000	0.00000	0.00000	0.00002	0.00004	0.00000	0.00002	0.0133
A9	0.00000	0.00001	0.00001	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00001	0.0075
A10	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.0036
A11	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.0061

Table 3.11: Distances between the target and the worst alternative or D- (results of equation 7)

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	D-
A1	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.0040
A2	0.00000	0.00000	0.00000	0.00000	0.00002	0.00003	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00002	0.0104
A3	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.0045
A4	0.00002	0.00005	0.00001	0.00000	0.00015	0.00009	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00006	0.00000	0.00006	0.0217
A5	0.00000	0.00000	0.00000	0.00000	0.00002	0.00009	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00002	0.00000	0.00001	0.0127
A6	0.00002	0.00002	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000	0.00006	0.0114
A7	0.00001	0.00002	0.00000	0.00000	0.00005	0.00006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00002	0.00000	0.00001	0.0134
A8	0.00001	0.00003	0.00000	0.00000	0.00010	0.00006	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00004	0.00000	0.00002	0.0163
A9	0.00003	0.00003	0.00002	0.00000	0.00015	0.00009	0.00000	0.00000	0.00000	0.00000	0.00001	0.00000	0.00010	0.00000	0.00004	0.0220
A10	0.00003	0.00007	0.00005	0.00000	0.00015	0.00009	0.00001	0.00000	0.00000	0.00001	0.00001	0.00002	0.00014	0.00000	0.00009	0.0260
A11	0.00001	0.00005	0.00001	0.00000	0.00021	0.00013	0.00000	0.00000	0.00000	0.00000	0.00001	0.00001	0.00010	0.00000	0.00006	0.0248

The last step is the computation of similarities, E_i $(i = 1,2, \dots, 11)$. As shown in table 3.12, E_i is calculated by using equation 8. For example, $E_1 = 0.1306$ is computed by 0.00405 divided by 0.02696 plus 0.00405.

Table 3.12: Final score of models (results of equation 8)

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
D+	0.02696	0.01938	0.02677	0.00801	0.01881	0.02284	0.01615	0.01328	0.00746	0.00358	0.00610
D -	0.00405	0.01044	0.00447	0.02171	0.01273	0.01136	0.01336	0.01631	0.02204	0.02600	0.02481
Ei	0.1306	0.3501	0.1431	0.7303	0.4036	0.3321	0.4527	0.5511	0.7471	0.8789	0.8025

As explained earlier, E_i presents the final score of the alternatives. As shown in figure 3.7, the E_i values are listed in an order from maximum score on the left to minimum score on the right. Because the value of E_i is a number between 0 and 1, the advantages of the models on the left side of the spectrum where their E_i are greater than 0.5 should be considered in the proposed model and the disadvantages of the models on the right sides where their E_i are less than 0.5 will be excluded.

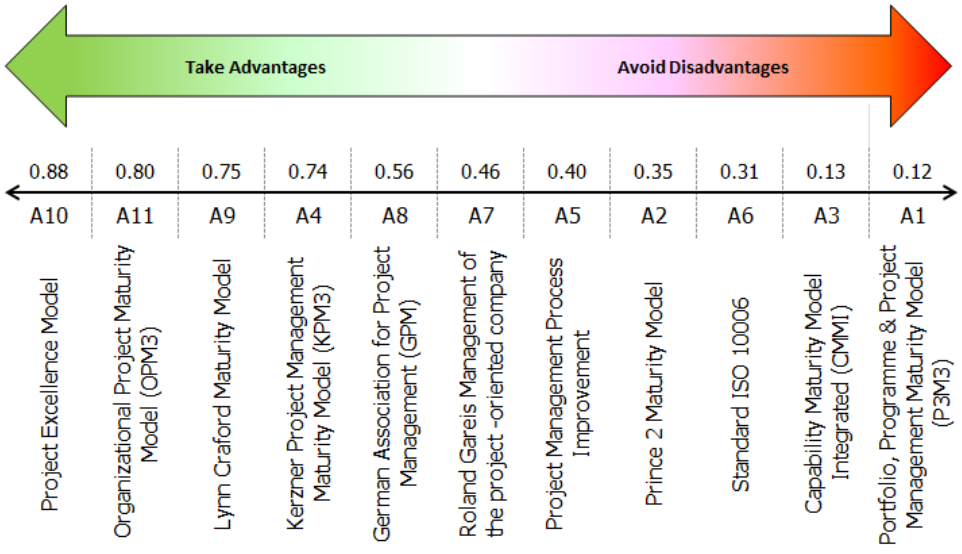


Figure 3.7: Final score (Ei) of models

3.3. Model development process

Using the TOPSIS results, the new project audit model will be developed through three phases: 1) developing the conceptual model - phase 1; 2) developing the detail model - phase 2; and 3) developing a scoring system for the model - phase 3.

In the conceptual model, the main structure of the project audit model will be designed. Three critical aspects of the project (process, function, and progress) are presented. In the detail model, each of those three aspects is described and categorised for measurement. Appropriate questions are selected and assigned to each category to measure the project situation in that specific category. Questions should be answered during the project audit. However, to satisfy each question, specific document(s) are necessary to be provided. A scoring model is needed to be designed to calculate the score of the projects after the audit.

3.3.1. Developing the conceptual model (Phase 1)

The advantages and disadvantages of the reviewed models are shown in table 3.1 and table 3.2, and the results of the TOPSIS ranking, is shown in figure 3.7, help in developing a theoretical framework of a conceptual model for the project audit.

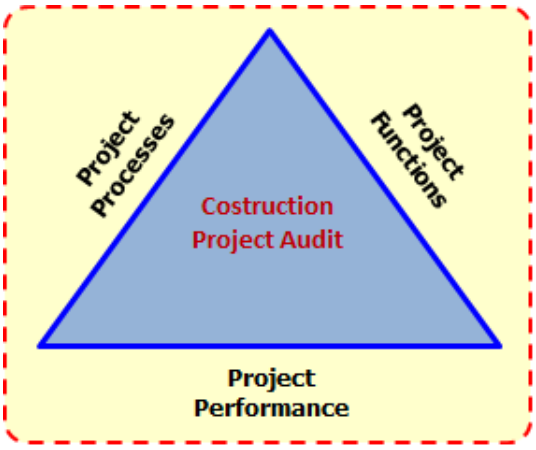


Figure 3.8: Project audit theoretical framework (conceptual model)

As shown in figure 3.8, the project audit can be conducted by considering three critical aspects of the project: 1) project processes; 2) project functions; and 3) project performance. Figure 3.8 shows these aspects on the three sides of a triangle. In other words, a project should be audited through its processes, functions, and the performance that it achieves through the audit data.

3.3.2. Developing the detail model (Phase 2)

The Detail model provides much more information about each of three aspects mentioned in the conceptual model. The project processes include four main parts:

1. **Project Planning or Basic Design;** which consists of all the processes required to establish the project plan, to cover the project scope and to achieve the project objectives.
2. **Project Executing or Implementation;** which consists of all the processes required to complete the project work as planned and to satisfy the project specifications
3. **Project Monitoring and Controlling;** which consists of all the processes responsible to track, review, and regulate the project work and progress.
4. **Project Closing or Turn over;** which consists of all the processes related to finalizing the project activities and closing it.

Project functions include nine parts:

1. **Project Cost;** which is related to estimating, budgeting, managing, and controlling project costs so that the project can be completed within the determined budget.

2. **Project Time;** which is related to the project activities duration, scheduling the project and completing it on time.
3. **Project Quality/Safety;** which needs to be performed in order to determine policies, objectives, and responsibilities to quality of the project specifications with defined safety.
4. **Project Scope;** which is required for ensuring that the project works will be completed and any other type of works that are out of the project scope will be reported.
5. **Project Human Resources;** which are necessary to organize, manage, and lead the project team.
6. **Project Communication;** which is related to collecting project information, generating appropriate reports, and distributing reports.
7. **Project Risk;** which is related to identification, analysis, response, and control of project uncertainties.
8. **Project Procurement;** which is needed to purchase or acquire products, services, or results needed from outside the project team.
9. **Project Integration;** which is necessary to combine and integrate project management activities.

Based on the advantages and disadvantages of the reviewed models and the results of the TOPSIS ranking, some questions are assigned to each process and function needed to audit the project and measure its status. Also, related documents are included to satisfy each question.

As for the project performance, it is computed through the application of the Earned Value Method (EVM). This part provides useful analysis related to the project indices. EVM relies on three key data points; 1) Budgeted Cost of Work Performed (BCWP); 2) Budgeted Cost of Work Scheduled (BCWS); 3) Actual Cost of Work Performed (ACWP).

BCWP indicates work progress at a given point in time. It indicates the amount of work put in place at a specific point of time. BCWS describes how the project work is supposed to be at any given point based on the project schedule. It is a number that presents the budgeted work that is scheduled. ACWP is a number that indicates the actual work performed to date.

The first index that presents the project time performance is Schedule Performance Index (SPI). SPI shows how efficiently the project used its time. As shown in equation 9, SPI is computed by dividing the BCWP by the BCWS. SPI is a number that can be either lower than 1 (under schedule) or bigger than 1 (ahead of schedule).

$$SPI = \frac{\text{BCWP}}{\text{BCWS}} \qquad \text{Equation 9}$$

The second index presents the project cost performance, which is Cost Performance Index (CPI). CPI indicates how efficiently the project used its budget to date. As shown in equation 10, CPI is computed by dividing the BCWP by the ACWP. CPI is a number that can be either less than 1 (over budget) or greater than 1 (under budget).

$$CPI = \frac{\text{BCWP}}{\text{ACWP}} \qquad \text{Equation 10}$$

Two other important values that EVM calculates are: 1) Schedule Variance (SV) and 2) Cost Variance (CV). SV indicates that a project is ahead of or behind schedule and it is calculated by subtracting the BCWP from BCWS as shown in equation 11. A positive value is a favorable condition and a negative value is an unfavorable condition.

$$SV = \text{BCWP} - \text{BCWS} \qquad \text{Equation 11}$$

CV indicates that a project is over or under budget and it is calculated by subtracting the BCWP from ACWP as shown in equation 12. A positive value is a favorable condition and a negative value is an unfavorable condition.

$$CV = \text{BCWP} - \text{ACWP} \qquad \text{Equation 12}$$

There are some other useful values that can be computed with the earned value method; 1) Time Estimate at Completion (EAC_t); 2) Estimate to Completion (ETC); 3) Estimate at Completion (EAC); and 4) Variance at Completion (VAC).

The ETC (t) is an approximate estimate indicates when the project will be completed, if current performance continues. As shown in equation 13, ETC (t) is calculated by project duration divided by SPI.

$$EAC_t = \frac{Project\ Duration}{SPI} \qquad \text{Equation 13}$$

The ETC is an approximate estimate indicates how much money is needed from now to complete the project, if current performance continues. As shown in equation 14, ETC is calculated by project budget minus BCWP divided by CPI.

$$ETC = \frac{Project\ Budget - BCWP}{CPI} \qquad \text{Equation 14}$$

The EAC is an approximate estimate indicates how much the final cost of the project will be, if current performance continues. As shown in equation 15, EAC is calculated by project budget divided by CPI.

$$EAC = \frac{Project\ Budget}{CPI} \qquad \text{Equation 15}$$

Knowing the value of EAC, VAC can be calculated. VAC indicates whether the project will finish under or over budget. As shown in equation 16, VAC is computed by subtracting the EAC from the project budget.

$$VAC = Project\ Budget\ - EAC \qquad \text{Equation 16}$$

EVM indices and its other values measure the current performance of the project and forecast its future performance if the project continues on the same trend.

3.3.3. Developing the scoring system for the model (Phase 3)

After defining the three aspects of the project audit, a scoring system is needed to compute a quantitative value for the project processes and functions. The proposed model has a flexible scoring system, which can be defined based on the company preference. This would help project oriented companies to adjust the level of details and accuracy when auditing their projects. However, to have reliable results and to ensure equality, the same scoring system must be applied to audit all company's projects. The auditor may assign any score between 0 and 9 to each question: nothing (0); very bad (1); bad (2); almost medium (3); medium (4); more than medium (5); good (6); very good (7); excellent (8); mature (9). For example, if an auditor assesses a question as good, the system assigns a score of 6 points to the planning process and scope function of the project. The performance of each

process and function is simply computed as a percentage according to the following equations:

$$\%\ process = \frac{\sum scores\ related\ to\ the\ process}{Max\ score\ that\ can\ be\ achieved\ for\ the\ process} \times 100 \qquad \text{Equation 17}$$

$$\%\ function = \frac{\sum scores\ related\ to\ the\ function}{Max\ score\ that\ can\ be\ achieved\ for\ the\ function} \times 100 \quad \text{Equation 18}$$

Each percentage computed by using equations 17 and 18 can be interpreted by using table 3.13. According to table 3.13, if the percentage score of process is a number between 0 and 0.2, it is interpreted that process of the project has a very bad condition, if the percentage score of process is a number between 0.2 and 0.4, process of the project has a bad condition, if the percentage score of process is a number between 0.4 and 0.6, process of the project has a medium condition, if the percentage score of process is a number between 0.6 and 0.8, process of the project has a good condition, and if the percentage score of process is a number between 0.8 and 1.0, process of the project has a very good condition,

Table 3.13: Score interpretation guideline

Percentage Between	**Interpretation**
%0 < score < %20	Very bad
%20 < score < %40	Bad
%40 < score <% 60	Medium
%60 < score < %80	Good
%80 < score < %100	Very good

As shown in figure 3.9, the proposed project audit model consists of three parts that are connected together; 1) input; 2) process; and 3) output.

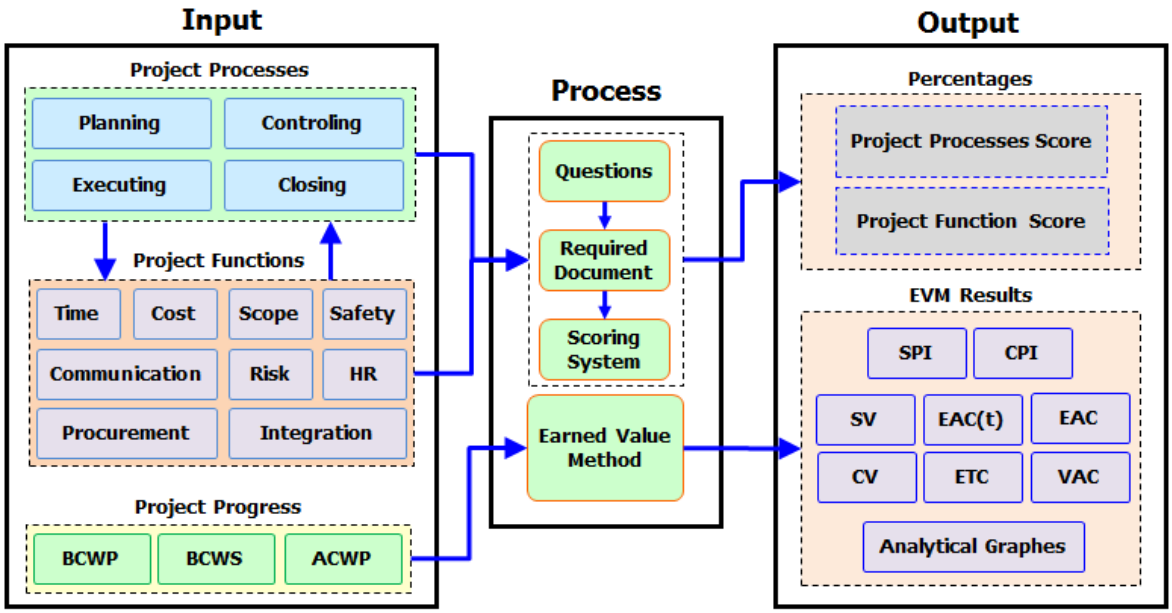


Figure 3.9: Project audit model

Current status of the project processes and its functions are inputted into the model, and other values are measured by their related questions. As mentioned earlier, to satisfy each question, specific document(s) is/are necessary to be provided. Then, the scoring system calculates the final score of each process and function. Also, project progress key data points (BCWP, BCWS, and ACWP) are inputted into the model. By using the earned value method, important project indices are calculated and related graphs are drawn. The output of the proposed model provides a comprehensive report of the project status. By reviewing the output, project owner and project manager can monitor the project status by having detail information about the different parts of the project.

3.3. Summary

In this chapter, the methodology that has been used to develop the project audit model is described and its components are clarified. First, project audit and improvement models are analyzed and their advantages and disadvantages are identified. Then, by using TOPSIS,

the reviewed models are ranked from the best to the worst. Their advantages have been included in the proposed model and their disadvantages have been excluded. Next, the proposed model is developed and a scoring system is designed to calculate the project processes and functions scores. For project performance, earned value method is used to measure the project progress performance. The proposed model is completely integrated and provides comprehensive report of the project status.

Chapter Four

Model Development

4.1. Introduction

This chapter illustrates the development of the integrated project audit model. The development process of the model consists of six components: 1) table relationship; 2) project information; 3) audit questions; 4) plan a project audit; 5) record audit results; 6) reports. The development has been implemented using Visual Basic for application Programming language, and Access 2010.

4.2. Table relationship

To develop the model, tables are needed to store the project data. These data consist of the project main information (i.e. name, code, start and finish date) and project progress data (i.e. time and cost). Also, some tables are needed to store the questions and the results of the calculations. Therefore, the following tables are designed:

- **Process Table:** that stores all the project processes that will be audited.
- **Function Table:** that stores all the project functions that will be audited.
- **Project Information Table:** that stores the project information (i.e. start date).
- **Contract Table:** that stores the type of the project contract.
- **Question Table:** that stores all the audit questions.
- **Stage Table:** that stores the different stages of the project (i.e. basic design)
- **Evidence Table:** that stores the documents needed to satisfy the questions.
- **Audit Table:** that stores the date where the project audits are scheduled and planned.
- **Score Table:** that stores the standard scoring level that can be used for the audit.

- **Performance Table:** that stores the project progress data.
- **Auditor Table:** that stores the list of auditors who participated in the project audit.
- **Audit Question Table:** that stores all the questions that have been selected for an audit.

Figure 4.1 shows how the tables are related with each other so that information is shared between them as needed. All the relationships that link these tables are one to many relationships.

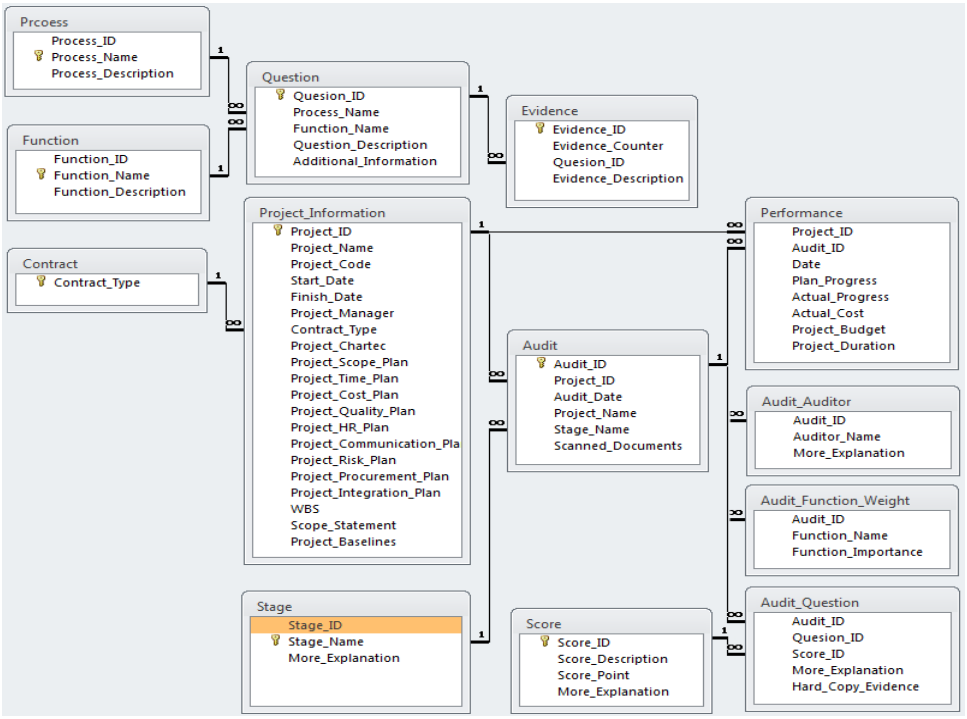


Figure 4.1: Tables relationships

4.3. Project Related Information

As explained earlier, first, fundamental information needs to be provided to implement the audit effectively. The information is divided into seven groups: 1) construction process; 2) construction function; 3) construction stage; 4) contract type; 5) scoring levels; 6) project plan; and 7) project information, as shown in figure 4.2. To activate this tab, in the main menu the user should click on related information button.

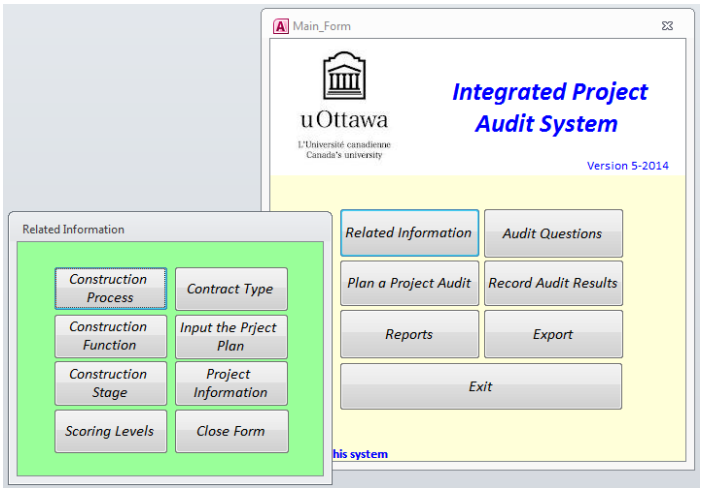


Figure 4.2: Related information tab

If the user clicks on either the project process or the project functions, different forms will be opened as shown in figure 4.3 and figure 4.4 respectively.

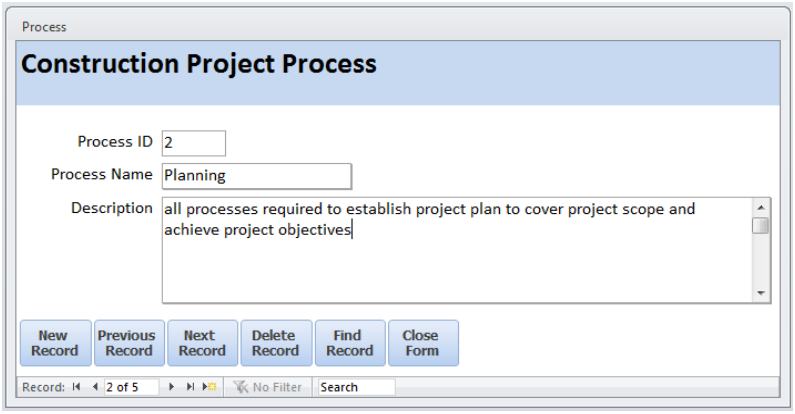


Figure 4.3: Project processes form

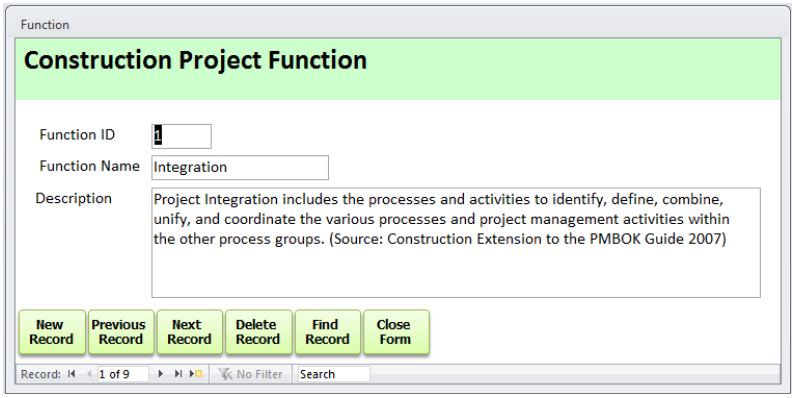


Figure 4.4: Project functions form

To show in which stage the project is audited, a standard list of project stages will be needed. This list is used when an audit is being planned as shown in figure 4.5 where the project stage is in a basic design stage.

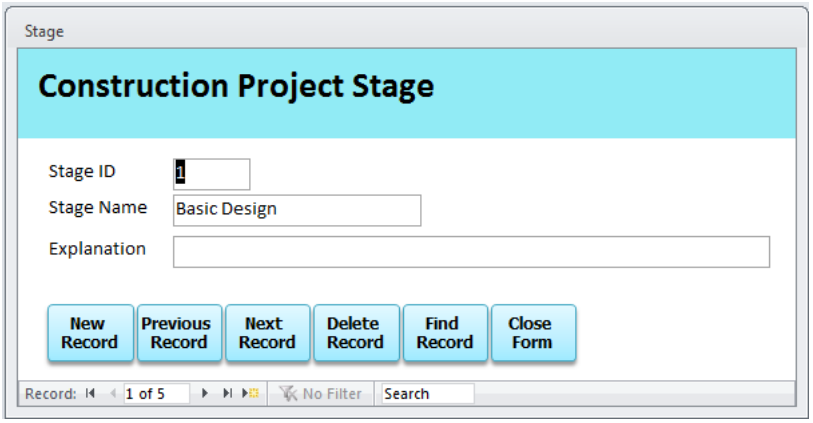


Figure 4.5: Project stages form

In this application, the scoring system is flexible and can be defined according to the owner's standards. As mentioned earlier, a flexible scoring category provides the opportunity to audit the project deeply and accurately. Figure 4.6 shows the scoring category form.

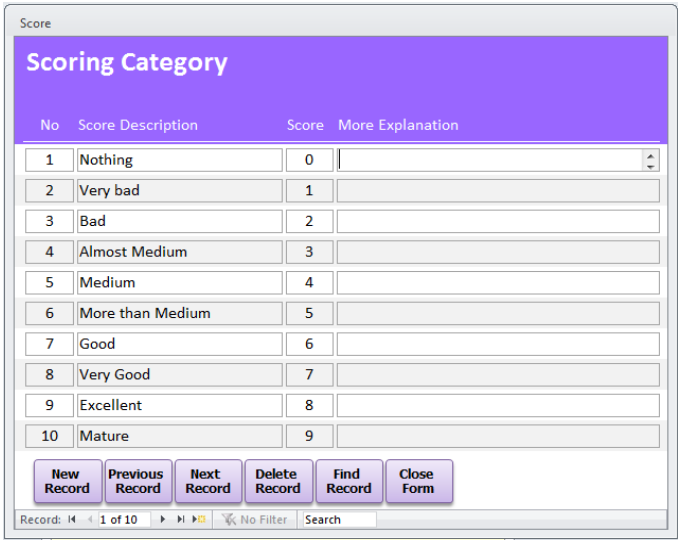


Figure 4.6: Scoring categories form

Usually, project-oriented companies implement several projects within a specific period of time. This provides the opportunity to learn more from previous projects. Storing the type of contract used in the project would help the audit process to find the type of contract that has good performance and the ones that need to improve its capabilities. Figure 4.7 provides a list of the contract types inserted in the developed model. For example, after implementing five or six audits, the company may find that it had a very good performance in lump sum contract for the project based on the audit results.

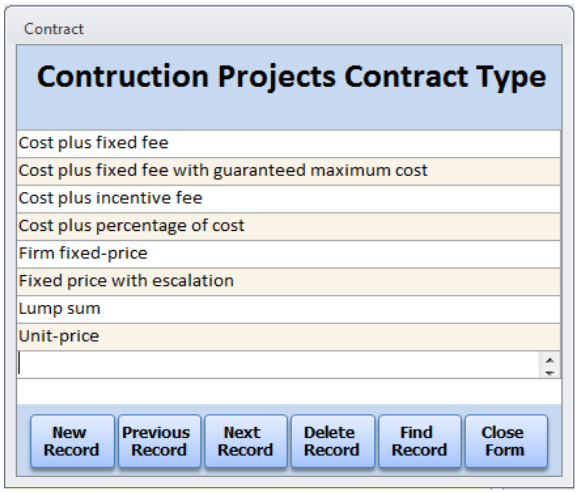


Figure 4.7: Contract types form

One of the most important forms in the related information tab is the project information form. In this form the main information about the project (i.e. project title, project manager, and the start and finish date) are required to be filled by users. The project code should be entered for future purposes (i.e. to pull up project information data for the report). Each project must have a unique code consisting of six characters. The first three characters are letters and the next three characters are numbers. This format allows the user to define a specific project code format for specific types of projects. For example, EPC000 is considered for construction projects and EEE000 for engineering projects. Also, a snapshot of the project plan can be seen, including the planned progress, actual progress, planned

cost, actual cost, project duration, and estimated time to finish with current performance and cost to completion.

There is a list of critical project documents in this tab and the user needs to check off any documents that are already prepared for the project. These documents are necessary to satisfy the related questions during the project audit. Figure 4.8 illustrates an example of the project information and its related documents.

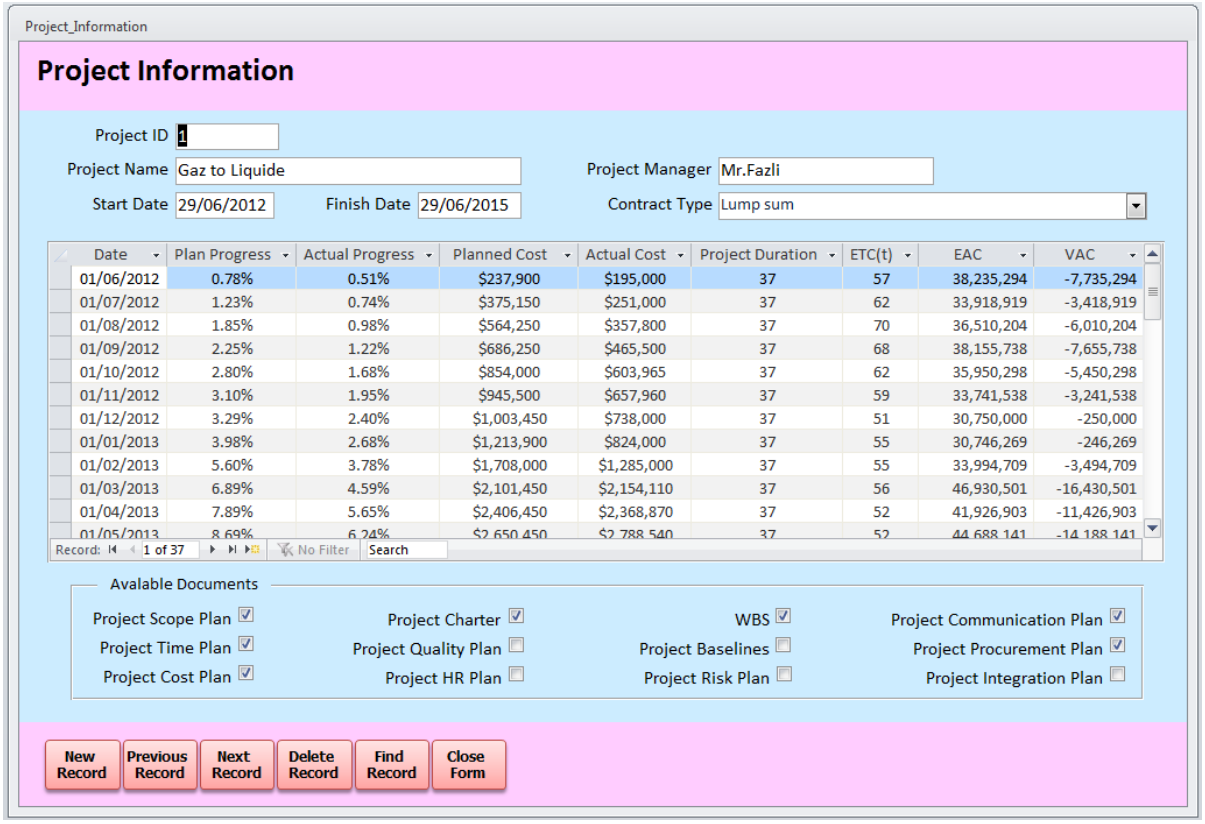


Figure 4.8: Project information form

4.4. Audit questions

Several questions have been designed to audit projects. Each question is related to a project process and a project function. Furthermore, to satisfy each question, two or more documents need to be prepared. As shown in figure 4.9, in the audit questions form, the

user can define questions and provide a process and function for them. To active this form, in the main form, the user should click on the audit question button.

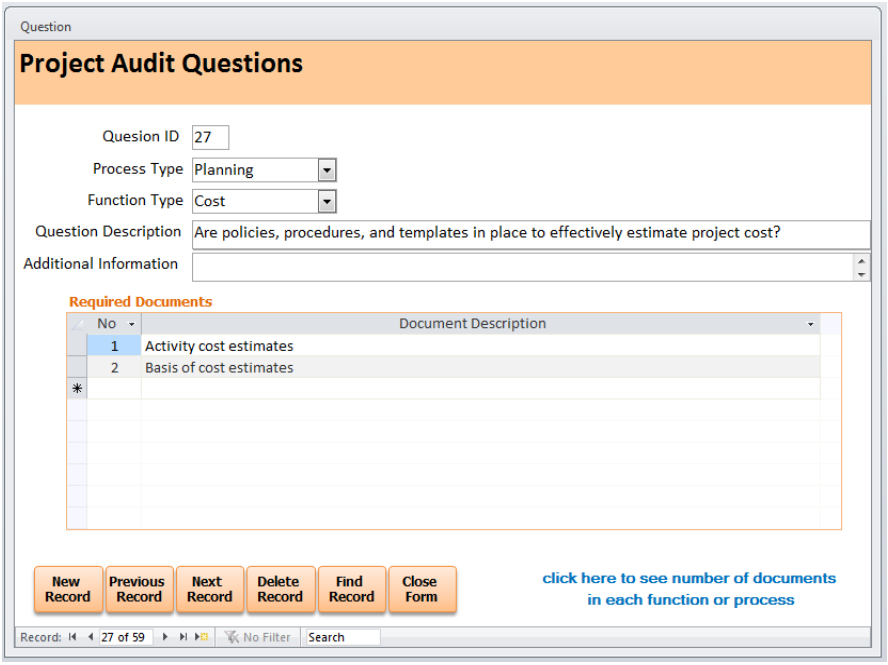


Figure 4.9: Audit question form

Also, the required documents and other additional information can be defined in that form. Figure 4.9 shows an example of the project audit questions as well as a list of documents required for that question.

4.5. Plan a project audit

Before an audit starts, it needs to be planned and scheduled. In other words, some information (i.e. audit date, project name, project stage, and auditors) need to be selected from the form that has been designed for this purpose. The developed model assigns a unique ID for each audit. This ID is important so that the data related to this audit can be recalled in the future for reports or other purposes. The ID consists of six characters. The first four characters represent the year that the audit is being implemented and the last two

characters count the number of audits in each year. For example, audit ID=201402 means that the second audit in 2014. Also, there are two ways to audit a project: 1) comprehensive; 2) quick. To active this tab, users should click on plan a project audit button in the main menu (figure 4.10).

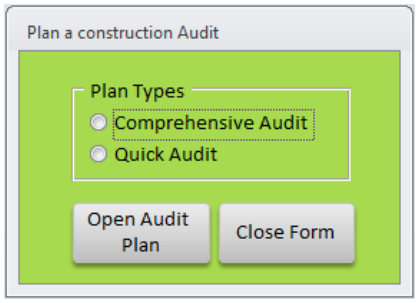


Figure 4.10: Audit types tab

- Comprehensive Audit: where a real project audit should be comprehensive and include all processes and functions. This audit is planned in advance where qualified auditors are chosen to participate during the predetermined date. Also, the user is able to attach any related document in this tab as illustrated in figure 4.11.

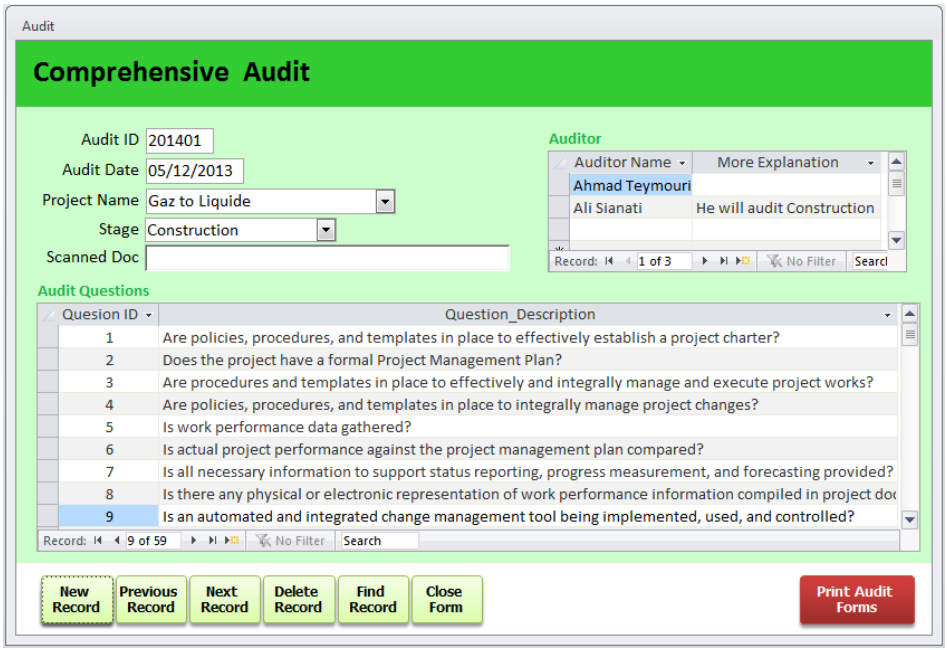


Figure 4.11: Comprehensive planning audit form

- Quick Audit: Sometimes, project managers need to prepare a report for a specific function or process and they do not have enough time or resources to implement a comprehensive audit. In this situation, Quick Audit is selected as shown in figure 4.12.

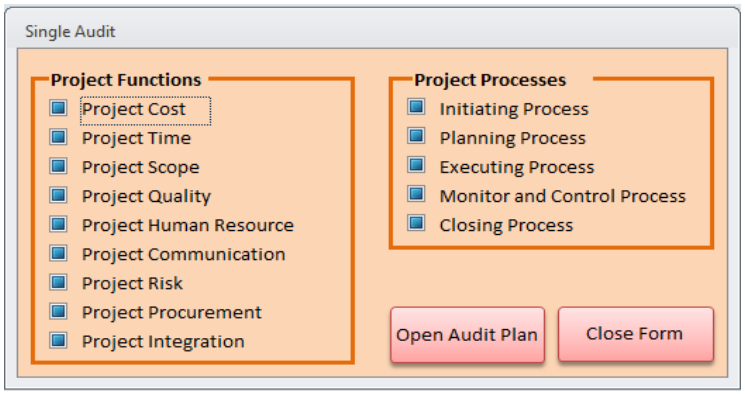


Figure 4.12: Quick audit tab

4.6. Recording audit results

To record the audit results which are divided into two categories as shown in figure 4.13.

- Question results: this part includes the results of all the questions related to project processes and functions as shown in figure 4.14.
- Performance results: this consists of the project progress information that should be entered in the model (i.e. actual progress and actual cost) as shown in figure 4.15. The model compares this progress with the planned progress and analyses the data by using the earned value method.

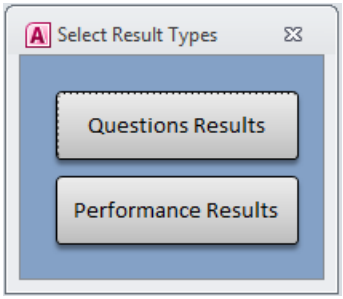


Figure 4.13: record result tab

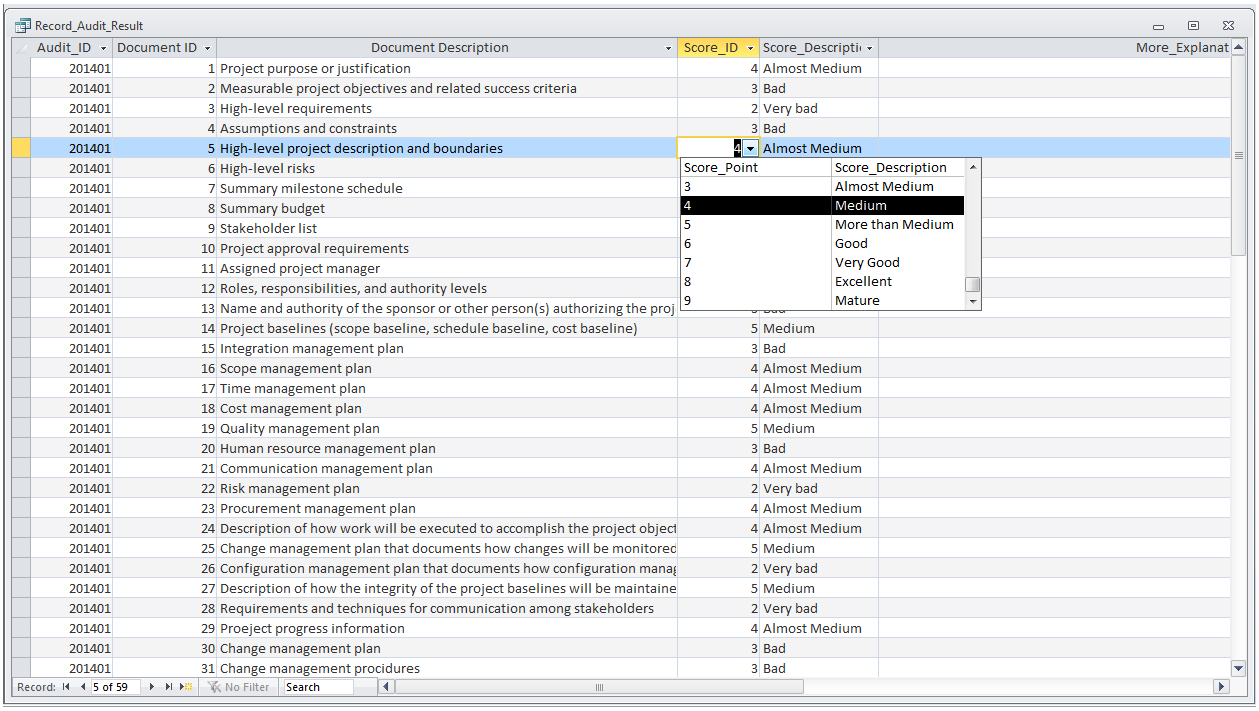


Figure 4.14: Recording questions' score

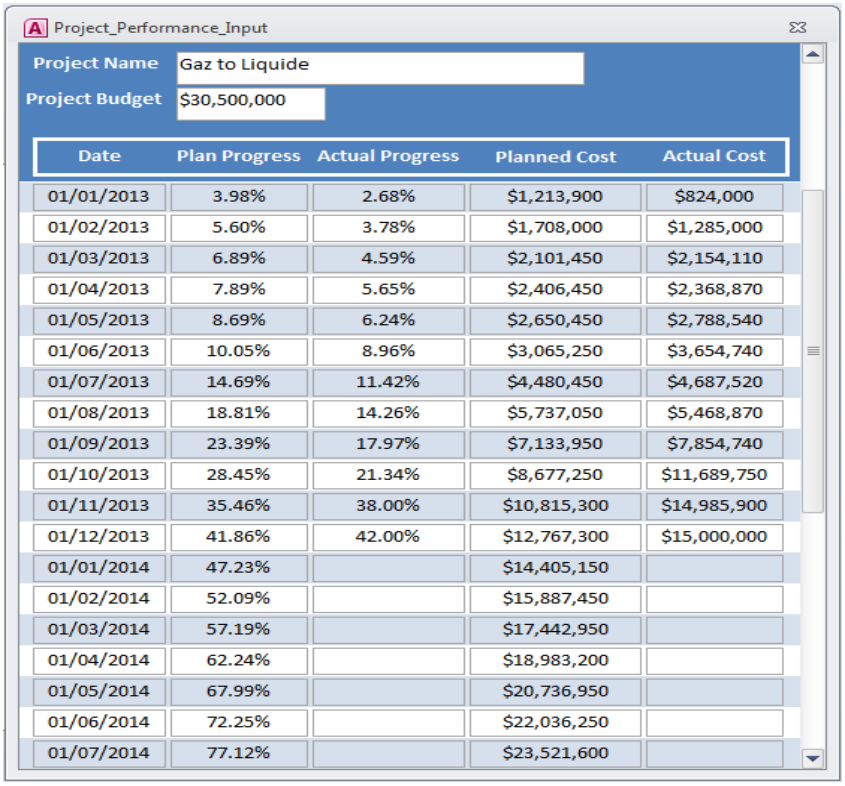


Figure 4.15: Recording performance data

4.7. Output Reports

Reporting is one the most important parts of an audit. The developed model is able to generate several types of reports and to generate a variety of new user-defined reports. In other words, some reports are generated from the main information (i.e. project information, processes, and functions) and others are the result of the analysis and computations that the model implement. Therefore, two groups of reports have been designed in this model as shown in figure 4.16.

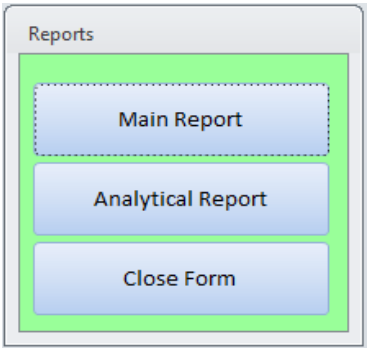


Figure 4.16: Selecting report type tab

1. Main report: the reports generated from the main information menu (i.e. project information, processes, functions) as shown in figure 4.17.

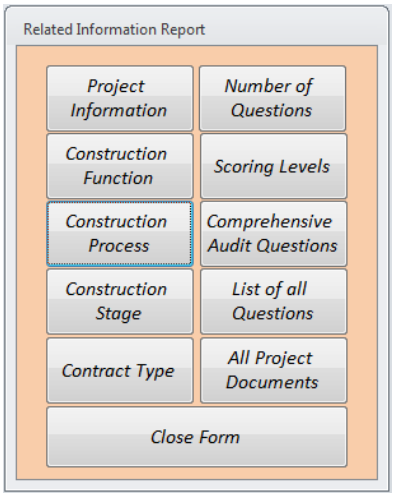


Figure 4.17: Main report tab

- **Project Information Report:** is a report of all the project information that was entered in the model before the audit.
- **Number of Questions Report:** is a report that shows how many questions and documents have been recorded in the developed model.
- **Project Function Report:** is a report of the functions that the project audit is based on.
- **Scoring Levels Report:** is the standard level of scoring system for the audit in the developed model.
- **Project Process Report:** is a report of processes that the project audit is based on.
- **Comprehensive Audit Questions Report:** is a report that includes all the questions that are needed for a comprehensive audit.
- **Project Stage Report:** is a report of the project stages included in the developed model.
- **List of All Questions Report:** is a simple report of the project questions included in the developed model.
- **Contract Type Report:** is a report of the project contract types inherited in the developed model.

- **All Project Documents Report:** is a list of important project documents included in the developed model.

2. Analytical report: This provides analytical results of the project audit. The user is asked to enter the project audit code and project code to generate the reports. The following reports are generated as shown in figure 4.18.

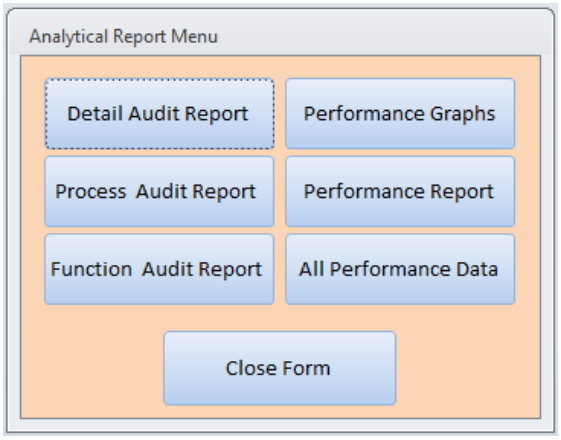


Figure 4.18: Analytical report tab

- **Detail Audit Report:** is an analytical report about the project processes and functions status.
- **Performance Graphs:** several analytical graphs that show the project performance trend from the start of the project to the audit date.
- **Process Audit Report:** is an analytical report about the project processes status.
- **Performance Report:** is an analytical report that shows the earned value indices based on a specific date.
- **Function Audit Report:** is an analytical report about the project function status.
- **All Performance Data Report:** is an analytical report that shows all earned value indices in a table format from the beginning of the project.

All forms in the developed model have a dashboard to manage records. In this dashboard, users are able to add a new record, move to the previous record, move to the next record, delete a specific record, search a specific record, and close the tab as shown in figure 4.19.

Figure 4.19: Data management dashboard

Also a very useful option of the developed model is the ability to export the data in other formats. The user can export audit data and other data from the developed model to three different formats: Excel 2003/2010, Adobe Acrobat, and HTML. This helps to generate more analytical reports, as shown in figure 4.20.

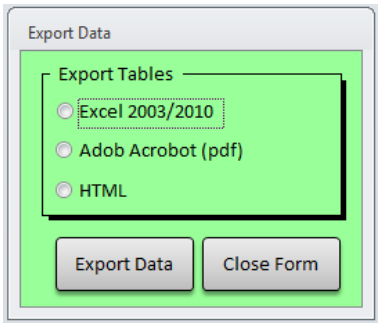


Figure 4.20: Export data tab

4.8. Summary

The process of developing of the proposed project audit model is illustrated in this chapter and the main steps that have been followed to generate an integrated project audit system are showed. First, the table relationships are defined. All the relationships that link these tables are one to many relationships. Then, the components of the main menu consist of project related information tab, audit questions tab, plan a project audit tab, recording the audit results tab, and output reports tab are described.

Chapter Five

Model Validation

5.1. Introduction

This chapter tests the capability and workability of the developed model to plan, implement, and report a project audit. To validate the model and its results, information from a real Oil and Gas project is used in the model to implement a project audit. It is commonly known that an Oil and Gas project is classified as an infrastructure project because it consists of different construction projects including un-industrial and industrial buildings, pipelines, roads, warehouses, refinery, tanks, vessels and etc. Selecting this type of projects would help in testing and ensuring that the developed model can be used in any type of construction projects. Therefore, a Refinery Gas Pars in Iran is selected. It has a starting date of October 2011 and a finishing date of October 2015. The project has two contractors: a design contractor and a construction contractor. The design contractor is responsible for project management, basic and detail engineering design and execution, procurement of the main equipment and materials of the project, construction supervision, engineering manpower supply, specialized commissioning operation. The construction contractor is responsible for civil activities, erection management, erection execution, site preparation and mobilization, material and equipment supply for erection, pre-commissioning, expert manpower supply for the commissioning operation. The contract is a lump sum and consists of engineering, procurement, construction, test & inspection, pre-commissioning, commissioning and training of establishing a Gas Treatment Plant.

5.2. Related Information Menu

First, the project information must be entered into the model. As shown in figure 5.1, the user should click on the “Related Information” button to open another tab that provides the main menu from which the user can select and input project information.

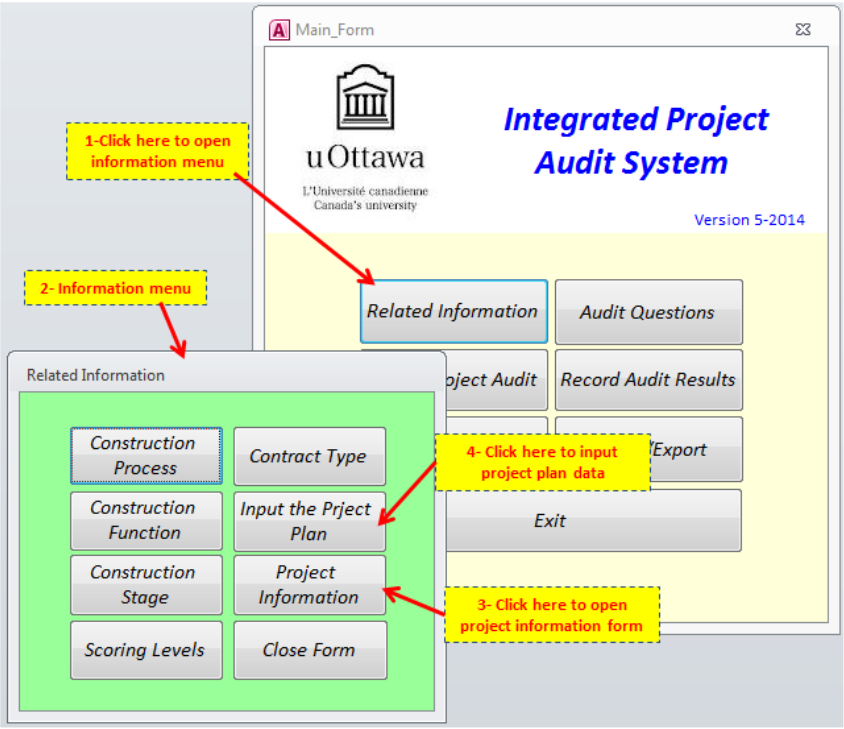


Figure 5.1: Related information menu

In the project information form, project name, project manager’s name, start date and finish date should be entered. While, other related information about the project such as the contract type and the list of current project documents can be added. The project code should be entered for future purposes (i.e. to pull up project information data for the report). Each project must have a unique code consists of six characters, three letters and three numbers, AAA000. This format allows the user to define a specific project code for specific types of projects. For example, EPC002 represent that a the project number two includes of Engineering (E), Procurement (P), and Construction (C) phases .There is a table

in the middle of the form that present a summary of the project progress information. This table will be filled by related data that will be added from the form “Input the Project Plan” as shown in Figure 5.2. The purpose for this table is to show a snapshot of the project status

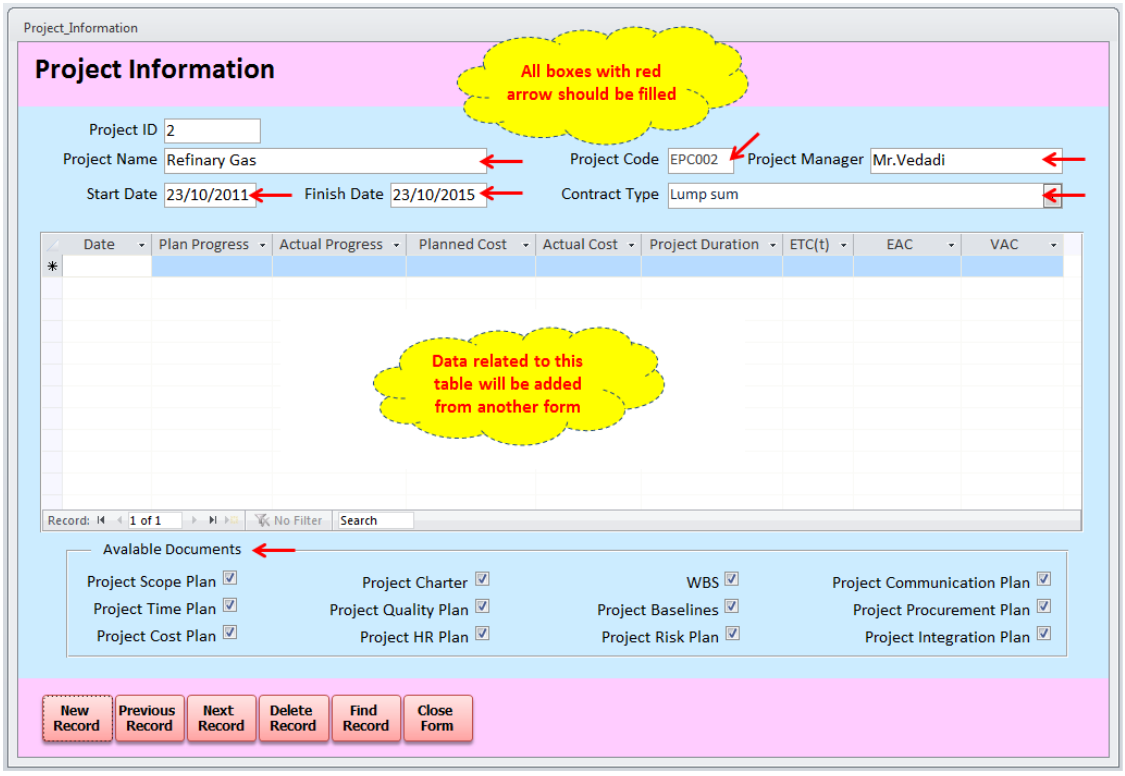
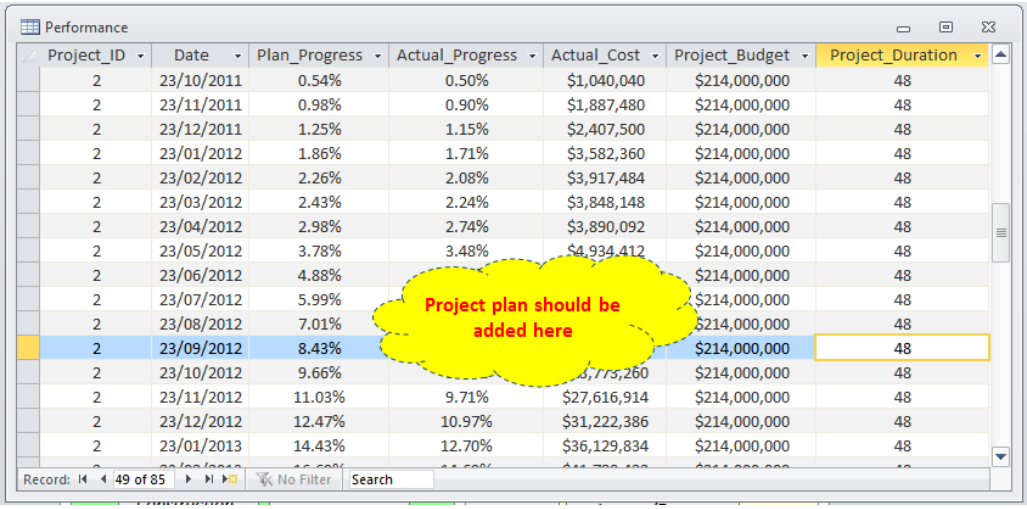


Figure 5.2: Project information input form without the summary plan

Clicking on “Input the Project Plan” button from the related information form, the data related to the project plan such as the date, plan and actual progress, actual cost, project budget, and project duration must be added by the user as shown in figure 5.3. This data can be easily copied from the project schedule but the Project ID should be the same as the one saved for the project in the project information menu.

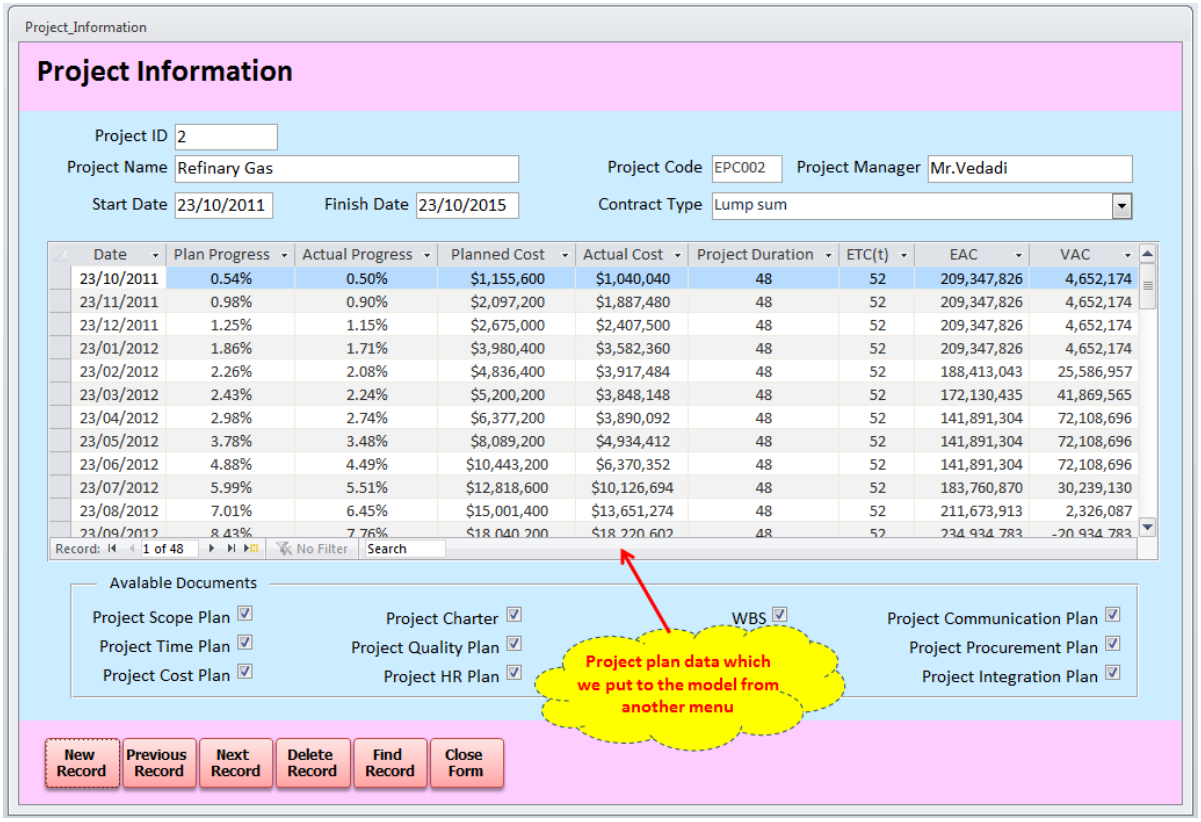
Figure 5.3 shows the data related to Project ID number 2. In the first row, planned progress and actual progress in 23/10/2011 are 0.54% and 0.50% respectively and increase during the project life cycle. Also, the project was planned to be implemented in 48 month with a budget of $214 million, this number is not changed.



Project_ID	Date	Plan_Progress	Actual_Progress	Actual_Cost	Project_Budget	Project_Duration
2	23/10/2011	0.54%	0.50%	$1,040,040	$214,000,000	48
2	23/11/2011	0.98%	0.90%	$1,887,480	$214,000,000	48
2	23/12/2011	1.25%	1.15%	$2,407,500	$214,000,000	48
2	23/01/2012	1.86%	1.71%	$3,582,360	$214,000,000	48
2	23/02/2012	2.26%	2.08%	$3,917,484	$214,000,000	48
2	23/03/2012	2.43%	2.24%	$3,848,148	$214,000,000	48
2	23/04/2012	2.98%	2.74%	$3,890,092	$214,000,000	48
2	23/05/2012	3.78%	3.48%	$4,934,412	$214,000,000	48
2	23/06/2012	4.88%			$214,000,000	48
2	23/07/2012	5.99%			$214,000,000	48
2	23/08/2012	7.01%			$214,000,000	48
2	23/09/2012	8.43%			$214,000,000	48
2	23/10/2012	9.66%			$214,000,000	48
2	23/11/2012	11.03%	9.71%	$27,616,914	$214,000,000	48
2	23/12/2012	12.47%	10.97%	$31,222,386	$214,000,000	48
2	23/01/2013	14.43%	12.70%	$36,129,834	$214,000,000	48

Figure 5.3: Project summary plan

After recording the data of the project plan data in the model, in the project information menu the data can be seen as shown in figure 5.4.



Date	Plan Progress	Actual Progress	Planned Cost	Actual Cost	Project Duration	ETC(t)	EAC	VAC
23/10/2011	0.54%	0.50%	$1,155,600	$1,040,040	48	52	209,347,826	4,652,174
23/11/2011	0.98%	0.90%	$2,097,200	$1,887,480	48	52	209,347,826	4,652,174
23/12/2011	1.25%	1.15%	$2,675,000	$2,407,500	48	52	209,347,826	4,652,174
23/01/2012	1.86%	1.71%	$3,980,400	$3,582,360	48	52	209,347,826	4,652,174
23/02/2012	2.26%	2.08%	$4,836,400	$3,917,484	48	52	188,413,043	25,586,957
23/03/2012	2.43%	2.24%	$5,200,200	$3,848,148	48	52	172,130,435	41,869,565
23/04/2012	2.98%	2.74%	$6,377,200	$3,890,092	48	52	141,891,304	72,108,696
23/05/2012	3.78%	3.48%	$8,089,200	$4,934,412	48	52	141,891,304	72,108,696
23/06/2012	4.88%	4.49%	$10,443,200	$6,370,352	48	52	141,891,304	72,108,696
23/07/2012	5.99%	5.51%	$12,818,600	$10,126,694	48	52	183,760,870	30,239,130
23/08/2012	7.01%	6.45%	$15,001,400	$13,651,274	48	52	211,673,913	2,326,087
23/09/2012	8.43%	7.76%	$18,040,200	$18,220,602	48	52	234,934,783	-20,934,783

There are five other buttons in the related information form. Clicking on the “Construction Process” button, the related form opens and three boxes need to be filled. The Process ID is used to make a connection with the developed tables. The process name and its description can be added. The user can also define and change processes for the project if it is necessary. The same steps should be taken for the project function as shown in Figure 5.5. There are five processes in the model; Initiating, Planning, Executing, Controlling and Monitoring, and Closing. Furthermore, there are nine project’s functions in the model; integration, scope, time, cost, quality/safety, human resources, risk, and procurement. The user can add or modify this data if required.

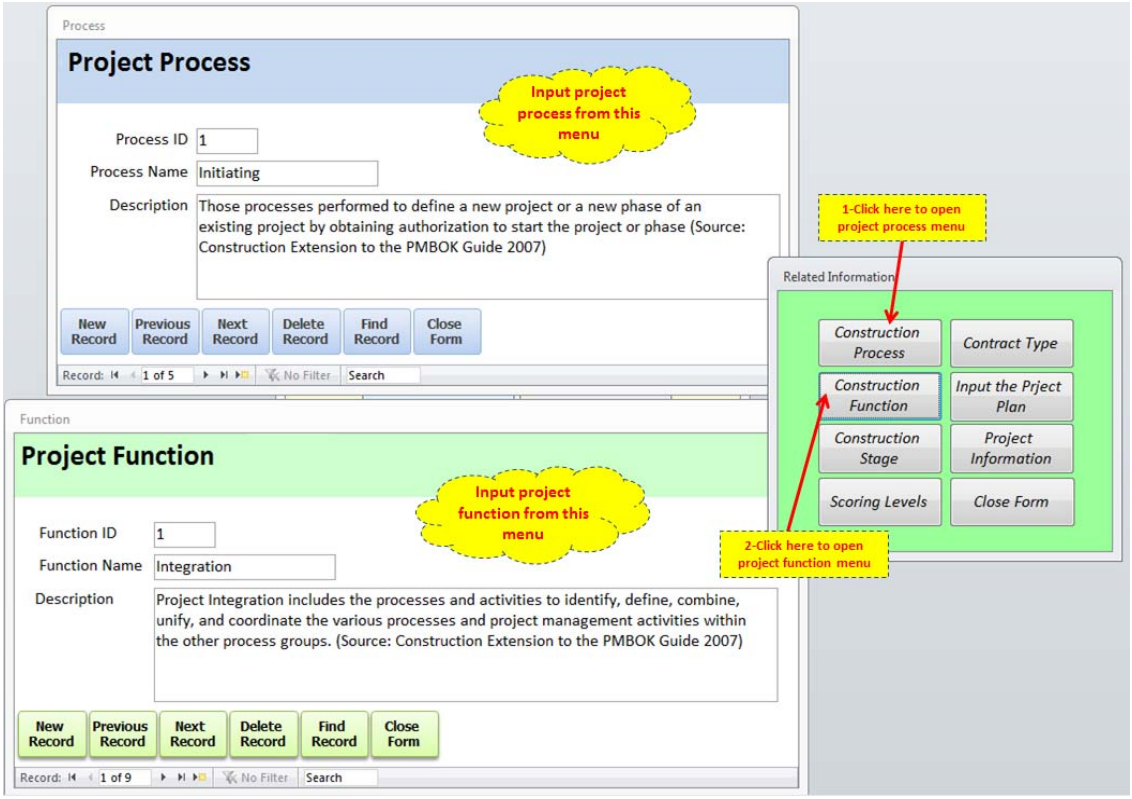


Figure 5.5: Project processes and functions input forms

There are two other buttons in the related information form, which are: contract type and project stage. As mentioned earlier, the user can define different types of contracts. Eight

types of contracts are considered in the model as shown in figure 5.6. For that actual project, the contract type is lump sum.

Also, five popular stages of a project are stored in the model as different project stages: basic design, detail engineering, construction, procurement, and turn over as shown figure 5.6. The user can easily add or modify the data in this part if it is required. For that actual project, project stage is construction.

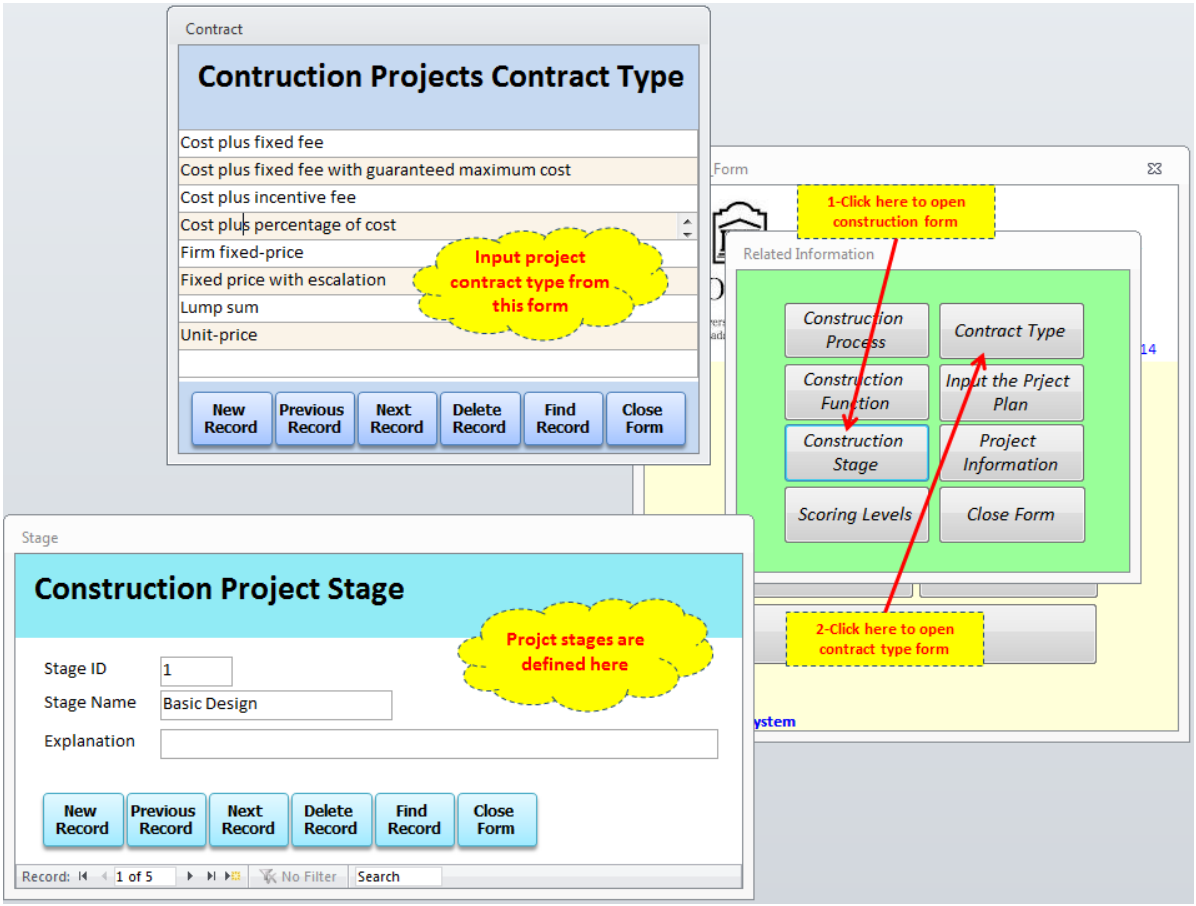


Figure 5.6: Project contract types and construction stages input forms

To have more accurate results, ten levels of scores have been included in the model. For each score, a description and score point is defined as shown in Figure 5.7.

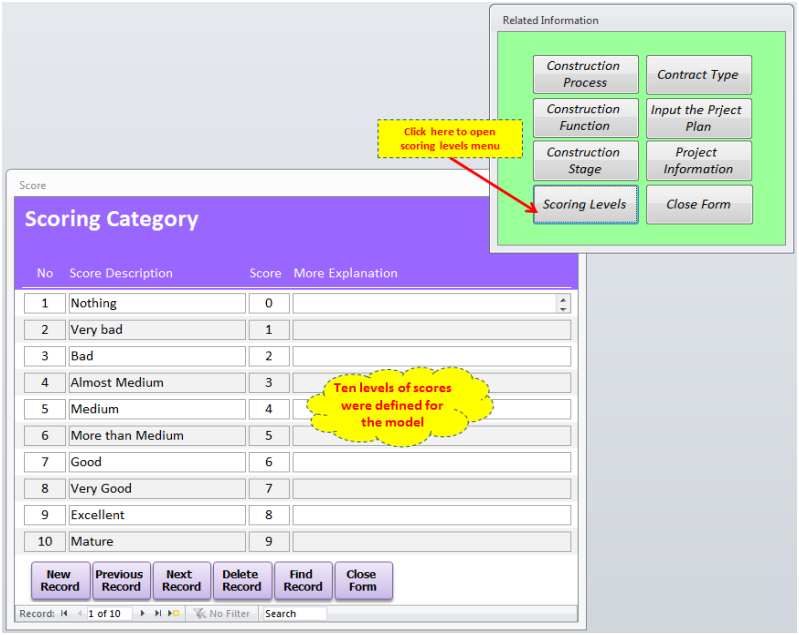


Figure 5.7: Project audit coring levels input form

5.3. Audit Questions Menu

Next are the audit questions that are defined and grouped according to the processes and functions as shown in figure5.8. There are five fields in the project audit form. Question ID is used for making the connection between the related tables. For each question, one appropriate process and function should be assigned. Also, the question should be clearly explained and additional information related to that question may be added. Furthermore, in order to increase the accuracy of the audit, some of the available documents should be checked and reviewed by the auditor. The number of questions and related documents is flexible and can be changed based on the auditor need and choice as shown in figure 5.8.

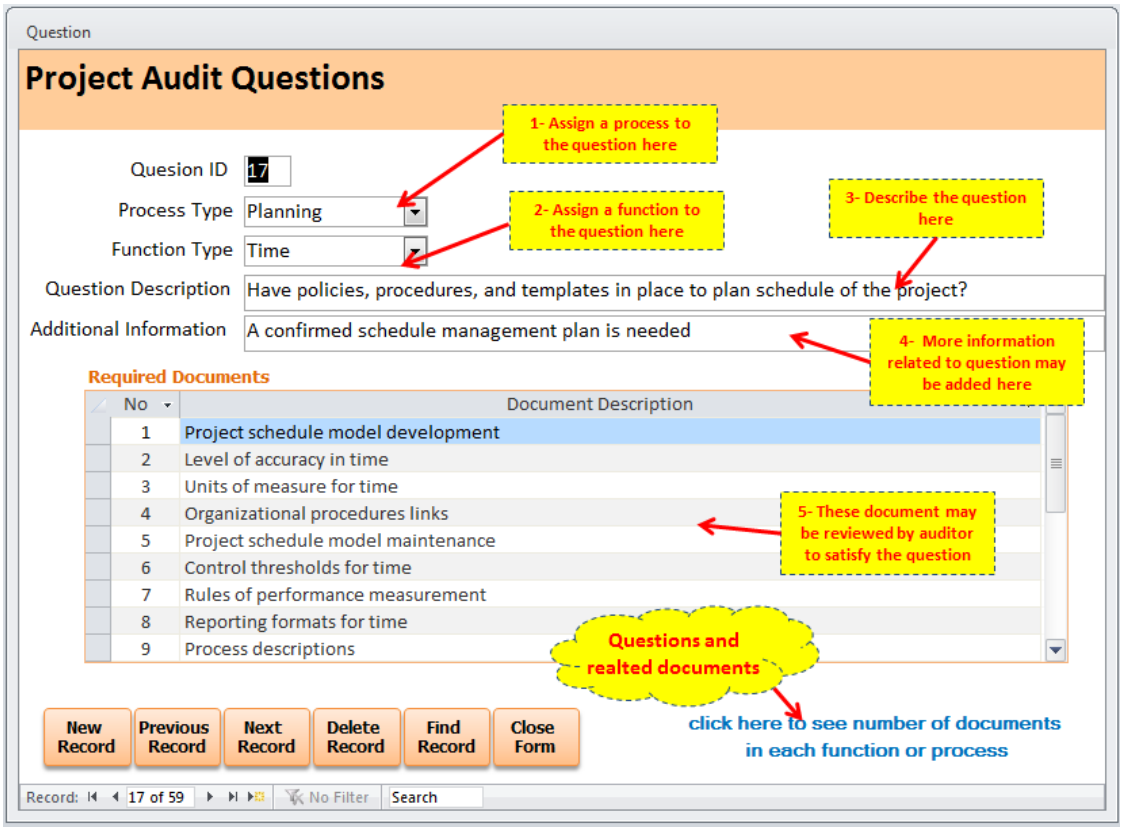


Figure 5.8: Project audit the questions form

Up to here, the user has been able to enter the project information and related data into the model. There are 59 pre-defined questions in the model and there is a specific report that presents these questions. The user can add or modify the data in this part if it is required.

5.4. Plan (schedule) a Project Audit

In this step, the user can plan and schedule the project audit. Because the audit of the case project covers processes, functions, and performance, the comprehensive audit is selected from the menu. There are two options in the “Plan Audit” form, comprehensive audit and quick audit as shown in figure 5.9.

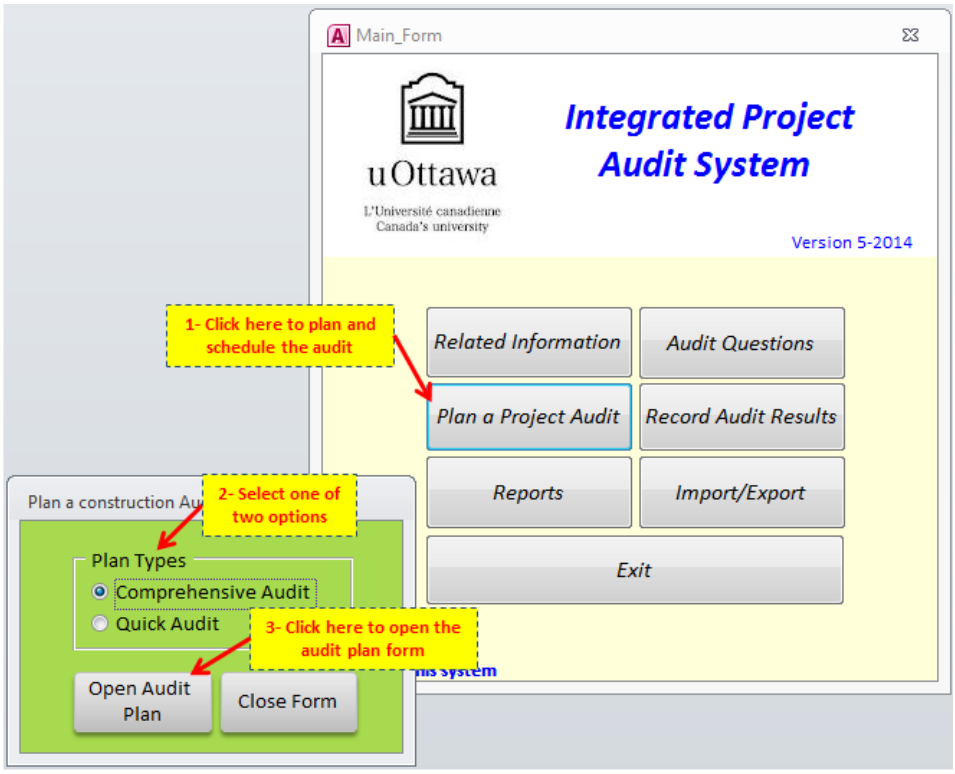


Figure 5.9: Plan a project audit selection menu

When the user selects comprehensive audit and click on the Open Audit Plan button, the form will be opened. There are several fields that should be filled in that form. Audit ID is a six character field in which the first four characters are for the year and the two other characters present the number of the audit in that year. For that actual project the ID is 201402. The date that the audit will be implemented and the project name should also be entered in this case it is 01/06/2014.

To see the name of a specific project here, the project information form should be completed in advance. The project that is going to be audited is in the construction stage. At this time, there are no documents to be added in the Scanned Doc. In the last field, the appropriate questions should be selected. Because this is a comprehensive audit, questions 1 to 59 have to be copied from the “Audit Questions” menu to the Question ID field and

Audit ID and the Question Description will be completed automatically as viewed in figure 5.10.

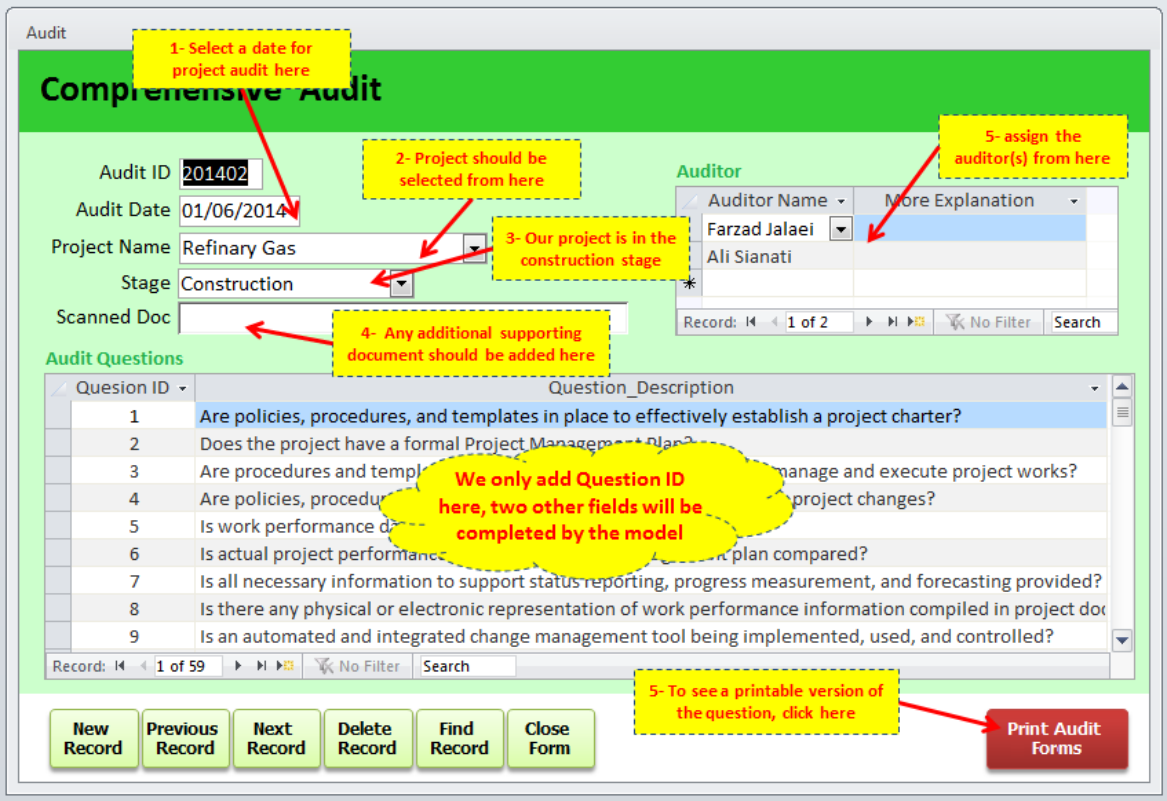


Figure 5.10: Plan a comprehensive project audit from

As previously mentioned, a comprehensive audit is implemented for our case project. But, if the user wants to have a quick audit, he/she would select the second type of audit, Quick Audit. This audit lets the user assess a specific process or function in the project, for example, project risk. When the risk function is chosen, two forms will be opened at the same time; the audit plan form and the question list. The first form is similar to what explained for the comprehensive audit form, but the second form will be opened to help the user to copy and paste the numbers related to risk. Figure 5.11 shows this process.

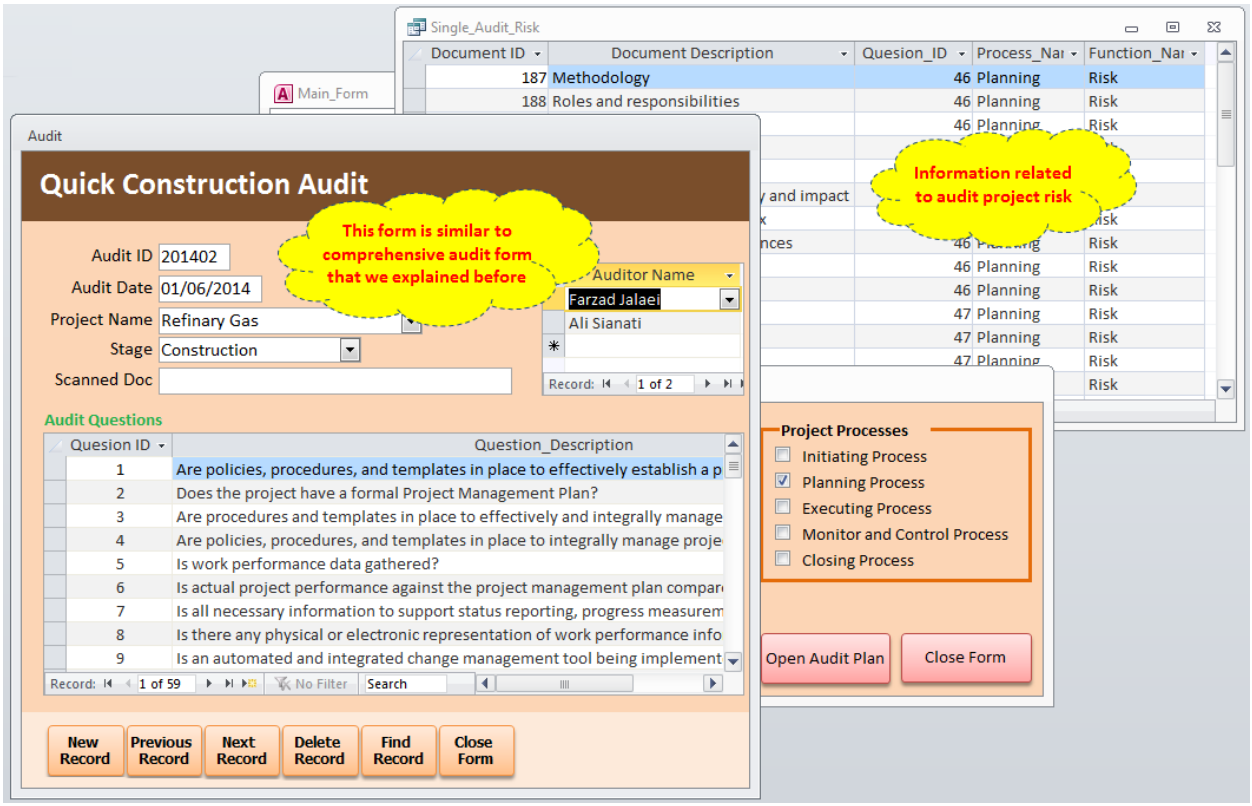


Figure 5.11: A sample to plan a quick project audit form for another project

5.5. Input Project Audit Results

There are two types of data that should be entered in the model to be analyzed: inputting the answer of the audit questions; updating the project progress. Usually, there is a project management office in any project oriented organization that supports project managers during the project lifecycle and it is the responsibility of that office to perform project audits. Therefore, all the project audit information is entered by that office into the developed model. In the main menu, first, the user should click on “Record Audit Result” button and after that one of the two options can be selected as shown in figure 5.12. For our project, first, the answers to the audit questions are inputted and after that the project plan progress is updated.

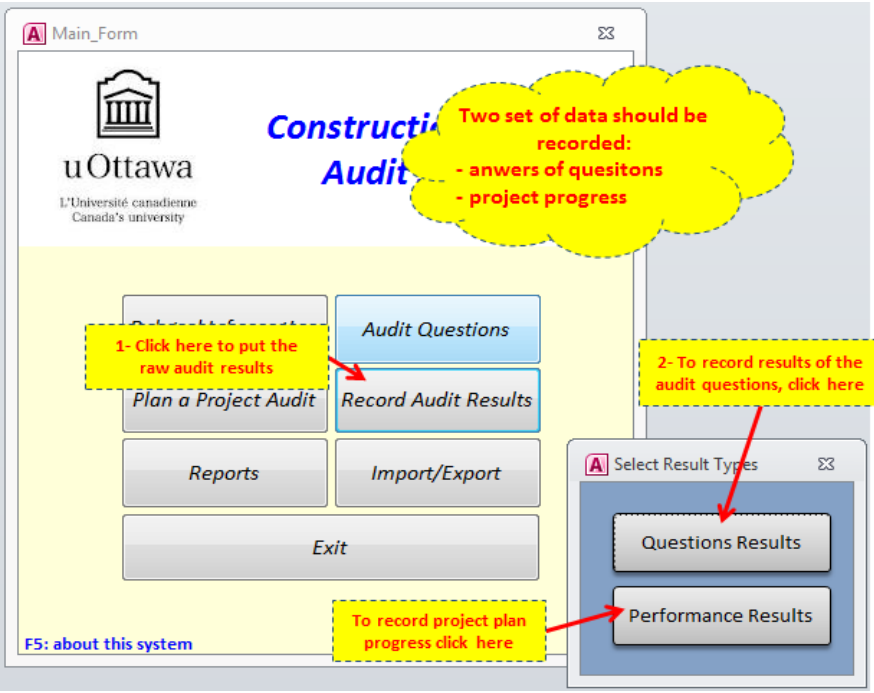


Figure 5.12: Input project audit results selection menu

Clicking on the "Question Results" button, the model asks to input the audit ID to pull up the related data as shown in figure 5.13. Number 201402 is inputted as previously defined.

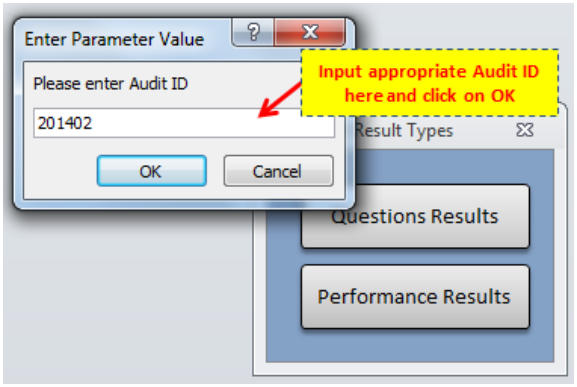


Figure 5.13: Selecting question part of the audit

The record audit result menu has four fields where three of them were already defined and selected as shown in figure 5.14. Here the project Audit ID is checked in order to make sure that the right project has been selected. Accordingly, the related questions are selected in

the Audit Questions menu. Based on the requirements of each question, the user can choose a score between 1 and 10. As explained earlier, there are some documents related to each question that should be reviewed during the audit. The score for each question depends on the judgment of the auditor when he/she reviews these documents and observes enough evidence.

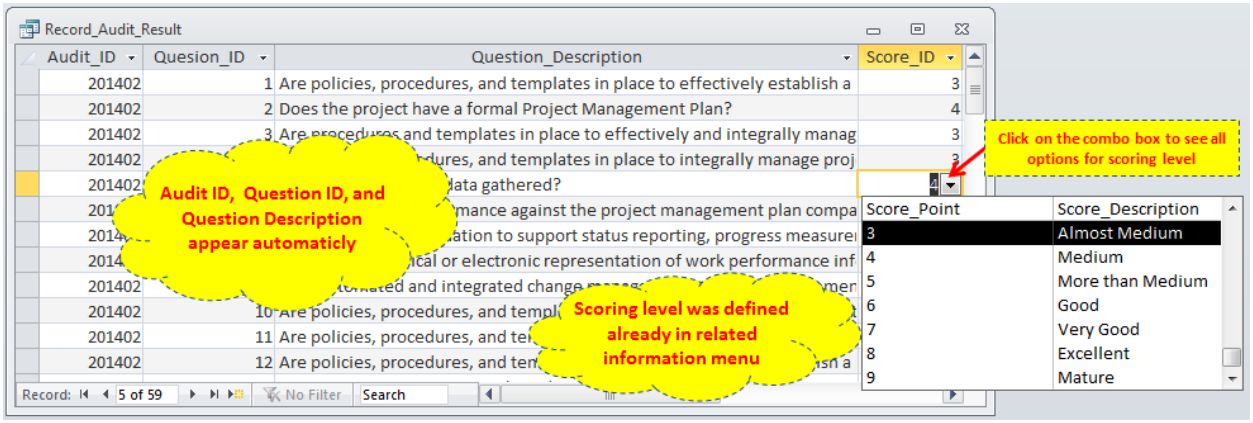


Figure 5.14: Input result of the questions form

5.6. Reports

Once all the audit data is entered, the model will analyse all these data and generate two different types of reports: 1) Main Reports; 2) Analytical Reports.

The main reports include reports from all information that is entered in the model by using the Related Information menu. When the user clicks on the Reports button, another menu is opened allowing the user to select which types of reports he/she needs as illustrated in figure 5.15. In the following section, all the types of reports will be generated so that to validate the model workability.

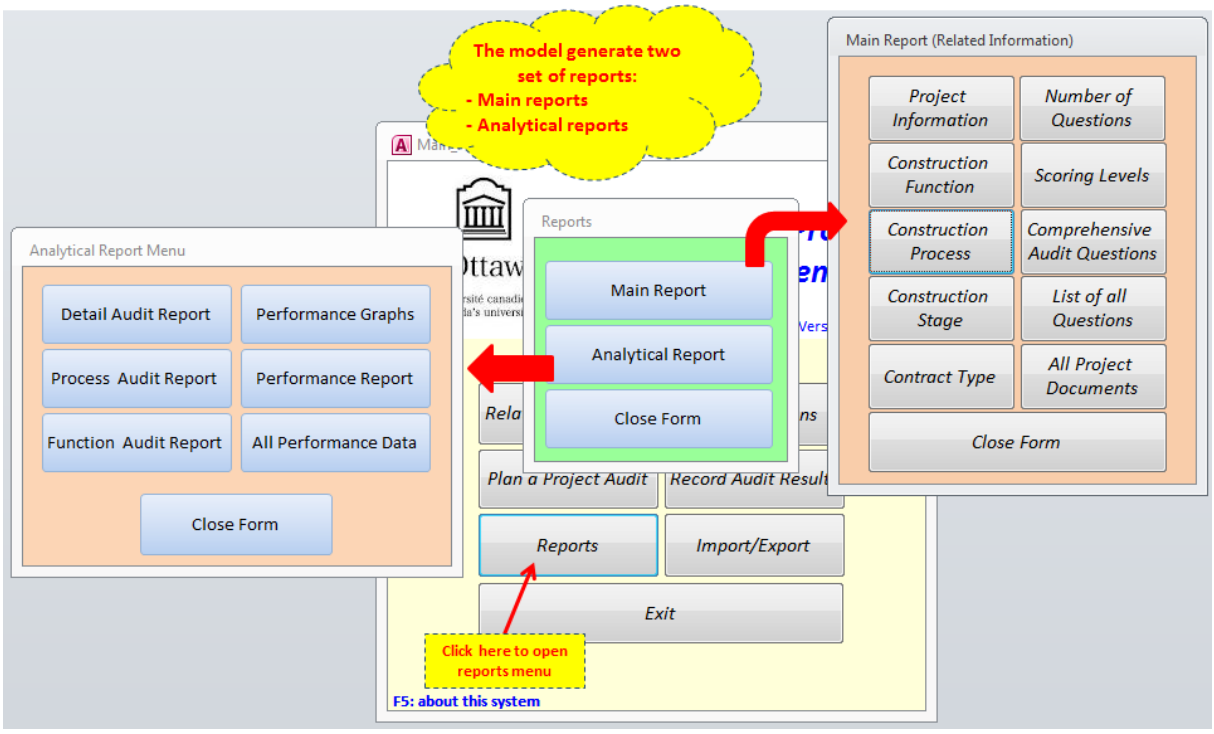


Figure 5.15: Report selection menu

As shown in figure 5.15, the user can click on the "Main Report" button to open a menu that contains all the related information reports, as illustrated in figure 5.16.

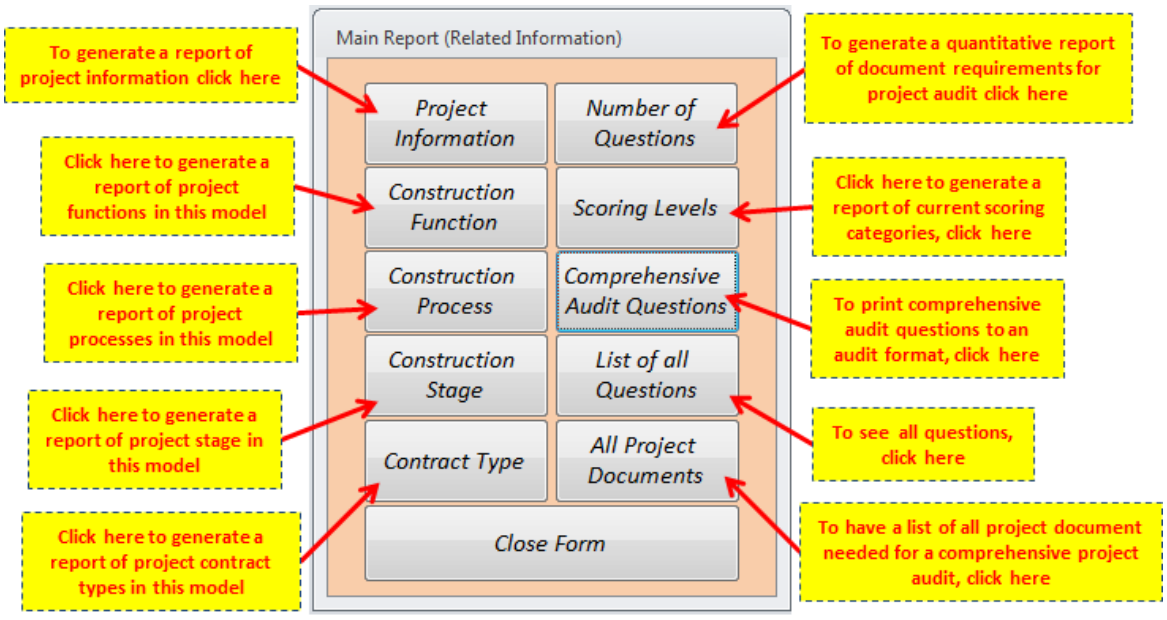


Figure 5.16: Main report selection form

When the user clicks on “Project Information,” the model needs a project code to generate the report. In the actual project, project code is EPC002 as illustrated in figure 5.17.

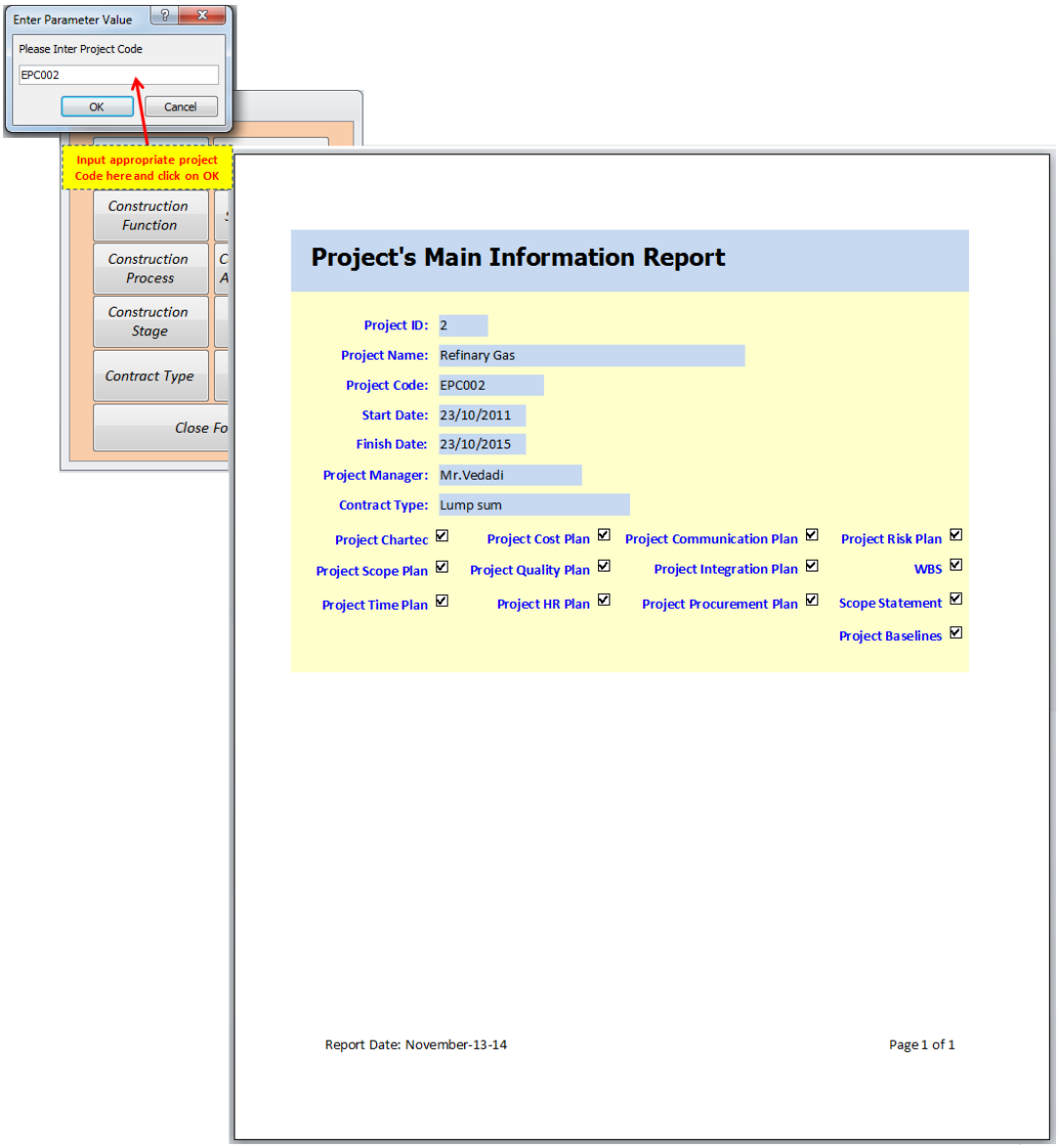


Figure 5.17: Project information report

There is a report about the project functions in this model. As shown in figure 5.18 the user can click on the “Project Function” button. Also, as shown in figure 5.19 the user can click on the “Project Process” button.

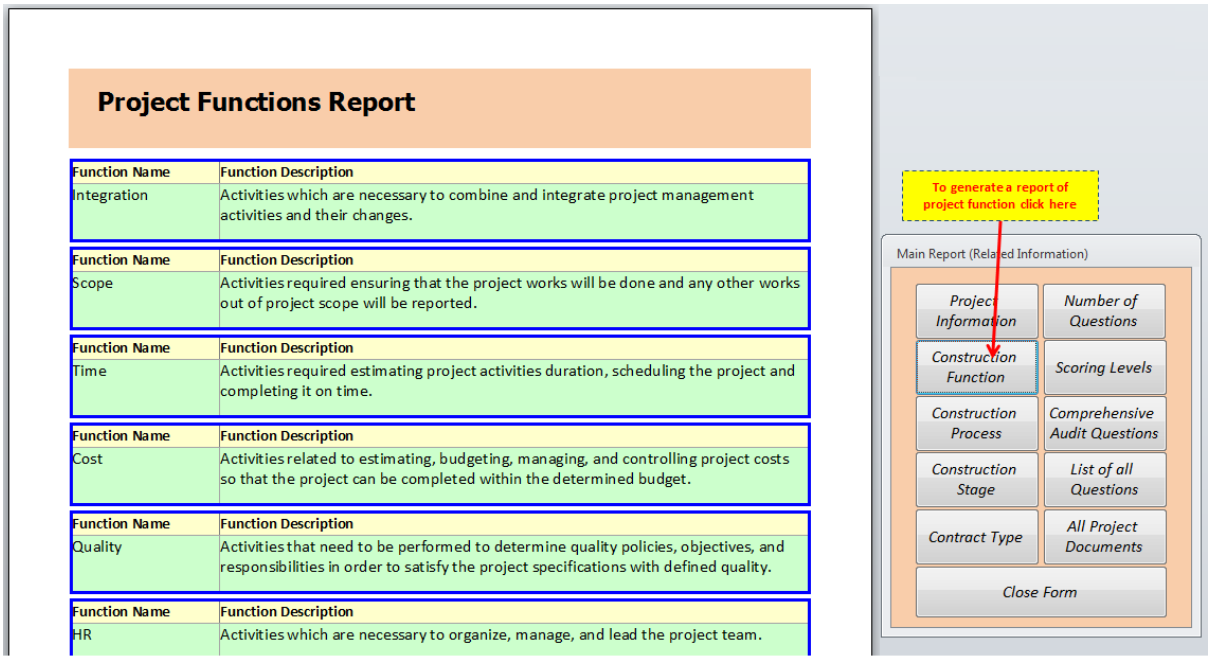


Figure 5.18: Project functions report

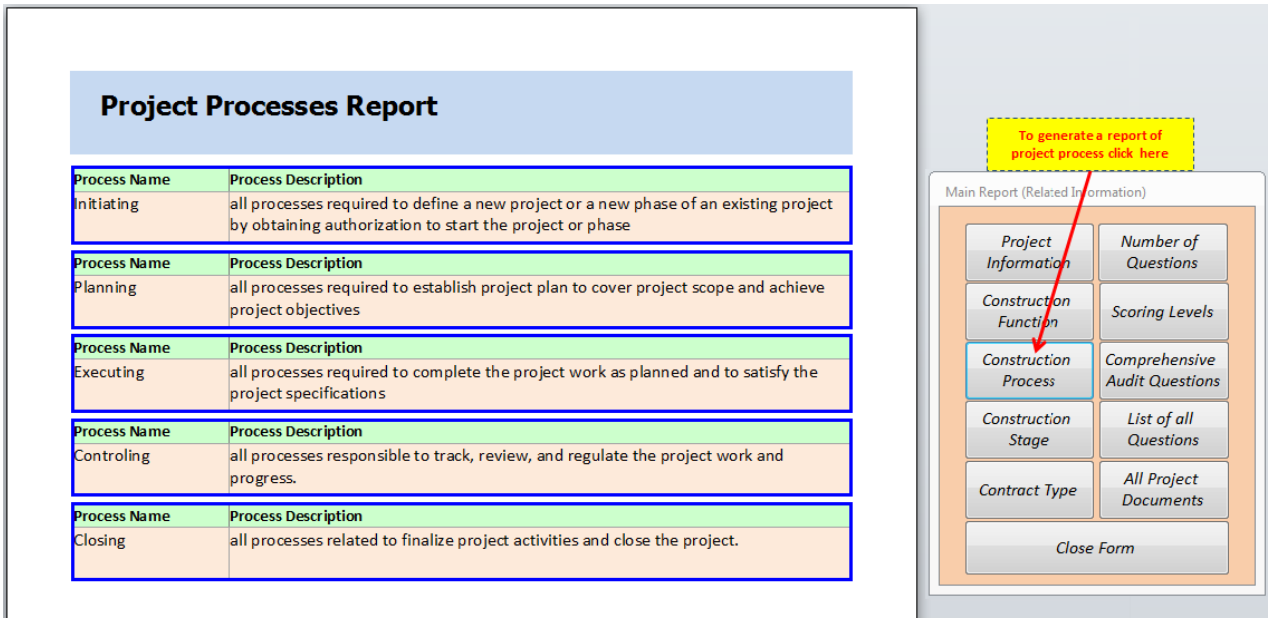


Figure 5.19: Project Processes report

Construction project stages and contract type reports are generated when the user clicks on "Construction Stage" and "Contract Type" respectively as shown in figure 5.20.

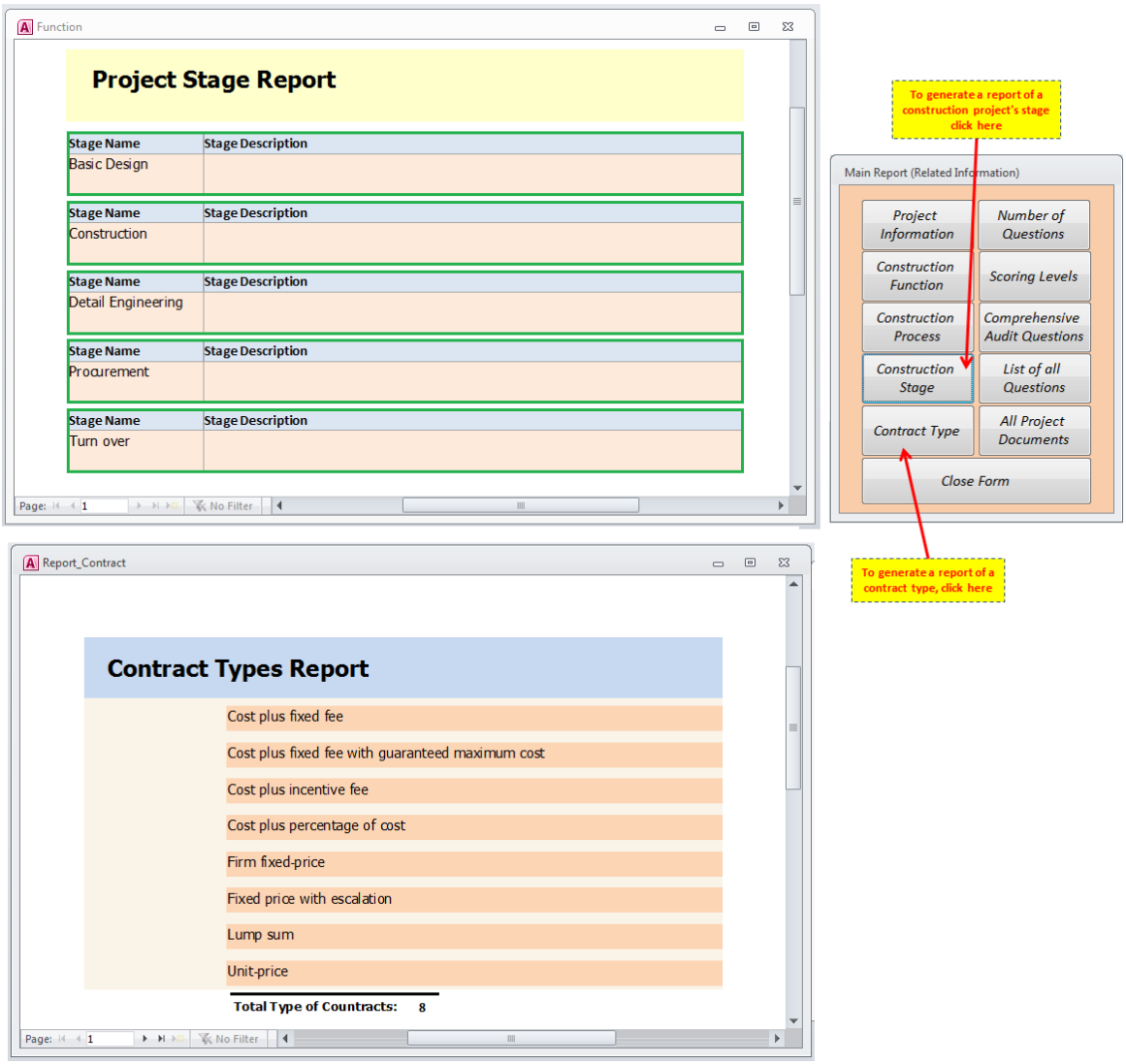


Figure 5.20: Project stages and contract types

Two other useful reports in this model are a quantitative report of the project documents and a score category report. The first report shows how many documents should be prepared in the process and function. The second report shows the scoring level preferences that the user can follow in the audit model. Figure 5.21 illustrates these reports.

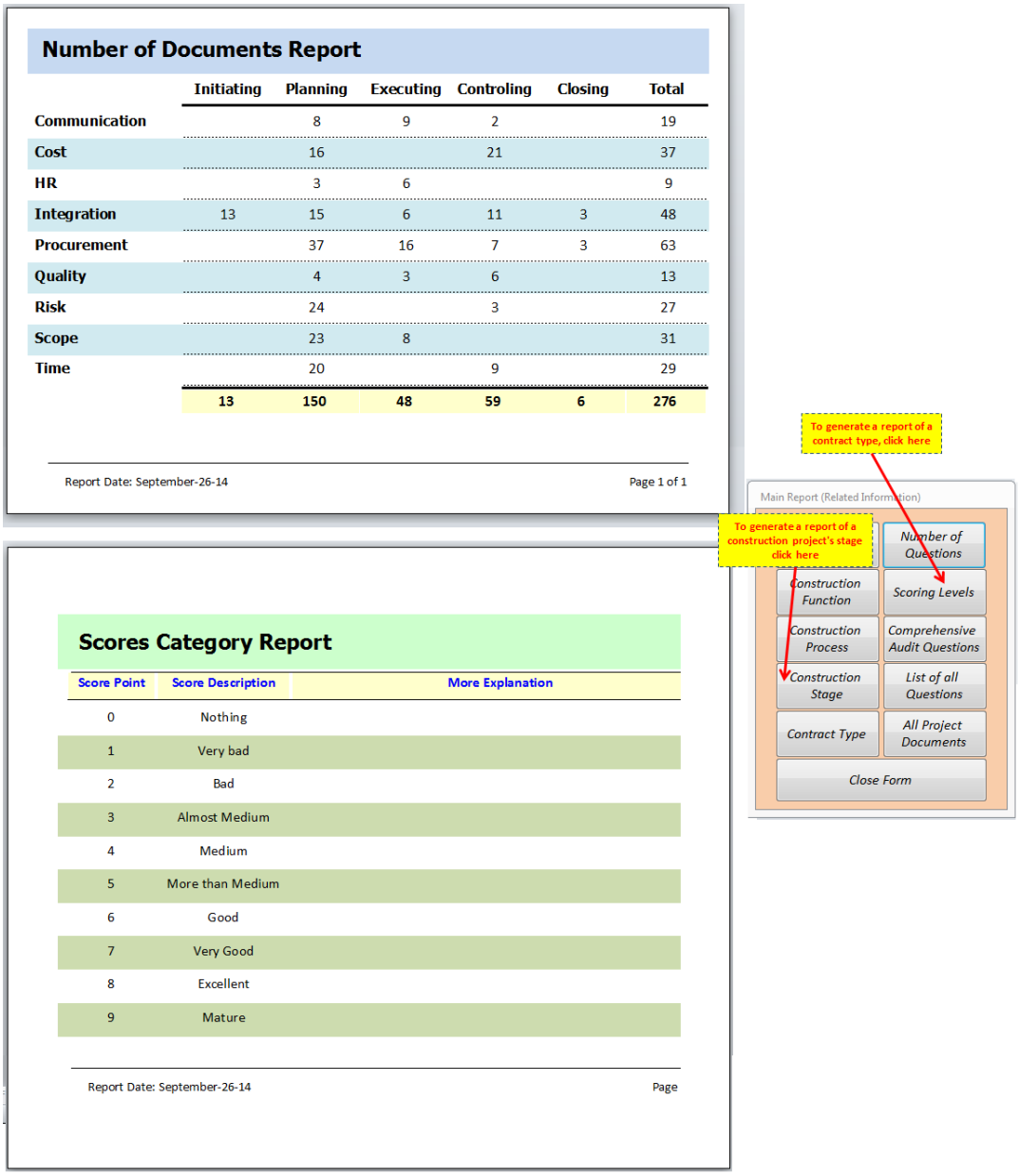


Figure 5.21: Audit scoring level and number of audit documents report

From the main report menu user can print a report of all questions in a simple format, which is very useful for the auditor to look at during the audit as shown in figure 5.22. In the actual project, 51 questions are selected for the project audit.

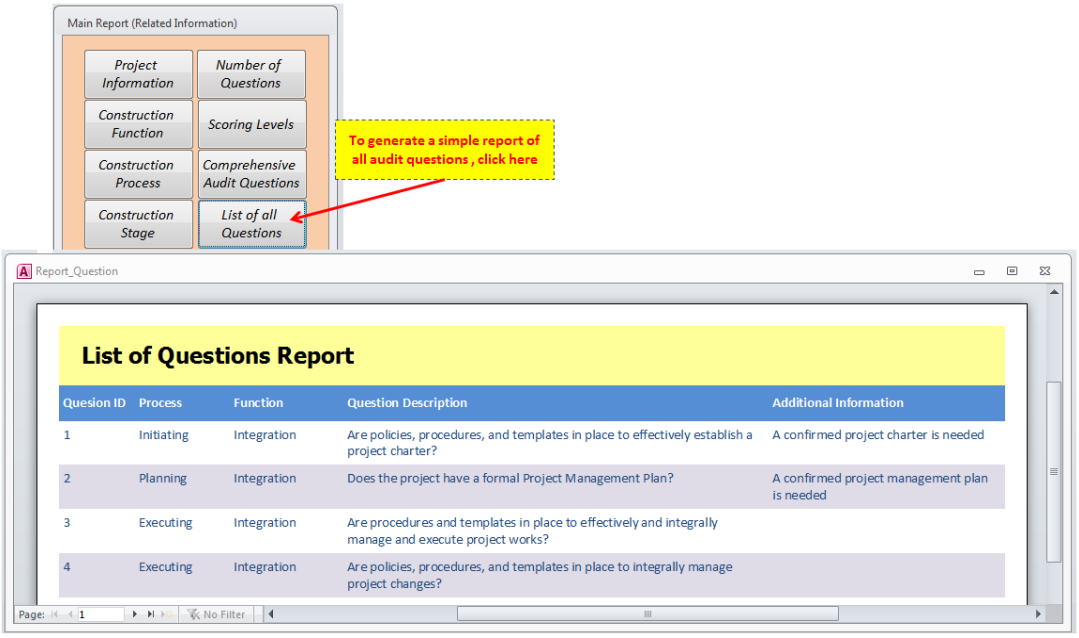


Figure 5.22: List of audit model questions report

The model can generate another type of report for the project questions in the audit format. In the audit format, the report shows the project process and project function that the question is related to. Also, in this format, the auditor can select a score between 0 and 9 as shown in figure 5.23.

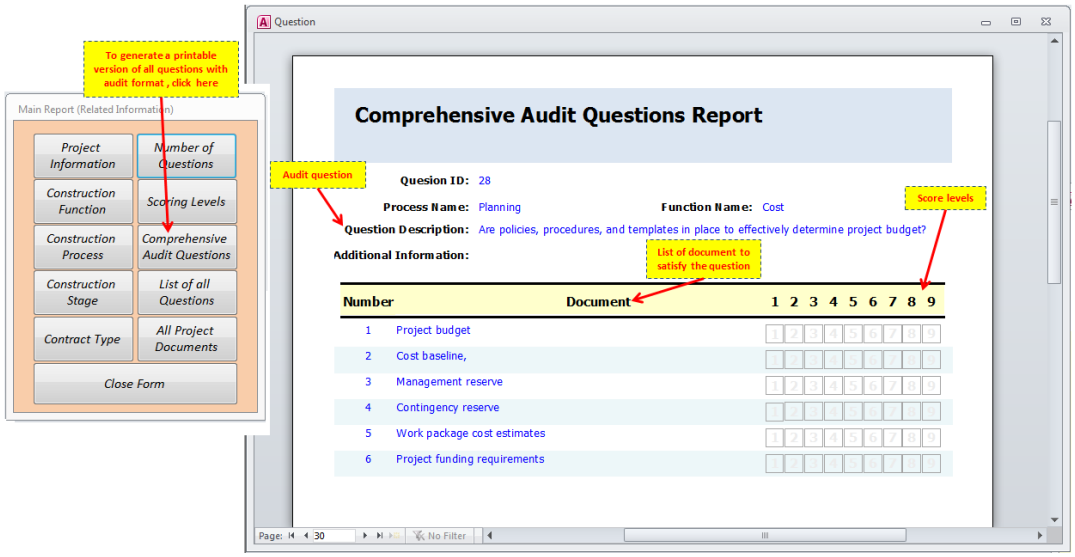


Figure 5.23: Comprehensive audit questions with audit format report

The last report in this menu is a list of all project audit documents which are important to be generated in every construction project as shown in figure 5.24. The list of all project documents is useful for future project so that the project team can provide many of them before starting the project.

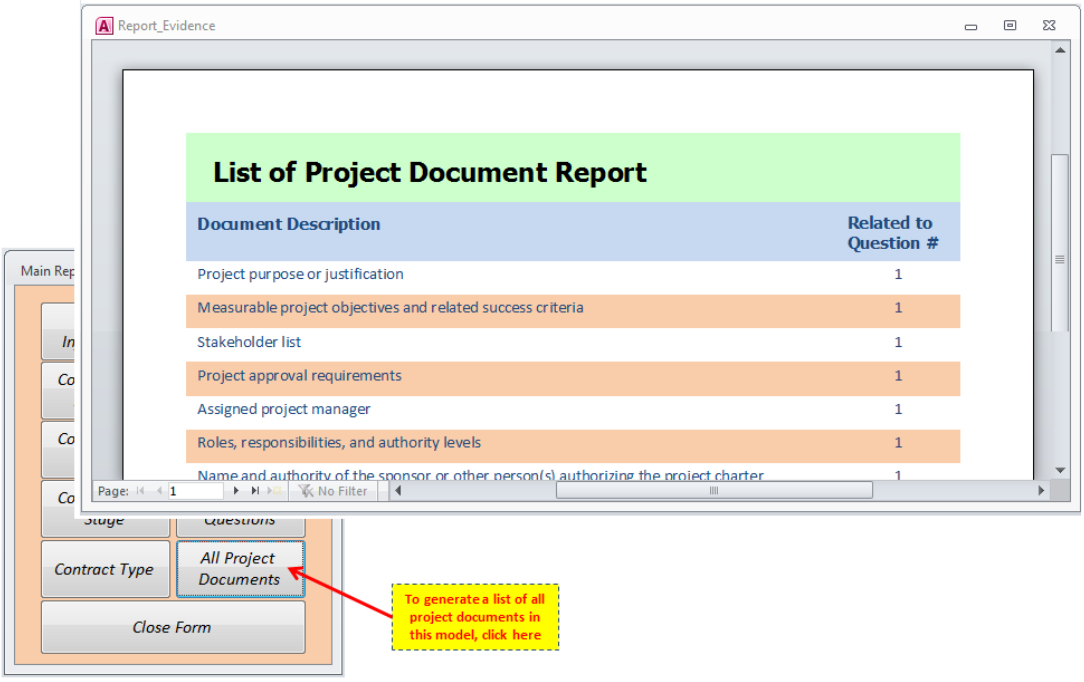


Figure 4.24: List of audit model documents report

The analytical reports of the model have been divided in two categories; audit questions and progress performance. As shown in figure 5.25, all analytical reports are generated from this menu. The auditors consider a score according to the scoring level for each answer. The model calculates the total score for project processes and functions.

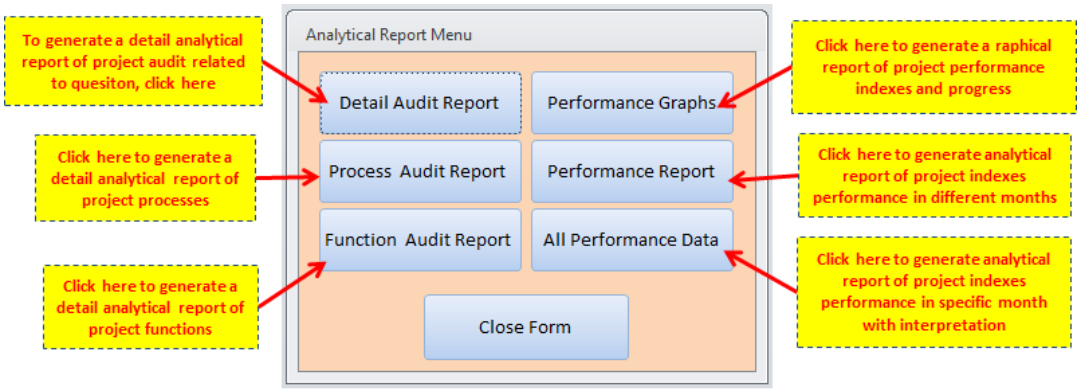


Figure 5.25: Analytical report selection menu

Figure 5.26 shows the analytical results of the Refinery Gas project processes, in June 2014. The score in initiating, planning, executing, monitoring and controlling, and closing are 33.3%, 44.9%, 58.1%, 44.4%, and 44.4% respectively. Based on table 3.13 in page 72, score interpretation guideline, except for initiating, which has a bad status, the other project processes have medium status.

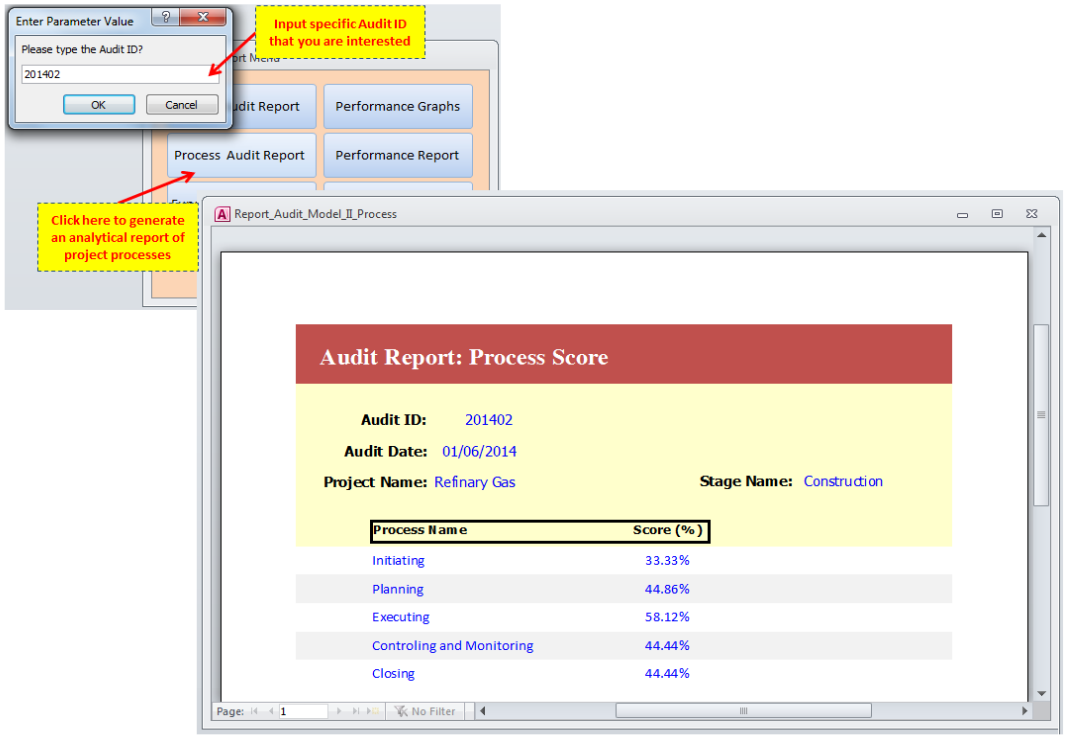


Figure 5.26: Analytical report of project processes

Figure 5.27 shows the analytical results of project functions. The scores in Integration, Scope, Time, Cost, Quality/Safety, Human Resource, Communication, Risk, and Procurement are 40%, 50%, 39.5%, 42.9%, 72.2%, 72.2%, 62.2%, 30.1%, and 49.2% respectively. Except for time and risk, which have a "bad" status, other functions of the case project have "medium" or "good" status.

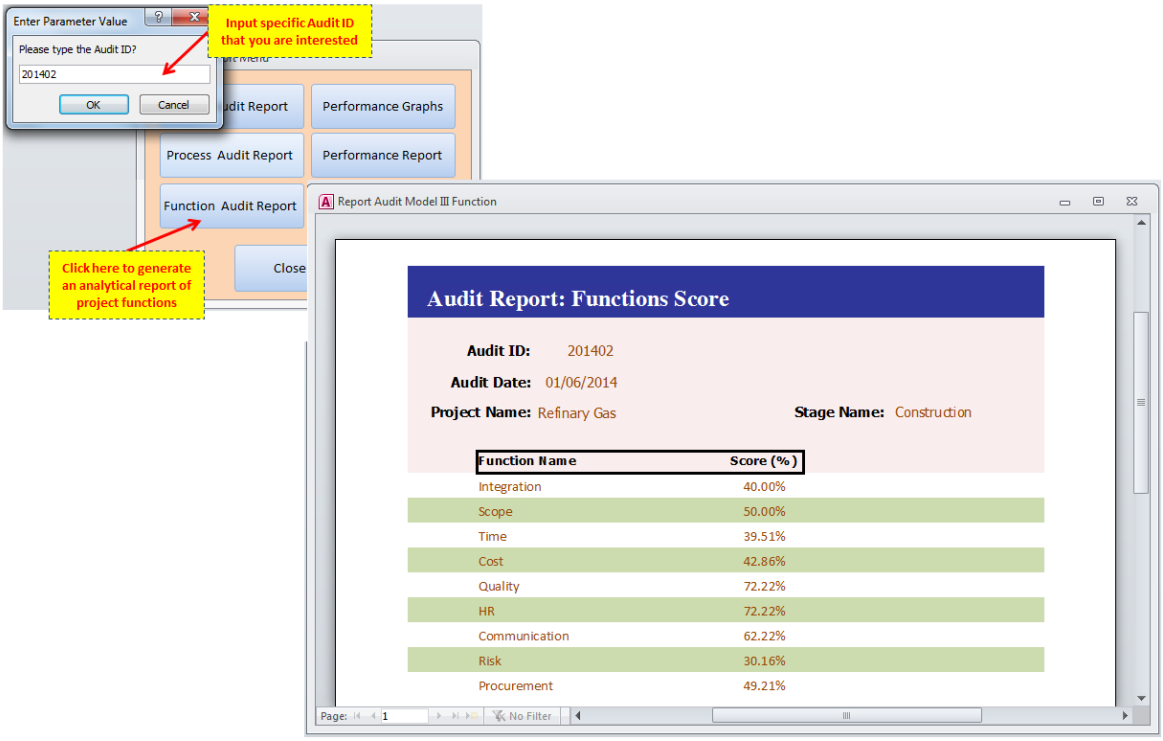


Figure 5.27: Analytical report of project functions

Project performance reports also can be generated by the model. These reports represent all the analytical indices of the project based on the project plan that was input into the model during the first step. Clicking on the "Performance Graph" button in figure 5.25, the model opens an Excel worksheet that includes all performance indices based on the project plan. Integrated time and cost graphs help project managers to measure the current performance of the project and forecast the future status.

Figure 5.28 shows the three important values, BCWS, BCWP, and ACWP. As explained earlier, BCWP indicates budgeted cost of the work performed at a specific point in time. BCWS describes the budgeted cost of work as scheduled before starting the implementation. It is a number that presents the budgeted work that is scheduled. ACWP is the actual cost of the work performed to date.

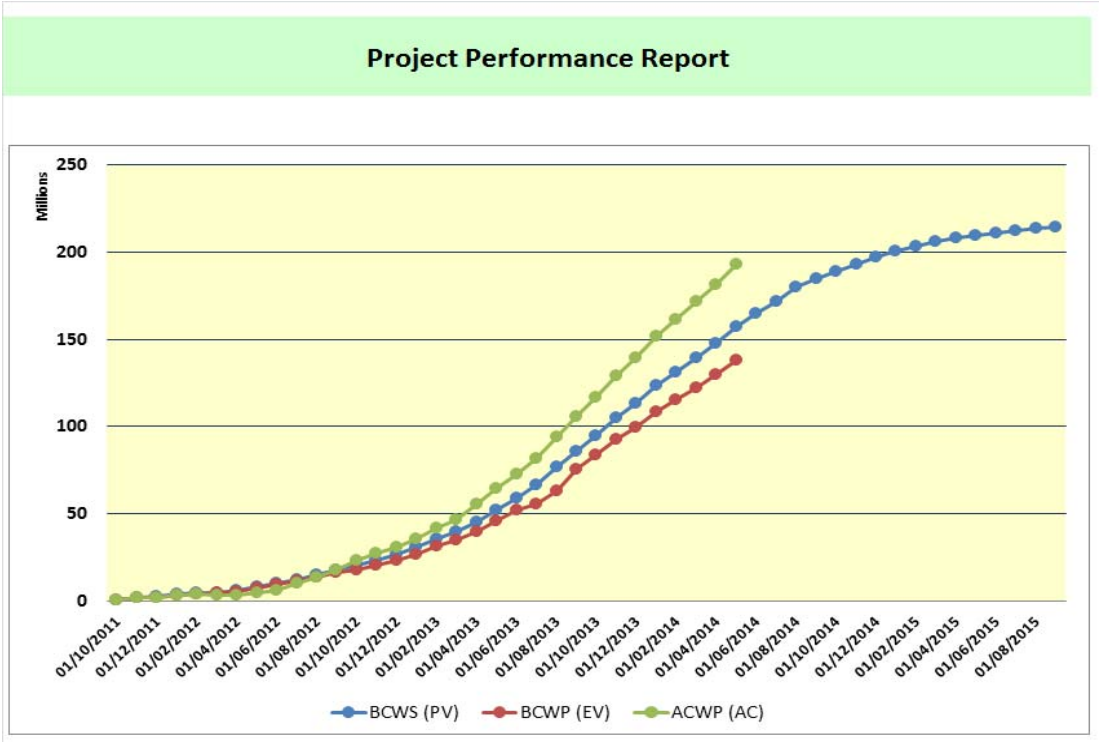


Figure 5.28: Earned value main indices

In Figure 5.29, the model forecasts the future costs of this project if it continues with the current performance. The red dot-line shows the forecast of the project cost to complete the project.

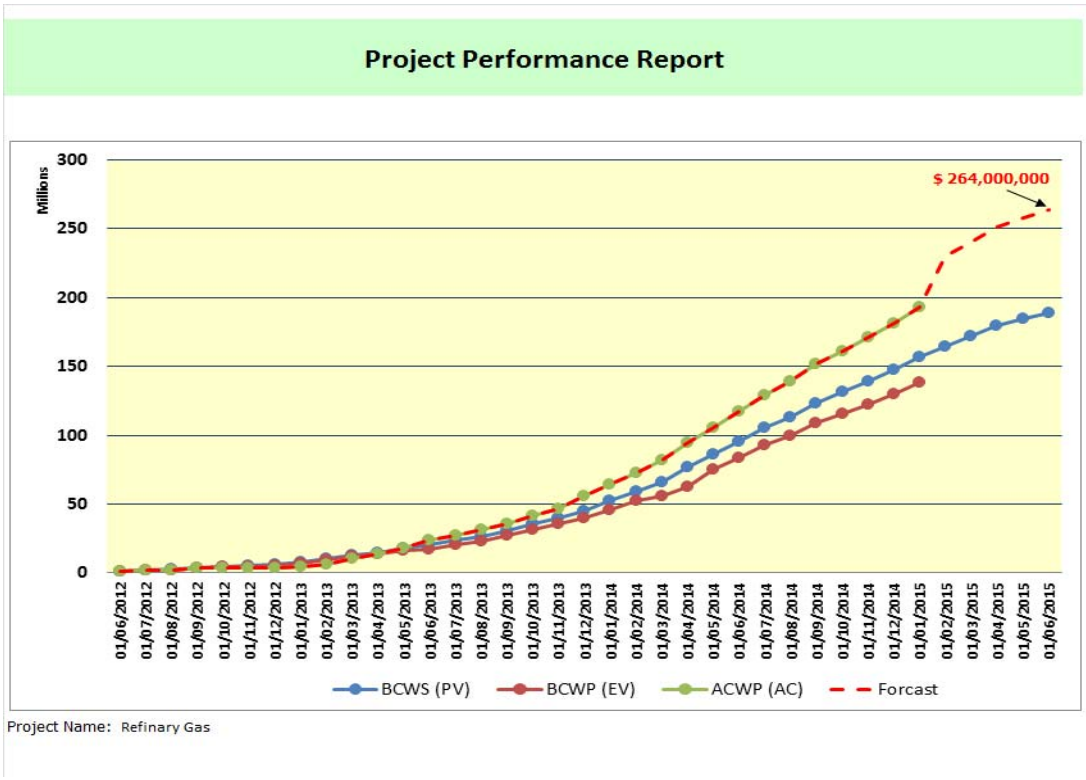


Figure 5.29: Earned value main indices with forecast

Two other graphs shown in figures 5.30 and 5.31 are generated by the model. The trend of the cost performance index (CPI) and schedule performance index (SPI) are less than 1, which is not good, and they were fluctuating between 0.5 and 0.9.

Also, the trend of Cost Variance (CV) and Schedule Variance (SV) shows negative values for these two factors, which is not good for the project performance.

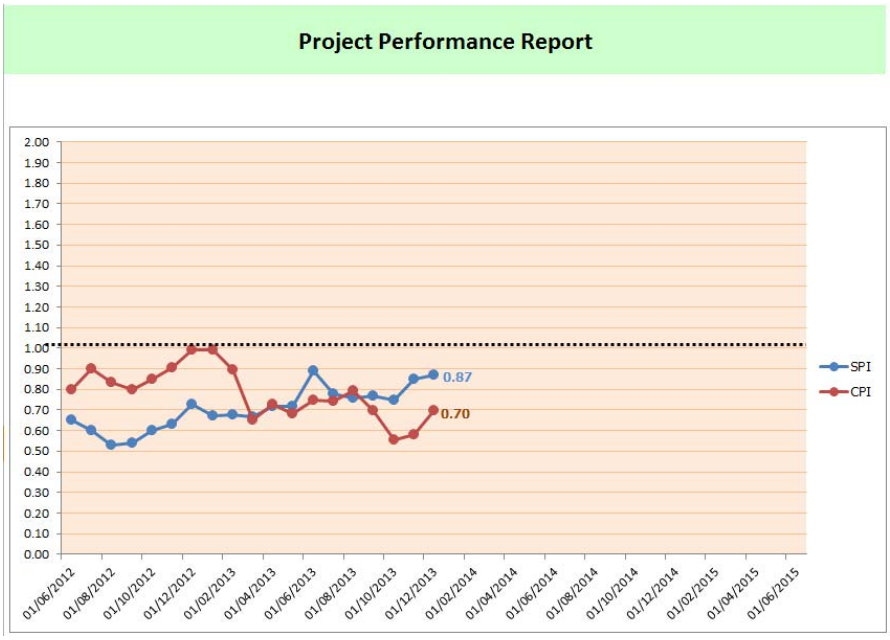


Figure 5.30: Schedule performance index (SPI) and Cost performance index (CPI) trend

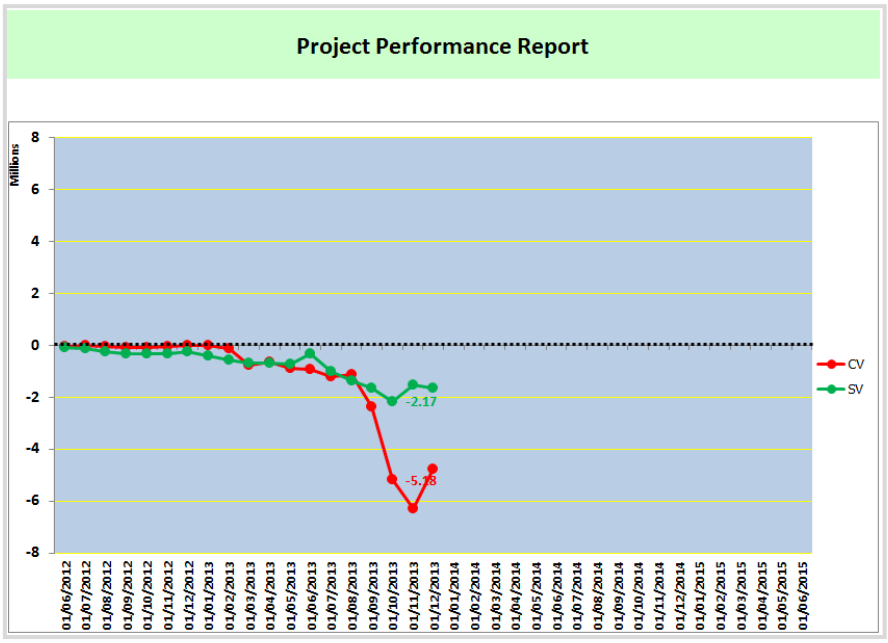


Figure 5.31: Schedule variance (SV) and Cost variance (CV) trend

The model as well can generate a comprehensive report of the project performance indices, which contains useful data and an interpretation of these results. If users click on “All Performance Data” button, two related data should be entered in the model: 1) audit ID; and

2) audit date. For the real case project Audit ID is 201402 and 23/05/2014 is entered in the box as shown in figure 5.32.

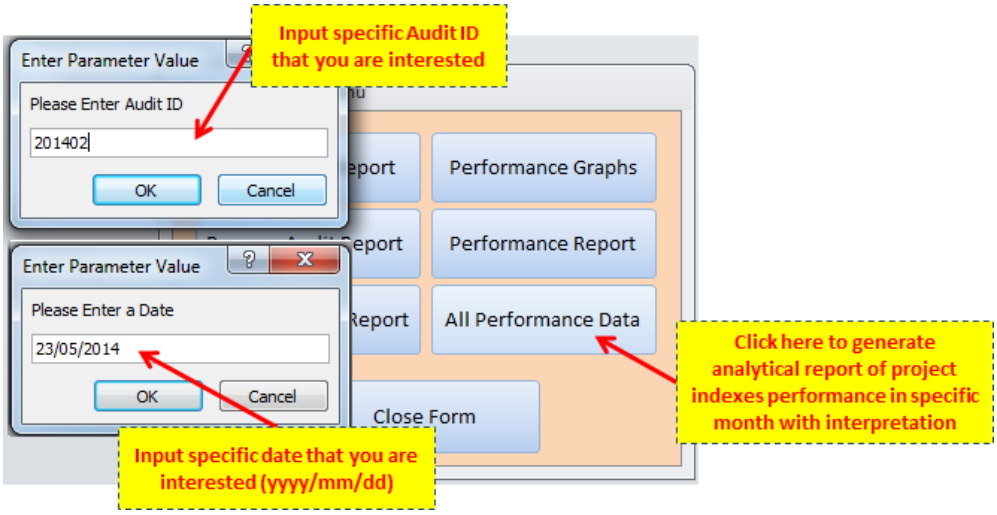


Figure 5.32: Project performance analytical report selection menu

For example, in August 2013, the project schedule variance (SV) is a negative number and the Schedule Performance Index (SPI) is a number less than 1 as shown in figure 5.33. These indices support the finding that the project is behind schedule. Also, indices related to cost performance, project cost variance (CV) and Cost Performance Index (CPI) are negative and less than 1 respectively. This means that the project is over budget. The value of ETC (t), which represents the estimated time to completion, is 55 months. Computing 55 months to the project planned duration, of 48 months means that with the current performance the project will take seven months more than had been planned. Cost forecast value also show that the project needs $105,831,190 from the project audit date, 2013/06/01, to be completed. This means the project final cost will be $299,113,636 instead of the $214,000,000 as planned, which means an extra cost of $85,113,636 from what is estimated as seen in figure 5.33.

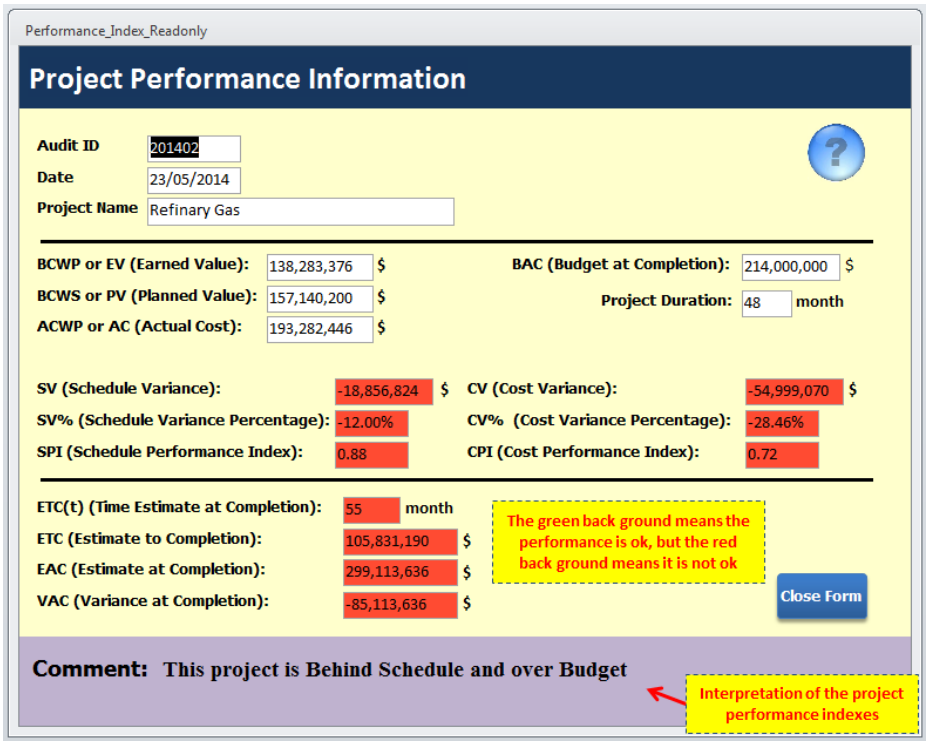


Figure 5.33: Project performance analytical report with comment

The system provides a guideline for interpretation of earned value indices if the user clicks on the blue question mark sign on the top-right of the form as shown in figure 5.34.

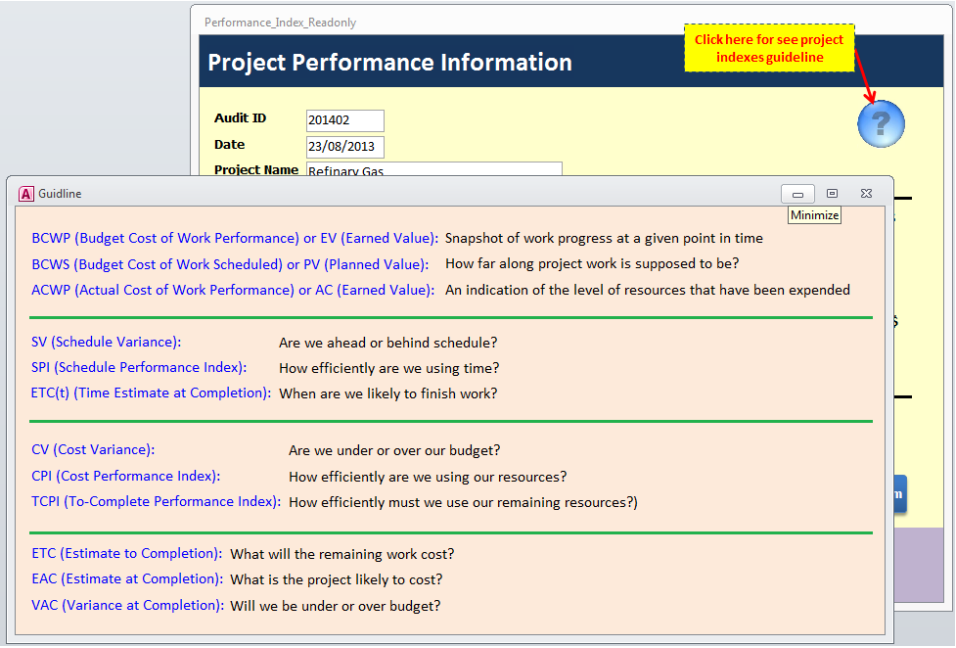


Figure 5.34: Project performance analytical guideline

Whereas Figures 5.35 through 5.38 show another types of the analytical results of both the project function and project process. These figures clearly show that only the Except Quality/Safety and Human Resources have good status while the other project functions are either in the medium or bad level. Also, all the project processes have a medium status. That specific project has only the executing process scored more than 50% (58.12%) whereas the rest of the processes scored less than 50%.

These graphs indicate that the project is not fully complying with the project management standards. Appropriate project management policies, procedures, and templates should be developed and applied to improve the scores of the project's functions and processes. For example, risk management procedures should be developed to identify, categorise, analyse, respond, and monitor project risks.

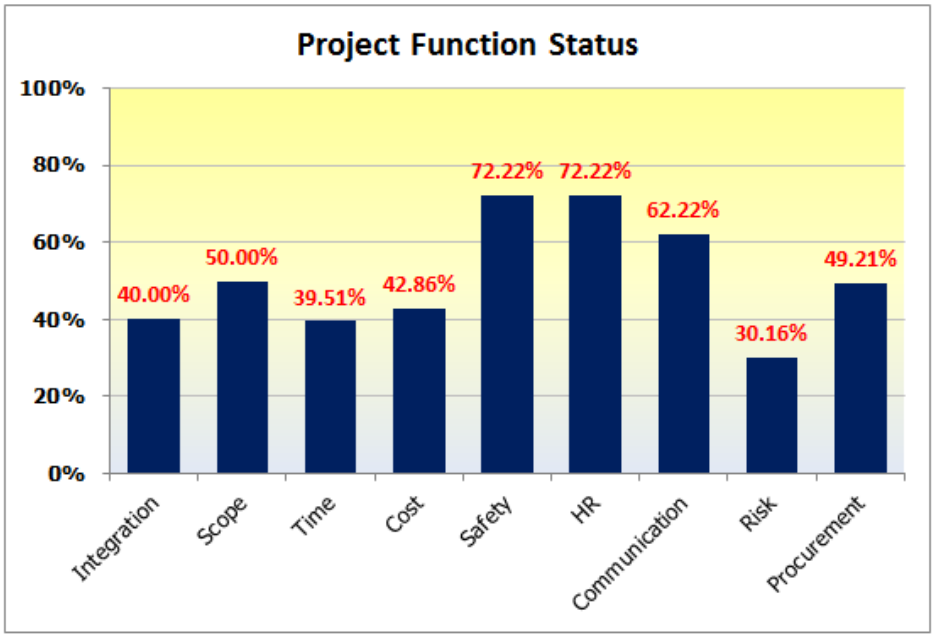


Figure 5.35: Project function status model I

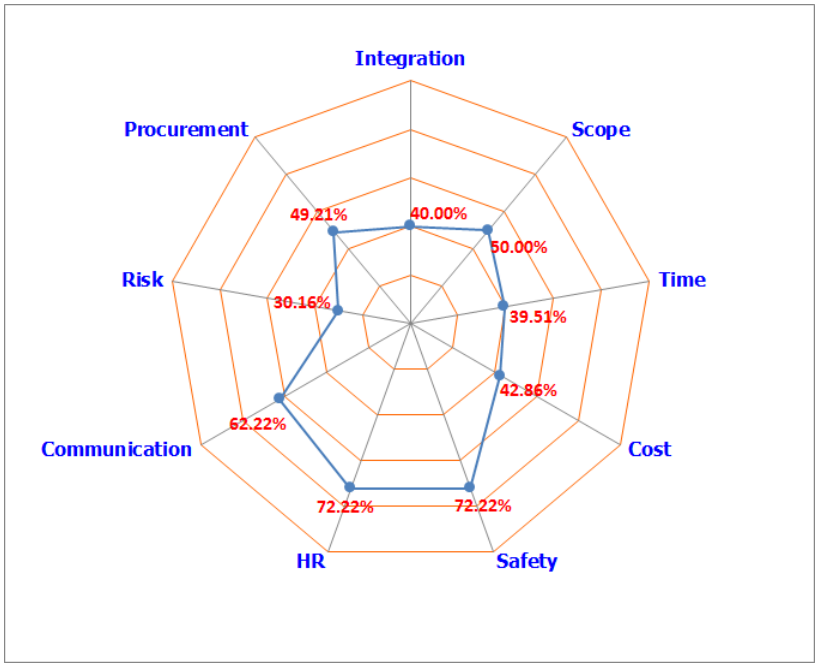


Figure 5.36: Project function status model II

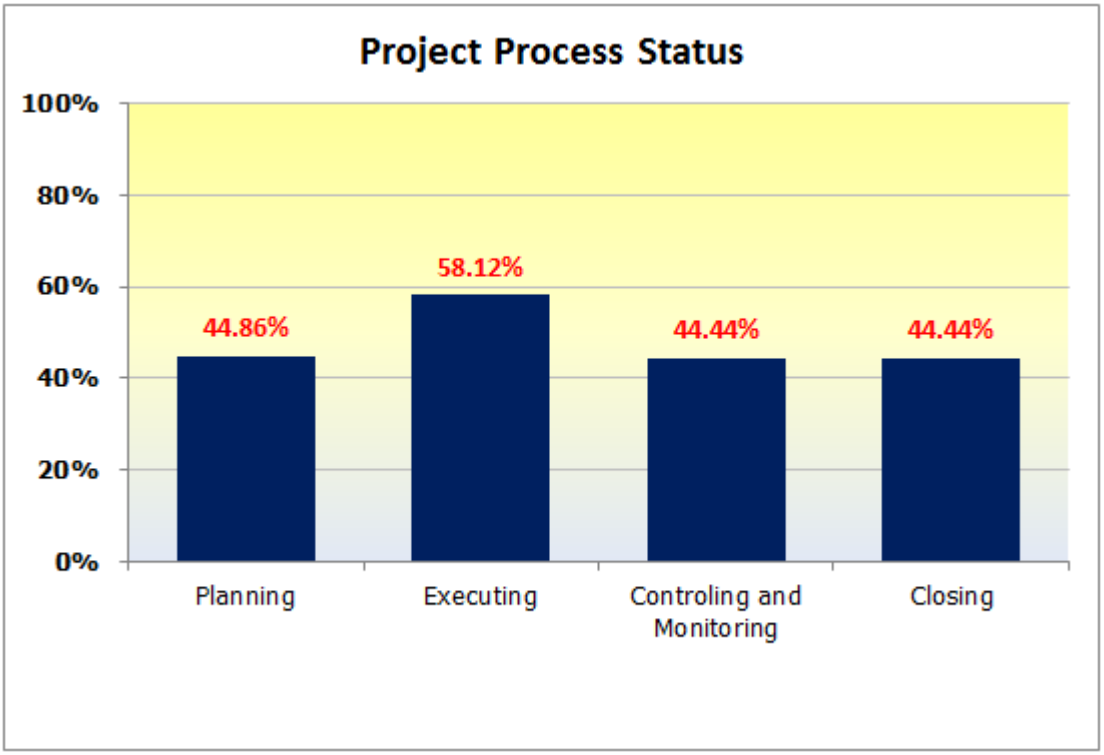


Figure 5.37: Project process status model I

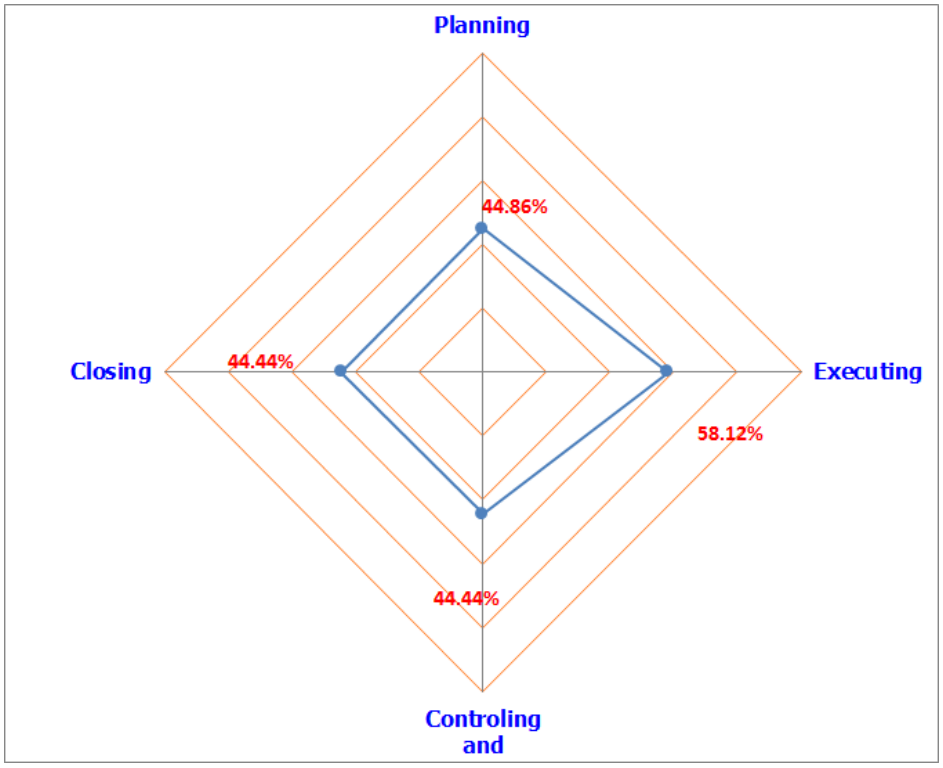


Figure 5.38: Project process status model II

Based on all the foregoing graphs and analytical reports generated for that specific project it is recommended to take the following corrective actions:

- Using crashing methods and techniques in order to shorten the project's schedule by adding resources, although, this may increase the risk and/or cost,
- Reviewing all the direct and indirect costs (labor, materials, equipment, services, facilities, information technology, and special categories such as cost of financing (including interest charges), an inflation allowance, exchange rates) for every single activity on the project,
- Reviewing the project's time and cost contingency reserves,

- Monitoring all projects' expenditures to ensure that they do not exceed the authorized budget,
- Managing the approved changes whenever they occur,
- Preventing the implementation of unapproved changes,
- Informing appropriate stakeholders about all the costs that are related to approved changes,
- Identifying and applying appropriate project management methodologies and standards,
- Providing continuous project management coaching, mentoring, training, and oversight for the whole project team,
- Performing periodic project audit to monitor the project performance trend,
- Developing and applying appropriate project policies, procedures, and templates,
- Developing procedures to control, receive, review, approve/reject, and validate changes,
- Developing procedures for risk management, including risk identification, risk analysis, and risk control.

Finally, the model has a valuable functionality, which is able to export all the project data to other formats such as XLS, PDF, and HTML as shown in figure 5.39. The XLS format provides the opportunity to analyse the project performance more deeply and more professionally. The PDF format is useful because it helps to combine different reports together and present them in one report. The HTML format allows sharing the project data with other departments and displaying it in different locations through the Internet.

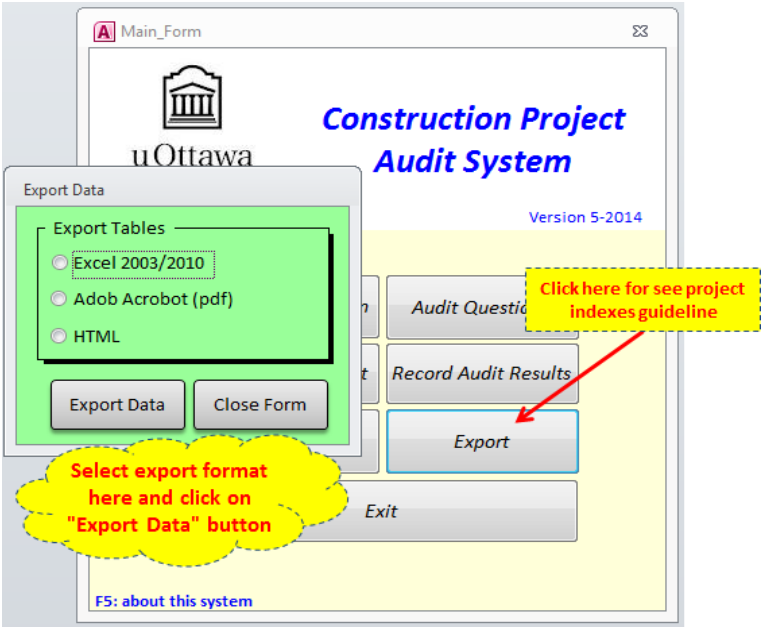


Figure 5.39: Data export selection menu

5.7. Summary

This chapter validated the capability and workability of the developed model by auditing an actual project. The project audit results are generated through two sets of reports: 1) audit questions; 2) progress performance. The model provided different analytical values (i.e. CPI, CV, SPI, and SV) the results of which supported each other. Also, some other values (i.e. ETC, EAC, VAC) are forecasted to predict the future situation of the project based on the cost and time constraints. Therefore, this model not only assesses the project process and function status but also calculates project performance through series of indices that can help project managers make timely decisions. Furthermore, the model provides valuable analytical information of the project that reflects the current status of the project. Also, auditor can provide appropriate recommendations to address the project low performance. Based on those recommendations and the audit results, several corrective actions should be taken to improve the project performance.

Chapter Six

Conclusion and Recommendations

6.1. Conclusion

A project audit provides the opportunity for the project team, especially the project manager and project sponsor, to find the problems, concerns, and challenges raised during the project life cycle including basic design, detail design, construction, and turn over. The audit increases the chance for the project team to discover what has gone well and what needs to be dealt with as soon as possible to successfully complete the project.

This thesis described the steps followed in developing an integrated model for construction project audit during the project life cycle. The model is developed based on the advantages and excluding the disadvantages of other project audit and improvement models. The model provides the opportunity to design organized and integrated tables. With this model all project data can be stored and pulled up anytime even after the project implementation. Reviewing the project audit results during the project implementation helps the project manager to find project problems, issues, and concerns and to try to address them on time. Furthermore, the audit results are documented as lessons learned of each project for consideration in future projects. The developed model has the following advantages:

1. Assessing all aspects of a project (process, function, progress performance),
2. Reporting critical project performance factors at the same time,
3. Ability to customise the audit to do a comprehensive audit or quick audit,
4. Applicable to all project stages and compatible with the project life cycle,

5. Covers all project processes and functions,
6. Having a clear questionnaire and scoring system,
7. A workable and reliable model is developed by using Visual Basic programming along with Microsoft Access 2010 and Microsoft Excel 2010,
8. The users can plan, schedule, and implement a project audit with this model and analyse the results within a minimal time frame,
9. Different project stakeholders (i.e. owners, project manager, project team) can use this model ,
10. The model can forecast the time and cost required to complete the project,
11. The model is able to store project historical data
12. The model is user friendly, flexible, reliable and executes quick calculations, and
13. The model has ability to modify and add information
14. The model can be used to audit any construction project regardless of its location

6.2- Research Contributions

The intention of developing this model is to help project stakeholders to track project performance and find project issues, problems, and concerns through several types of useful reports. Also, the model can accurately show the trend of the project's performance during its life cycle and it helps to find if the project is on the right track. This research has the following contributions:

1. An integrated model has been developed in which project processes performance, functions performance, and project indices are computed to audit projects.
2. Project processes and project functions are integrated and measured through series of specific questions.

3. A trend of project functions and processes performance can be showed during project lifecycle. It represents project management weaknesses and strengths which are very important factors for project oriented companies.

6.3- Limitations of the Developed Model

The developed model holds some limitations related to the lack of information and explanation (structure, scoring system, specification, or questionnaire) for some project audit models. This model has not been developed to provide cost estimation of the project activities. Also, it cannot be used for technical audit such and civil or electrical audits which need specific information related to project execution. The model can be used in construction projects.

6.4- Recommendations for Future Expansion

Although a fully integrated project audit model was developed, the model can be enhanced by adding the following features:

1. Adding other project functions to the model (i.e. claim, finance, environment)
2. Adding the fourth aspect of the construction project to the model (i.e. piping, electrical, welding)
3. Using other forecasting models for project performance
4. Providing other type of reports based on the project's Work Breakdown Structure (WBS). In this case, the project can be divided to sub-projects (small projects) and therefore the model would report the performance of each of them.

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