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Model for the Automated Generation of Optimized Work Packages in Results-Based-Finance Mega Sanitation Projects

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MODEL FOR THE AUTOMATED GENERATION OF OPTIMIZED WORK PACKAGES IN RESULTS-BASED-FINANCE MEGA SANITATION PROJECTS

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DEDICATION

This dissertation is dedicated to the soul of my mother, who is the kindest and the purest person I have ever known. She and my father are the reason behind all my success, and they will always be the reason for any achievement to come in my life. I hope I am making them both proud. I would also like to thank my brothers for their care and support during the rough times of this journey.

I would also like to dedicate this dissertation to my two beautiful daughters. I hope to provide a good example for them. I also would like to dedicate this to my husband, whom I would like to thank for all the support, love, and care during this period of my life.

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ABSTRACT

The sanitation sector is one of the critical sectors in any country. The lack of proper sanitation systems causes many environmental hazards that threaten people's health and well-being. In many developing countries, the sanitation sector constitutes a significant part of their strategic plans of reform. However, with the public treasury's very limited budget, countries opt to major lending institutions for funds. "Results-Based-Finance" is a new funding mechanism used by many lending institutions. The mechanism has proven its efficiency in achieving the necessary reform in sanitation sectors. Due to the complexity of the funding tool, it is crucial to be able to decompose the project into smaller packages to be able to manage and control the project effectively.

The objective of this dissertation is to reach an optimum packaging scheme that enables mega sanitation infrastructure projects to be successfully managed through better planning and cost control practices. The model aim shall be to minimize the amount of funds needed from the borrowing country through three options: by reducing the peak value of the negative cashflow curve, by normalizing the negative cashflow curve, or by a combination of the previous two objectives. With the aid of Unified Modelling Language (UML), an algorithm is developed to map the logic behind the model suggested with detailed illustrations of its different modules. Object-oriented processes and operations are modeled using various diagrams of the language, which automatically generate the optimum packaging combination. The packaging model is then implemented via a number of computer-aided programs. Microsoft Excel is used for calculation purposes. Visual Basic for Applications (VBA) programming language is used to make the model user-friendly

for non-engineering stakeholders. Palisade's Decision Tools Suite is used for the genetic algorithm optimization process.

In order to verify the model, different approaches have been used, which include system checks to minimize programming errors. Moreover, a sensitivity analysis module has been designed with the aid of Top Rank software in order to ensure the flexibility and the capabilities of the constructed model. After the model verification is conducted, the model shall be validated using data from a case study of a mega sanitation results-based financed project located in Egypt. The project is achieved through the World Bank and aims to strengthen the Egyptian Institutions for better service delivery by providing incentives. The project worth is 550 Million USD. The ability of the model to plot the optimization process and the suggested outputs is proven feasible. The model output is not only the content of the packages but also a complete managing plan which demonstrates much useful information to the decision-makers and government officials. Moreover, the model has reduced the peak value of the negative cashflow curve by 18.7 percent, normalized the negative cashflow curve by 5.4 percent, and the model has reduced the funding gap in general by 8.9 percent.

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Abbreviation	**Meaning**
AACE	Association for the Advancement of Cost Engineering
ADB	Asian Development Bank
AFDB	African Development Bank
AFREXIM	African Export-Import Bank
AIR	Annual Information Reports
AW	Annual Worth
BCA	Benefit Cost Analysis
CAPMAS	The Central Agency for Public Mobilization and Statistics
CCT	Conditional Cash Transfers
CVPS	Construction Value Packaging System
DANIDA	Danish International Development Agency
DFATC	Department of Foreign Affairs, Trade and Development
DLI	Disbursement Linked Indicator
DPF	Development Policy Finance
DPL	Development Policy Lending
ECA	Export Credit Agencies
ENID	Egypt Network for Integrated Development
ESIM	Evolutionary Support Vector Machine Inference Model
ESIS	Evolutionary Support Vector Machine Inference System
EWRA	The Egyptian Water Regulatory Agency

Abbreviation	Meaning
FHWA	Federal Highway Administration
fmGA	fast messy Genetic Algorithms
GA	Genetic Algorithms
GDP	Gross Domestic Product
GoE	Government of Egypt
HCWW	The Holding Company for Water and Wastewater
HCWW	The Holding Company for Water and Wastewater
HH	Household Connection
IBRD	International Bank for Reconstruction and Development
ICSID	The International Centre for Settlement of Investment Disputes
IDA	The International Development Association
IFC	The International Finance Corporation
IPF	Investment Project Financing
ISC	Implementation Support Consultant
IVA	The Independent Verification Agent
KFW	KFW Development Bank in Germany
KPI	Key Performance Indicator
LBS	Location Breakdown Structure
LCCA	Lifecycle Cost Analysis
LIBOR	London Inter-bank Offered Rate
MARS	Monitoring Analysis and Reporting System
MHUUC	The Ministry of Housing, Utilities, and Urban Communities

Abbreviation	**Meaning**
MIGA	The Multilateral Investment Guarantee Agency
MoF	The Ministry of Finance
NOPWASD	The National Organization for Potable Water and Sanitary Drainage
NORAD	Norwegian Agency for Development Cooperation
NPV	Net Present Value
P4R	Program for Results
PBC	Performance-Based Contracting
PBF	Performance-Based Financing
PMI	Project Management Institute
PMU	Project Management Unit
RBE	Risk-Based Estimating
RBF	Results-Based Finance
SIL	Specific Investment Loan
SVM	Support Vector Machine
UML	Unified Modelling Language
VBA	Visual Basic for Applications
WBS	Work Breakdown Structure
WSC	The Water Sanitation Company

CHAPTER 1 : INTRODUCTION

Mega projects have a different nature than conventional projects. On a countrywide scale, mega public projects have a more complex nature than ordinary mega projects. This is due to its strategic nature, which is usually contributing to a bigger plan to be executed over many decades. Often, when a country decides to enhance a specific infrastructure sector, such as the wastewater treatment sector, the target is to develop a complete network or system for the coverage of the largest area possible in order to increase the number of beneficiaries. Hence, a large number of infrastructure projects are actually mega projects. Therefore, governments give special care to such mega projects and are very careful when planning such enormous achievements. The success of one mega project is typically an essential step towards a bigger goal yet to be achieved. On the contrary, delays, derailments, or interruptions in these mega public projects lead to spiral effects and may lead to the failure of the bigger strategic plans and goals.

1 . 1 Mega Projects

1 . 1 . 1 Definition and Characteristics of Mega Projects

Mega infrastructure projects are defined to be projects that have large investments and a high economic impact on the surrounding society, (Ma & Fu, 2020). Besides, Locatelli and Mancini describe mega projects that are projects which are usually instructed by the public sector and procured by the private sector. It goes on to state the different aspects of mega projects, which are uncertainty, complexity, coordination, integration of activities, and political sensitivity. Moreover, mega projects usually consist of smaller projects which can be clustered into larger projects. Those projects generally have different components, yet they serve the same global objective, which defines the mega project goal, (Locatelli & Mancini, 2010).

Governments make significant investments in mega infrastructure projects. This constitutes a large portion of a country's Gross Domestic Product (GDP). The Dutch government has published statistics that showed that the investments in infrastructure projects represent 1.55% of Dutch GDP, (Cantarelli *et al*, 2010). A study was conducted on Dutch infrastructure projects, which showed that the average cost overruns varied from 10.6% to 21.7%, (Cantarelli *et al*, 2012). In addition, in 2003, the total cost of infrastructure projects in the world GDP is estimated to be 22 trillion dollars, (Flyvbjerg, Garbuio, & Lovallo, 2009). Dealing with such a considerable portion of GDP makes no room for errors. Government officials are at a high risk of misallocating the funds of the wrong project, given that cost estimates prepared early feasibility stage is, in most of the cases, inaccurate enough, as will be explained in the literature.

On the other hand, a report was issued by the World Bank, which surveyed the portion of the GDP allocated to capital investment expenditures on public infrastructure projects in the Middle East and North Africa. For countries like Jordon and Tunisia, the percentage allocated to public infrastructure projects of the GDP was estimated to be 30 to 40 percent, while for Egypt, the rate varied between 45 to 50 percent, (Agenor, Nabil, & Yousef, 2005).

In the same context, a study was made on over 258 infrastructure projects with a total cost of 90 billion dollars, where the projects are located in over 20 countries on the five continents. This ensured the randomness of the sample and that the study is viable regardless of the geographic location or the time aspect as well. It is found that 9 out of 10 projects suffered from significant cost estimate inaccuracy, with an average of 86% of the projects had their actual costs above the preliminary cost estimate of the project at the feasibility study stage, (Flyvbjerg, Holm , & Buhl, 2002).

Dealing with such a considerable portion of GDP makes no room for errors. Hence, officials must be very thorough when planning public mega infrastructure projects to be able to achieve the famous triangular key performance indicators, which are time, cost, and quality. Mega projects have a different nature than any other conventional projects. One of the mega projects' characteristics explained by Toor and Ogunlana is that it can not be evaluated against ordinary key performance indicators measures. Cost, time, and quality are no longer the only performance measures in perspective. Toor and Ogunlana state that project managers need to consider new standards such as: "safety, efficient use of resources, and reduced conflicts and disputes when evaluating mega projects. In general, they have classified the different project stakeholders into two groups depending on which type of KPIs they are interested in. The first group is concerned with the "Micro-level Success," which comes with the achievement of the cost, time and quality goals. The other is concerned with "Macro-level Success," which has to do with the new KPI criteria, Toor and Ogunlana have come up with, (Toor & Ogunlana, 2010).

1 . 1 . 2 Different Stakeholders of Mega Projects

The Project Management Institute (PMI) defines stakeholders are "persons and organizations such as customers, sponsors, performing organization and the public, that are actively involved in the project, or whose interests may be positively or negatively affected by execution or completion of the project. They may also exert influence over the project and its deliverables", (PMBok, 2013). In this context, mega projects tend to have a considerable number of stakeholders that need to be wisely managed. For instance, in the case of a public mega infrastructure project, the government is a key stakeholder where it has a power/influence relationship in the project. The public are also stakeholders, yet they lack the power to affect the project. Hence, it is not necessary to be a party in the project execution to be considered a stakeholder. However, regardless of whether a person or an entity is a part of the decision-making board of the project or not, all stakeholders need to be considered when planning for a mega project.

Zhai *et al* have introduced in their paper entitled "Understanding the Value of Project Management from a Stakeholder's Perspective: Case Study of Mega-Project Management", the different stakeholders typically involved in a mega-project which are: sponsor, customer, performing organization, subcontractors, suppliers, the public, investors, and other stakeholders. They have proposed a multidimensional model to create a value framework in order to evaluate a company project management strategy against the different stakeholders of the project, (Zhai, Xin, & Cheng, 2009).

Eweje *et al* have also addressed one of the key plays of mega project stakeholders, which is the project manager. Typically, the project manager is involved from the early stages of the project till the completion; moreover, he is responsible for almost all of the significant decisions of the project. Hence, it is essential to study the relationship and theories behind those decision-making processes. Eweje *et al* have stated that many mega projects costs are in the range of 0.3 billion dollars to 20 billion dollars; on the other hand, if one single project has been allocated to an unqualified project manager, this means that the project is endangered and may suffer a significant loss. In the case of a mega project, the loss of one project can cost an organization the whole of its annual profit. In theory, Eweje *et al* suggest that project managers should focus on the global and strategic goals of the organization rather than working on attaining the project delivery cost and delivery time. In this way, it is guaranteed that the value acquired from managing a project will benefit the organization in enhancing its methods and techniques globally that will consequently lead to a greater value for the company itself, (Eweje, Turner, & Muller, 2012).

1 . 1 . 3 Pitfalls of Mega Projects

Mega projects are very dynamic projects that need special management techniques to manage them properly. Most mega projects are dealt with in a traditional way rather than dealing with the complex nature of the project. Traditional management methods are based on focusing on providing a detailed plan for the project that needs to be followed precisely to guarantee the success of the project. However, when the actual execution of the projects starts, following a rigid plan can be very harmful and not as beneficial to the project. Hence, Taxen and Lillieskold suggest following more flexible operational techniques in order to adapt according to the present situation given in the project. The new techniques deal with the dynamic nature by managing changes and new requirements and focus on achieving the planned dependencies, which help in managing projects with very complex and continuously changing tasks, (Taxen & Lillieskold, 2006).

One of the noticeable aspects of the mega projects is that socio-economic aspects of the surrounding project environment can not be ignored. Due to their significant goals and objectives, mega projects usually involve many stakeholders; hence, it affects a high number of personal and organizations. With so many parties involved, mega projects can face many problems starting from socio-economic conflicts with the surrounding community to the intervention of many parties with different political interests. In other words, mega projects usually suffer from pressures that enforce constraints on both time and cost, (Chu & Spires, 2001). This can lead to poor decision making which may harm the project.

Mega Projects, as its name denotes, are substantially large-scale projects, which makes the planning process a very tedious and time-consuming process. However, the variables in mega projects are many and can be easily missed or assessed in the planning stage. At the planning stage, lack of information or the supply of incorrect information may result in poor decision-making practices with regards to the cost-benefit analyses, (Bruijn & Leijten, 2007). On the other hand, early on in the project, government officials are the ones usually making significant assumptions with regards to the project scope, yet as the project proceeds and more reliable information become available. Typically, those assumptions are not changed to reflect the new information received, (Bruzelius, Flyvbjerg, & Rothengatter, 2002).

Nash *et al*, in their paper entitled "Assessing the Feasibility of Transport Mega-Projects: Swissmetro European Market Study", have summarized the problems that are facing the transport infrastructure projects. The problems are induced by the fact that mega project costs are significant, and their durations tend to be very long. Also, there is the aspect of forecasted operation capacity or demands which may have been over-estimated during the planning stage and constitutes significant uncertainties, (Nash *et al*, 2007). Moreover, uncertainty is also accompanied in many of the scenarios with "optimism bias," which makes decision-makers tend towards believing in much more benefits than anticipated, (Flyvbjerg B. , 2008).

Many other authors have also tackled the different pitfalls of mega projects, such as Priemus. In his paper "Mega-Projects: Dealing with Pitfalls", he has discussed 13 of them. The absence of methodological project analysis, prioritization, and poor cost-benefit analysis are three of the main pitfalls that are common between Priemus paper and many papers in the literature. Priemus states that mega projects usually suffer from an underestimation of the costs and overestimation of the benefits. The higher the benefits with reference to the costs, the more appealing the project is to decision-makers, (Priemus, 2010). Flyvbjerg has used an expression that reflects the outcome of the pitfalls mentioned above, which is "survival of the unfittest" which means that as a result of underestimating the costs and overestimating the benefits, projects with the higher add in value shall misleadingly seem more profitable to decision making, (Flyvbjerg B. , 2007).

Creedy *et al* have focused on one of the most significant pitfalls of mega projects, which is cost overruns. Creedy *et al* have collected data from 231 highway projects which have suffered from cost overruns. They ran research to determine the reasons for cost overruns in those projects, which has resulted in detecting 28 common reasons for cost overruns, which has shown a repetitive manner. The reasons include project acceleration required, constructability difficulty costs, and quantities increase than what is estimated. The researchers have developed a regression model that has resulted in defining a relationship between the reciprocal of the project budget and the percentage of cost overruns. This relationship, along with the identification of major cost overruns causes, can be used in determining a more realistic contingency percentage to be added to the project budget, (Creedy, Skitmore, & Wong, 2010).

Molenaar has also studied mega highway projects and the problem with considerable uncertainty, which also leads to cost overruns. Molenaar stated that cost overruns have occurred in almost 90% of infrastructure projects based on a study that was conducted over 258 infrastructure projects over a span of 70 years. It is also important to note that the cost overruns are not minor and were estimated by an average of 28% higher than the estimated budget, (Molenaar, 2005). In general, Liu and Napier estimate the average cost overruns in the mega infrastructure projects to be within a range of 20.4% to 44.7%; moreover, it has been reported that in some cases, the inaccuracy of cost estimates has exceeded 100%, (Liu & Napier, 2010). In another study, it is estimated that 77% of transportation projects in the USA have suffered from cost escalation, (Kaliba, Muya, & Mumba, 2008).

Jergeas and Ruwanpura have done an extensive literature review to determine the common reasons for cost overruns in mega projects. One of the top reasons that most researchers have agreed upon is having a poor initial cost estimate. Unrealistic cost estimates are very common in mega projects, according to Jergeas and Ruwanpura. The authors have given many examples, such as the Denver International and the Channel Tunnel Airport, wherein the former; the cost overruns have reached 200% of the initial cost estimated, which indicates a massive deficiency in that area. Due to their long durations, another two common reasons for cost overruns are underestimating the cost of delays and contingencies, (Jergeas & Ruwanpura, 2010).

Cantarelli *et al* have also investigated the causes of cost overrun. They were able to narrow down the causes into four categories, which are technical, economic, psychological and political. The technical reasons include reasons like scope changes due to insufficient design and errors in forecasting the cost estimates. The economic aspect deals with a lack of resources and inadequate financing and contract management. On the other hand, psychological causes are mainly a result of optimistic bias during the cost estimate process, while political aspects are such as the deliberate cost underestimation as a result of wanting to gain the proposal approval, (Cantarelli *et al*, 2010).

In order to overcome the cost overrun pitfall, Gharaibeh has used Delphi Method by developing a three-around questionnaire to define the causes of the problem, the solutions to the problem, and the lesson learned. The top three ranked reasons for cost overruns are: "high employee turnover rate, heavily regulated industry, and shortage of qualified resources". The top three solutions suggested are: "clear understanding of the scope of work, engineering and project controls to be heavily involved during the process of estimation and spend sufficient time detailing and clarifying subcontractor's scope". It can be concluded that defining a clear and detailed scope of work can lead to a better cost estimation and cost control process, (Gharaibeh, 2014).

1 . 2 Work Packaging of Mega Projects

In order to avoid the above pitfalls, mega-projects need to be managed very carefully and efficiently. Mega projects need to be transformed into a group of projects, smaller in scale yet bigger in terms of focusing on the details of the project. The management of mega projects has always been a big challenge to project managers. Project managers usually resort to different packaging techniques to be able to divide mega projects into smaller, manageable projects. Each of the packages shall be assigned to different executors, contractors, consultants, etc. In that way, the project manager shall be able to efficiently use all the available resources in the construction market and execute the project in a fast and efficient way. The packaging is usually done manually using some factors such as the works location or the works nature, and the project manager often does it. Hence, the efficiency of the packaging technique used is highly dependent on the experience of the project manager and his/her team.

1 . 3 Mega Projects Funding

Another significant aspect of mega projects is securing funds for project execution. For developing countries, securing funds for mega projects is very critical. Public treasuries are very limited in finances compared to the considerable number of sectors requiring reforms and improvements. Hence, developing countries usually opt to borrow money from different financial institutions, as shall be explained in the following chapters.

Nevertheless, this research shall focus on a relatively new funding mechanism titled “Results-Based-Finance,” which has been introduced in order to secure funds for the fundamental reform required in infrastructure projects. Typically, in the conventional funding mechanisms, the lender and the borrowing government shall both be working together to execute the project. In other words, for every step of the way, approvals and signatures and other lengthy procedures are required from both parties. The “Results-Based-Finance” limits the intervening nature of the lender in the decision-making process, which saves a considerable amount of time, (Pearson, 2011). This mechanism is not only a mere financial tool to deliver a service, but also it is a mechanism to work on governments’ long-term strategy making. This improves the capacity of the public sector to be fully responsible for the execution of the project and learn so many lessons along the way. The lessons learned shall be the new inputs to restructure the system and overcome its weaknesses, (Brien & Kanbur, 2014).

1 . 4 Problem Statement

The lack of a proper sanitation system in a country can lead to many health problems and environmental hazards. USAID has made a report which states that improper sanitation treatment has been the primary reason for the spread of many diseases as a result of the pollution caused by untreated wastewater. For instance, statistics show that 85% of rural areas in Egypt lack the existence of sanitation networks. Moreover, only two-thirds of the 15% collected wastewater is actually treated. A deep and serious reform in the sanitation sector can only be done via massive amounts of investments in the sector.

A relatively new delivery method has been introduced in many developing countries like Egypt in order to secure funds for the fundamental reform required in the sanitation sector. “Results-Based-Finance” is a recommended funding instrument that aids governments in developing the necessary means to enhance the execution and delivery of mega projects. Being responsible for the results means that the loan disbursements are not to be released to the borrowing government unless tangible results are achieved and delivered to the lending institution. Hence, the borrowing country is to be held accountable for delivering the project objectives.

Given the complexity of the above delivery method, the borrowing country has to have a clear management plan to be able to ensure the delivery of the results on time, as defined by the loan agreement, in order to receive the disbursements on time. Late disbursements will result in increasing the funding gap in the project cashflow. In other words, the government shall need to secure more funds from its treasury and may also result in delaying the project due to the lack of finances, especially in developing countries where funds are not abundant. When mega public projects start to exceed the allocated budget, the decision shall be either to stop the projects or to minimize their scope of works. In the case of the Results-Based-Finance scenario, the descoping is not one of the acceptable alternatives. Hence, the money shall be wasted on uncompleted projects or partially completed ones while the money could have been allocated in an earlier stage to another project that could have been completed with the same budget.

In order to effectively plan a mega sanitation project, the project has to be broken into packages to assign each package to a competent party to manage. Packages should be decomposed carefully in order not to have extra-small packages and waste the benefit of the economy of scale, or to have extra-large packages which shall be hard to manage effectively. Having the optimum package size shall ensure better planning and more accurate cost control. However, it is a challenging and difficult task; especially, when the project cashflow is very sensitive and intolerant to delays like in the Results-Based-Finance mechanism.

A need for an optimized generation of the packages is rising. The optimization process shall target minimizing government expenditures at any point in time in the project. Moreover, in order to facilitate the packages generation process, a need for an automated computerized model that generates the packages and assigns the scope required to the optimum package size is rising as well. The optimum package size shall result in achieving the required disbursement linked indicators (DLIs) in order to avoid any delays in receiving the loan disbursements on time or earlier to minimize the funding gap of the project.

1 . 5 Objective

The objective is to optimize the packaging process in results based financed projects. The optimization process shall target minimizing the government expenditures at any point in time in the project by optimizing the funding gap, which is the difference between the cash-out and the cash-in in the project cashflow. The optimization process shall be conducted through three options, which are to minimize the negative net amount of government spending, to normalize the negative net cashflows by minimizing its net present value, and a combination of the previous two options.

Moreover, a computerized model shall be prepared that automatically generates the work packages for mega sanitation projects. The model shall also ensure compliance with the Results-Based-Finance method by providing a complete simulation of the RBF financing method policies and requirements. The model shall define the major contractual agreements, including the major parties such as the bank and the borrower representatives. The model shall define responsibilities and important dates. It shall incorporate the assessment of the results, as explained by the World Bank protocol, which depends on Disbursement Linked Indicators (DLIs). The DLIs shall be the basis of the release of the loan disbursements.

After defining the required scope, it shall be decomposed into the proposed packages. The decomposition criteria shall be selected carefully from the literature review, and a coding system shall be generated to define the different characteristics of the project and its attributes. The different packaging scenarios shall be generated through an iterative process in order to ensure that decision-makers select the most optimum combination.

In this case, the decision-makers shall be the borrowing country representatives who shall be responsible for the procurement of the scope in order to achieve the required results. To optimize the selection process, the project planning processes and cost estimation processes, including the funds received from both the bank and the borrowing country, are to be simulated. The objective of the model is to be able to predict the optimum packaging scenario to receive the disbursements on time, or earlier if possible, and reduce the funding gap required to be filled by the borrowing country.

For the purpose of the constructed model, the Unified Modelling Language (UML) is selected to model the processes and operations of the model. The UML is a universal programming language that was developed in the nineties. The advantage of the UML is that it can be understood even by nonprofessionals in the software development industry and has been used in the construction management field before. The object-oriented language provides many types of useful charts such as the activity diagram, the class diagram, and the sequence diagram that will help in understanding the model flow for both developers and the end-users.

The model itself is constructed by using several computer-aided programs, including Microsoft Excel, Visual Basic for Applications (VBA) programming language, and Palisade's Decision Tools Suite. The Visual Basic for Applications (VBA) programming language has given the model a friendly user interface module to be handled easily by the government's officials. The Palisade's Decision Tools Suite is a popular tool for performing optimization processes using the Genetic Algorithms solving technique and performing sensitivity analysis.

1 . 6 Research Methodology

The objective of this dissertation is to develop a tool that optimizes the funding provided by the borrowing countries in results-based financed projects. The new emerging funding mechanism is adopted by many regimes in developing countries and has proven its effectiveness. The tool shall aid in providing an automated way to develop the different project packages; moreover, it shall generate a complete management plan with detailed schedules and cashflows to support the appropriation cost estimate process. To be able to construct the management plan, parameters and variables that affect the costs and timing of the different project components are to be defined and studied thoroughly. Main cost categories are defined along with the assumptions and the adjustments required for exchange rates and inflation.

The tool suggested is designed with the aid of the unified modeling language (UML), which is a unified language used among software developers to ease the communication among engineers with different specialties. The object-oriented nature of the language provides a common ground when developing an interdisciplinary tool for all parties to grasp the bigger picture. The model shall contain only important information rather than the programming details of the tool.

A model is constructed to simulate the different project stages starting from the contract agreement phase until the loan repayment process. The project cashflow is defined in order to optimize the negative net cashflows that define the funding gap, which shall be financed by the borrowing country. The model shall define the different project packages along with their execution dates and related cost information. The output of the model is a comprehensive simulation of the project lifecycle starting from the agreement signing up until the loan repayment schedule at the end of the project. The model consists of four phases: the agreement phase, the procurement phase, the results phase, and the fund phase. Each of the phases has several inputs and outputs that shall be implemented via a number of computer-aided programs. Microsoft Excel is used for calculation purposes. Visual Basic for Applications (VBA) programming language is used to make the model user-friendly for non-engineering stakeholders. The Palisade's Decision Tools Suite is used for the genetic algorithm optimization process and the sensitivity analysis.

For the purpose of verifying the model, the model shall be designed with system checks to minimize common programming errors such as syntax errors and semantic errors. The model shall be validated statistically using different approaches, such as the sensitivity analysis approach. The model is also validated using data from a case study of a mega sanitation project located in Egypt.

1 . 7 Thesis Organization

This thesis is organized into six chapters. Chapter One is an introduction to mega projects characteristics. It defines definitions, characteristics, and pitfalls of mega projects. It also highlights the importance of the packaging concept the dilemma of funding when it comes to developing countries. It also clarifies the problem statement, the thesis objective and methodology.

Chapter Two is a literature review of the concept of appropriation cost estimates and their different techniques and schools. The literature details the life cycle cost and cashflow calculation of mega projects and the project finance approach. It explains the various technologies of water and wastewater treatment and an overview of the Sanitation Egyptian

Code. The chapter surveys some of the current sanitation projects in Egypt as an example of a developing country that needs improvements in the sanitation sector. The different funding methods for mega governmental projects are also clarified, including the world bank group, the regional development banks, and the export credit agencies. The literature details the results-based finance funding method. The different techniques of mega project packaging are discussed. In addition, meta-heuristic optimization methods are analyzed to ensure the effectiveness of genetic algorithms in tackling the problem studied. Finally, the literature review is summarized in order to come up with the actual contribution to the body of knowledge.

Chapter Three illustrates the methodology and model development. The chapter details the different phases of typical results based financed project. A case study is used for the sake of demonstrating examples of different processes. The results and funds flow between the different parties of the project are explained along with the monitoring and evaluating reporting system. The cashflow formulation process is explained, and the packaging time is selected. The model phases are detailed. The Unified Modelling Language (UML) is used to map the different modules of the suggested model. Also, different UML charts are presented and explained.

Chapter Four is the model verification chapter. The model provides the different techniques used to verify the model results. Both system checks and sensitivity analysis are chosen to be the techniques of verification. On the other hand, Chapter Five is the model validation chapter, which provides a detailed demonstration of the model. Screenshots are provided for illustration purposes. A step-by-step hands-on experience is provided via a detailed explanation of the different screens of the applied model. The chapter also discusses the results of the model. Finally, the conclusions, limitations, and expected future works are presented in the sixth and last chapter.

CHAPTER 2 : LITERATURE REVIEW

The literature review shall cover different aspects in order to ensure the viability of the subject. Since the objective of the topic is to develop an automated packaging mechanism that shall optimize the project cashflow and schedule, the first section of the literature review shall be concerned with developing a projects' cashflow and determining the factors affecting the different cost components. The second part of the literature review shall concentrate on sanitation mega infrastructure projects. Egypt is selected as an example since the validation was performed using a case study that is located in Egypt. The following section shall discuss the different funding methods, which are usually used by developing countries in order to execute mega infrastructure projects. Finally, different papers are surveyed to come up with the different packaging techniques used by construction managers in the industry.

2 . 1 Appropriation Cost Estimate

Cost Estimation is an important field in project management. Without accurate cost estimates, projects can exceed the allocated budget, which jeopardizes the success of the project. Cost estimates can be very crucial, especially at the early stages of project preparation. During the concept and preliminary stages, estimates are required first to give the decision to build the project and to obtain the necessary funds for the project.

Njeem defines four stages of cost estimates. The first stage is the feasibility estimate, which is used in determining the decision of whether or not to proceed with a certain project. The second stage is the appropriation estimate, where it is used in obtaining the required fund for the project. The third stage is the capital cost estimate, which is the budget to be controlled in the project. Finally, the definitive estimate is prepared to obtain the final cost of a project, (Njeem, 2012).

According to AbouRizk *et al* the decision of whether to fund the project is determined at the conceptual stage of the project, while at the preliminary design stage, the approval of the budget is obtained. The estimate to get the funds is usually referred to as "appropriation cost estimate", and according to AbouRizk *et al*, the ability to establish an accurate appropriation cost estimate at this stage is questionable, (AbouRizk, Babey, & Karumanasseri, 2002).

The research shows that cost overruns are highly noticed in the appropriation cost estimate phase where it needs to be developed to obtain the necessary fund for the project. At this stage, estimates tend to be more detailed, and the project nature and circumstances tend to be more explicit. In more extreme situations, project feasibility estimates can be deliberately underestimated in order to get necessary approvals on the project inauguration, (Cantarelli *et al*, 2012).

2 . 1 . 1 Deterministic vs. Stochastic Approaches

Molenaar stated that the deterministic approach is the conventional norm where it is used by determining project cost and adding a contingency markup, which is not very accurate. It is recommended to use stochastic approaches as at the early stages of mega projects, and it is hard to be deterministic when assessing the contingency added, (Molenaar, 2005).

Association for the Advancement of Cost Engineering (AACE) has developed a manual for a cost estimate classification system. The system consists of 5 classes where each class is defined by primary and secondary characteristics. Table 1 shows the different relations between the classes and the characteristics of the cost estimate. In class 5, the estimate is of a stochastic nature where the maturity level of the project is still very minimal as the classes evolve and the maturity level increases, the estimate shifts from being stochastic to be more deterministic, (Christensen & Dysert, 2011).

Table 1: Generic Cost Estimate Classification Matrix, (Christensen & Dysert, 2011)

	Primary Characteristic	*Secondary Characteristic*			
ESTIMATE CLASS	**MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical +/- range relative to index of 1 (i.e. Class 1 estimate) [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Screening or feasibility	Stochastic (factors and/or models) or judgment	4 to 20	1
Class 4	1% to 15%	Concept study or feasibility	Primarily stochastic	3 to 12	2 to 4
Class 3	10% to 40%	Budget authorization or control	Mixed but primarily stochastic	2 to 6	3 to 10
Class 2	30% to 75%	Control or bid/tender	Primarily deterministic	1 to 3	5 to 20
Class 1	65% to 100%	Check estimate or bid/tender	Deterministic	1	10 to 100

2 . 1 . 2 Purpose of Cost Estimate

Cost estimates are very critical to construction projects of different sizes, and it is specifically of high importance in the case of mega projects in order to develop the project cashflow accurately. An ill-prepared estimate will result in major cost overruns, which in the case of mega projects shall result in the termination of the project before reaching the full scope intended. Hence, it is essential to be able to have a decent margin of accuracy when preparing cost estimates. This can be very hard in the early stages of the project preparation, where very little information is available.

Gwang *et al* have developed three different models that perform cost estimation techniques. The purpose of the research is to assess the level of accuracy of each model methodology. The three models used are a multiple regression model, a neural network model, and a case-based reasoning model. The models have been applied to a database of 530 residential projects in Korea. The research concludes that the neural network model has given the most accurate cost estimate among the three of them in the short run; however, in the long term, the case-based reasoning model has proven to be more accurate, (Kim, An, & Kang, 2004).

Roy *et al* have introduced a quick way to estimate the feasibility of water supply projects in India. The purpose of such a cost estimate is to be able to determine the project cashflow and whether the benefits outweighed the costs. The authors have stated that India's government has allocated very low fees for the water; on the other hand, the transportation cost is very high, which makes it inefficient to spend high transportation costs to collect very low tariffs. Roy *et al* have used neural networks and Monte Carlo's simulation in estimating the suitable water tariff mechanism for each city in India, (Roy *et al*, 2010).

2 . 1 . 3 Cost Estimate Survey

There exist many cost estimation techniques and schools; however, it is crucial to be able to determine the appropriate cost estimation method that will suit a specific project. In general, Holm *et al* define three types of cost estimates: conceptual, semi-detailed and detailed cost estimates, (Holm *et al*, 2005). Table 2 demonstrates the different cost estimate methods and their corresponding phase of design and expected percent error.

Table 2: Cost Estimate Types, (Holm, Schaufelberger, Griffin, & Cole, 2005)

Type of Estimate	Construction Development	Expected Percent Error
Conceptual	Programming and Schematic Design	±10-20%
Semi-Detailed	Design Development	±5-10%
Detailed	Plans and Specification	±2-4%

Cost studies can be generally divided into two broad categories: qualitative analysis and quantitative analysis. Qualitative analysis is based on mere points of view and experts' opinions, while quantitative analysis is based on values and numbers. Quantitative approaches can be classified into three main categories: parametric models, analogous models, and analytical models. Parametric models are also called statistical models that are using top-down techniques. This is done by correlating a project with a similar project in characteristics and depends on statistical data in obtaining the cost estimate. There are several tools used to prepare this estimate, such as regression analysis, optimization techniques, and neural networks, Figure 1. The second quantitative technique is the analogous models, which depend on bottom-up techniques by using the cost information of the cost components in the project from a similar project in terms of functionality or geometry, or even geographical location to obtain the estimate. The last type is the analytical models, which is a detailed cost estimate based on dividing the project into smaller tasks to obtain their costs, (Layer *et al*, 2002).

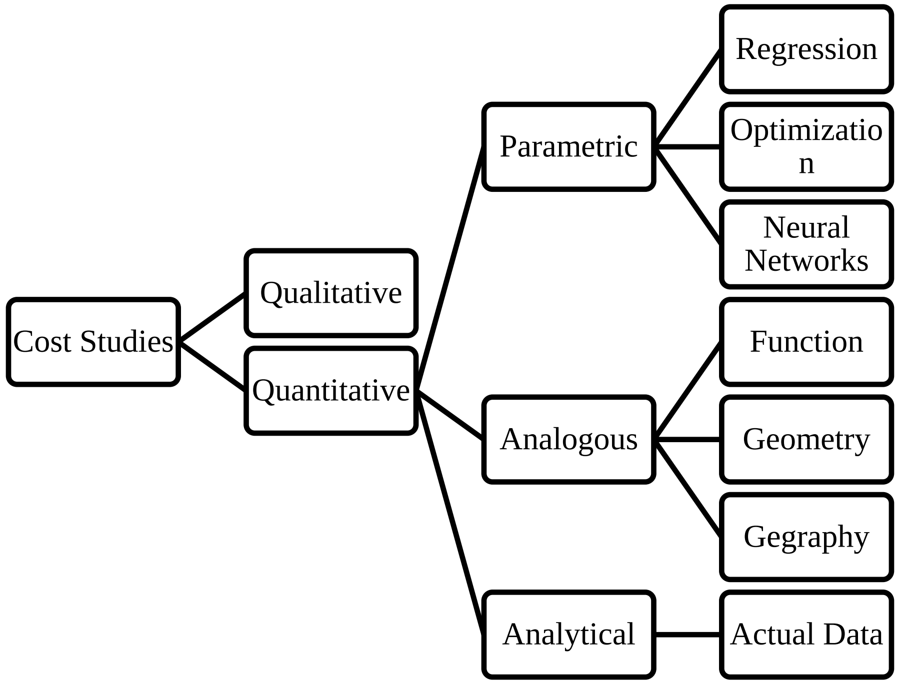


Figure 1: Cost Studies Techniques

Leonard *et al* have mentioned in their paper entitled "Prioritizing Sanitary Sewers for Rehabilitation Using Least-Cost Classifiers" that linear regression methods were used in a sewer rehabilitation project to predict the status of uninspected pipes using the results obtained from some inspected ones. The results of their research have proven that this method underestimates the number of pipes that need rehabilitation, and the "logistic discrimination" method and the "metaheuristic discrimination" method give more accurate results. This is another example of how choosing the wrong cost estimation method is very important in order not to have an inaccurate estimate, (Wright, Heaney, & Dent, 2006).

Risk-based estimating (RBE) is another method that is used in cost estimation. The technique depends on dividing the base estimate of the project into subcategories where each category is assigned a contingency. The contingency is composed of a probabilistic distribution that is obtained through collecting experts' opinions from the field. The resultant of this method is a range with a certain degree of confidence that the total project cost shall lie within. Liu and Napier have conducted a comparison between risk-based estimating (RBE) and conventional cost estimating methods. They have found that RBE obtained more accurate results from a sample of 11 mega projects from water infrastructure field projects in Sydney, (Liu & Napier, 2010).

An important aspect of any cost estimate is to be able to assess the accuracy of the estimate. Trost and Oberlender have developed a mathematical regression model that measures the accuracy of a certain estimate. They have come up with 45 drivers that affect the estimate accuracy and have conducted a survey to measure the importance of each one of the drivers. The drivers were then summarized into 11 factors. Regression analysis was performed to come up with the most significant factors which affect the estimate accuracy. Five factors were identified, which are: "basic process design, team experience, and cost information, time allowed to prepare the estimate, site requirements, and bidding and labor climate", (Trost & Oberlender, 2003).

2 . 1 . 4 Cost Estimate components

For a wastewater treatment plant, the cost categories are investment costs and operation costs. The operation costs are divided into fixed operating costs and variable operating costs. Examples of fixed costs are regular operation costs and maintenance costs, while examples of variable costs are electricity costs, chemicals costs, sludge treatment, and disposal costs and taxes. The research aimed to unify the different cost estimation methods in order to compare the different plant types based on the kind of treatment. The benefit of this research is defining areas of cost savings. Gillot *et al* have presented in their paper a comprehensive literature review, which included cost formulas to calculate the different components of investment and operation costs, (Gillot, et al., 1999).

Mbav *et al* have defined the cost components of a Landfill Gas Energy Project. Those components can be generalized to be used in many other mega projects. The components are the cost of the system, the operation and maintenance costs, the sale price, and the funding terms and financing interest, (Mbav, Chowdhury, & Chowdhury, 2012).

One of the significant components of the cost estimate is contingency. In order to be able to assess contingency, project risks need to be identified and quantified. Flyvbjerg defined the different risks which can arise in any mega project and was able to categorize most of them into four main categories: "Risks of Cost, Risks of Demand, Financial Risks and Market and Political Risks", (Flyvbjerg B. , 2007).

The complexity of the project is one of the main factors which determines the contingency used in the project. Another factor is the time factor; in other words, at the feasibility study stage, contingency tends to be higher than at a later stage where the project is developed and the scope becomes clearer. In general, Davis and Peng have summarized the percentage contingency that agencies usually use during the different stages of an ordinary infrastructure project, which is shown in Table 3, (Davis & Peng, 2010).

Table 3: Contingency Percentage, (Davis & Peng, 2010)

Stage	Planning	Preliminary	Budget	Definitive
Contingency	25% - 35%	20% - 25%	10% - 20%	5% - 15%

2 . 2 Life Cycle Cost and Cashflow Preparation

2 . 2 . 1 Definition

The life cycle cost method is a widely used method to determine the economic worth of a mega project. In general, there are two conventional methods used in making decisions related to the economic valuation of mega projects: The Lifecycle cost analysis (LCCA) and the benefit cost analysis (BCA), (He, 2015). The difference between the two approaches is that the life cost approach analyzes the costs of actual physical components of the project, yet the benefit-cost approach also considers the value of the benefits as a result of executing the project. From the literature, one of the main reasons for cost overruns is the "optimism bias," which makes decision-makers exaggerate benefits, (Flyvbjerg B. , 2008) (Cantarelli *et al*, 2010) (Jergeas & Ruwanpura, 2010). Hence, this research shall only consider the life cycle cost method for economically evaluating a prospective project.

Optimization of the life cycle cost has been an interesting field of research for many authors. Aziz *et al* have developed a model using genetic algorisms to optimize the resources used in simultaneously constructed mega projects in order to reduce the project total cost and time; moreover, it ensures full utilization of the project resources. They have produced a computer software called the smart Critical Path Method System "SCPMS," which, as its name denotes, employs the critical path concept yet after some modification to introduce the multi-objective genetic algorithms concept, (Aziz, Hafez, & Abuel-Magd, 2014).

2 . 2 . 2 Components

Li *et al* divide the life cycle of mega projects into five processes which are: Alternatives Analysis, Preliminary Engineering, Final Design, Execution, and Operation. They introduced a decision support system that continuously incorporates new inputs and information into the decision-making process to evaluate the management approaches at the different phases of the project. The decision support system controls the movement from one process of the life cycle of a mega project to the other; or in other words, it controls the start of the following process of the life cycle, (Li, et al., 2010).

Esty states that at the early preparation stages, many transaction costs are incurred, such as feasibility study preparation costs, legal advisors' fees, financial advisors' fees, tax advisors' fees, and loan documentation. Esty estimates that transaction costs constitute 5 to 10 percent of the total cost of the project along a span of six to eighteen months, (Esty, 2004).

Finally, the last component of the life cycle cost is the cost of finance. The cost of finance is the costs corresponding to borrowing money in order to fund a mega project. It includes interest charges, fees of financial institutions, salaries of involved personals, and any other expenses involved in the process.

2 . 2 . 3 Calculation Techniques

After determining the components of the life cycle cost, it is essential to decide on the method of calculation to be used. The first question is whether the components shall be evaluated in terms of nominal dollars or constant worth dollars. The nominal dollar method is the dollar's value in terms of its purchasing power while accounting for the effect of inflation in the dollar value, (Federal Highway Administration (FHWA), 2003). While the constant worth dollar method does not account for inflation. In this research, the constant worth method is used as it is difficult to predict inflation, which constitutes a very high source of error in the calculations.

Another important aspect of the life cycle cost technique is the selection of the discount rate in order to calculate the net present value (NPV) of the project. This rate is significant, and there exist several methods for selecting a suitable rate for a project. In general, the discount rate should not be less than the risk-free rate, which is the rate of investing the same amount of capital in a local bank. Jiang *et al* state that the discount rate selected in economic evaluation is equal to the interest rate acquired by banks on borrowing money, (Jiang *et al*, 2013). He also adds that the economic and financial situation of a country may also govern the selection of a suitable interest rate, (He, 2015).

2 . 2 . 4 Project Cashflow and Funding Gaps

Studying the project prospective cashflow is one of the major aspects when determining the viability and feasibility of a mega project. Specifically, for lenders, a net positive cashflow is the only guarantee that their debt will be repaid.

Funding gaps are areas in the cashflow of a certain project, which gives a negative net cashflow at a certain time in the cashflow. This indicates the need to have a funding source to cover this gap. When preparing the "appropriation cost estimate", the purpose of the estimate is to come up with the funding gap in order to identify the periods at which funding is required. Companies seek short-term loans to cover short funding gaps, while long-term loans are preferred in case of long-term gaps. The term "maturity match" is used to describe the process of matching the periods with funding gaps with the terms of the loans required. The main concept in this mechanism is to select the loan term or duration to allow for the asset to recover enough profit from repaying the loan and its interest, (Peterson, 2009).

Figure 2 shows an example of calculating the funding gap for an annual cashflow of the operations phase of a project. The last row shows the minimum monthly bank balance required to fulfill the obligations of the project; in other words, it represents the funding gap needed to be funded.

Annual Cash Flow from Operations

Item	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Cash Receipts	605,600	707,200	653,600	720,900	708,100	760,400	506,500	466,000	364,700	317,400	440,000	632,400	6,882,800
Cash Disbursements	606,800	677,650	610,200	686,750	614,700	578,250	456,650	419,250	328,350	345,100	397,450	542,800	6,263,950
Overhead:													
Advertising	7,680	7,120	7,850	7,690	5,600	5,450	5,000	3,910	3,420	4,600	4,920	5,160	68,400
Promotion	—	—	—	—	—	—	8,000	—	—	—	—	15,000	23,000
Car and Truck Expenses	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	13,200
Computer and Office Furniture	—	—	—	—	—	—	18,000	—	—	—	—	—	18,000
Employee Wages and Salaries	22,618	22,618	22,618	22,618	22,618	22,618	22,618	22,618	22,618	22,618	22,618	22,618	271,416
Employee Benefits	750	750	750	750	750	750	750	750	750	750	750	750	9,000
Employee Retirement	679	679	679	679	679	679	679	679	679	679	679	679	8,142
Employee Taxes	2,340	2,256	2,054	1,998	1,925	1,878	1,809	1,809	1,809	1,646	1,144	1,144	21,811
Insurance	4,366	4,086	4,451	4,371	3,326	3,251	3,026	2,481	2,236	2,826	2,986	3,106	40,514
Taxes & Licenses	100	—	—	—	—	—	—	—	—	—	—	—	100
Office Supplies	500	500	500	500	500	500	500	500	500	500	500	500	6,000
Office Rent	500	500	500	500	500	500	500	500	500	500	500	500	6,000
Office Utilities	350	350	250	250	250	350	350	350	250	250	350	350	3,700
Postage and Delivery	100	100	100	100	100	100	100	100	100	100	100	100	1,200
Janitorial and Cleaning	433	433	433	433	433	433	433	433	433	433	433	433	5,200
Telephone	440	440	440	440	440	440	440	440	440	440	440	440	5,280
Charitable Contributions	—	—	—	—	—	—	—	—	—	—	—	3,000	3,000
Dues and Memberships	—	—	—	1,500	—	—	—	—	—	—	—	—	1,500
Legal and Professional Services	1,000	—	—	3,000	—	—	1,000	—	—	1,000	—	—	6,000
Meals and Entertainment	867	867	867	867	867	867	867	867	867	867	867	867	10,400
Bank Fees	50	50	50	50	50	50	50	50	50	50	50	50	600
Miscellaneous	100	100	100	100	100	100	100	100	100	100	100	100	1,200
Total Overhead	43,972	41,949	42,742	46,946	39,238	39,066	65,321	36,686	35,851	38,459	37,537	55,897	523,663
Cash Flow from Operations	(45,172)	(12,399)	658	(12,796)	54,162	143,084	(15,471)	10,064	499	(66,159)	5,013	33,703	95,187
Interest Received	448	222	198	186	235	547	1,292	1,235	1,308	1,247	929	841	8,687
Loan Payments	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	1,626	19,512
Estimated Income Taxes	—	—	—	—	—	—	—	—	—	—	—	50,303	50,303
Cash Flow After Income Tax	(46,350)	(13,803)	(770)	(14,236)	52,771	142,005	(15,806)	9,673	181	(66,538)	4,317	(17,385)	34,059
Savings Account													
Beginning Balance	200,000	153,650	139,847	139,077	124,841	177,613	319,617	303,812	313,484	313,665	247,127	251,444	
Deposit or (Withdrawal)	(46,350)	(13,803)	(770)	(14,236)	52,771	142,005	(15,806)	9,673	181	(66,538)	4,317	(17,385)	34,059
Ending Balance	153,650	139,847	139,077	124,841	177,613	319,617	303,812	313,484	313,665	247,127	251,444	234,059	
Monthly Labor Costs	220,618	218,618	200,618	203,618	155,618	136,618	122,618	113,618	103,618	128,618	122,618	166,618	
Minimum Monthly Bank Balance	(20,618)	(64,968)	(60,771)	(64,541)	(30,777)	40,995	196,999	190,194	209,866	185,047	124,509	84,826	

Figure 2: An Example of Calculating Funding Gap, (Peterson, 2009)

2 . 2 . 5 Project Finance

2 . 2 . 5 . 1 Definition

When financing mega projects, there exists two methods of financing: project finance and corporate finance. Project finance is when a separate entity is formed for a specific project like in the case of public-private partnerships, a consortium or a single purpose vehicle is formed for the sake of executing a particular project only. The financial statements, assets, and cashflows of this entity are separate from its creators. In order to finance the project, this entity borrows a non-recourse debt, which is a debt that is guaranteed by the entity itself. In other words, in case of default, the lender can only seek the properties of the entity, not the original creators. On the other hand, in the case of corporate finance, borrowers can seek the assets of a company to collect debts.

Project finance is defined as "the financing of long-term infrastructure, industrial projects and public services based upon a non-recourse or limited recourse financial structure where project debt and equity used to finance the project are paid back from the cashflow generated by the project", (Fink, 2014). Alam states that project debt accounts for 70% to 90% of the total project value. Project Finance has become a favorable mechanism in financing mega governmental projects. The global project finance value has been compared in the late 1980s versus 2006, which has grown from 10 billion dollars to 328 billion dollars, which shows a tremendous rate of growth in recent years, (Alam, 2010).

2 . 2 . 5 . 2 Characteristics

As a result of their complicated mechanisms, project finance requires a significant number of contractual agreements between the different players in the project, starting with the project company, the lending institution, and the public sector. Those contracts need to be studied thoroughly and prepared professionally in order to guarantee the success and the continuation of the project. Risk sharing and clear identification of rules and responsibilities need to be clearly stipulated in the contract terms.

Project finance is usually a long-term financing approach, which generally lies between 15 to 20 years, including the construction stage and a fairly lengthy operation phase. The interest is repaid to lenders through the project cashflow itself; hence, it is essential to be able to accurately predict the project cashflow along the lifetime of the project. Project finance is also known for a high leverage ratio, and the debt to equity ratio is typically 7:3 or, in some projects 9:1. Non-recourse finance is another characteristic of project finance where the lender is only entitled to collect the interest from the profits generated by the project, (Yescombe, 2002).

2 . 3 Water and Wastewater Systems

The mega project type profoundly affects the preparation of the project cashflow. The factors affecting the cashflow of a transportation project are different than the factors affecting a housing project. Hence, it is vital to understand the dynamics of the components affecting a mega project cashflow by understanding the different technologies used in its construction and operation. Water and wastewater systems are usually connected when planning a strategic plan. The below section shall explain the components of the treatment systems and the different technologies used in the treatments. The case study used in this thesis is located in Egypt; hence, Egypt shall be used as an example below.

2 . 3 . 1 Potable Water Systems

Potable water Networks consist of several components which depend on many factors with regards to the design and structure of the concerned area. It usually consists of an Intake Pump Station, which takes the water from the Nile and purifies it. Intake Pump Stations are typically located near the Nile, like the Intake Pump Station in Giza, which is located directly in the Nile. The network also consists of Pump Stations which are used to increase water pressure in order to be pumped to distant places across the network. This is essential for prominent cities and vast areas in order to be able to move the water for considerable distances. An example of a pump station is Emaar Pump Station in front of Cadbury Factory on the Ring Road. Water Networks start with "Balance Tanks" to elevate the water at the beginning of the network, then the pipes distribute the water to the users. Control Chambers exists along the network to be able to control the flow and is also used for maintenance purposes.

2 . 3 . 1 . 1 Water Treatment Plant Process

Figure 3 below shows the components of a typical Water Treatment Plant. The first component is the Intake pipe of the Crib, which collects the water from a nearby lake or reservoir. The pipe is provided with zebra mussel control, which prevents large debris from entering the pipe. The Preliminary treatment system consists of a protective bar screen and a travelling bar screen, which prevents small debris like fish and garbage from entering the system. The low list pump well purpose is to pump the water to higher levels to be able to flow with the effect of gravity through the treatment plant.

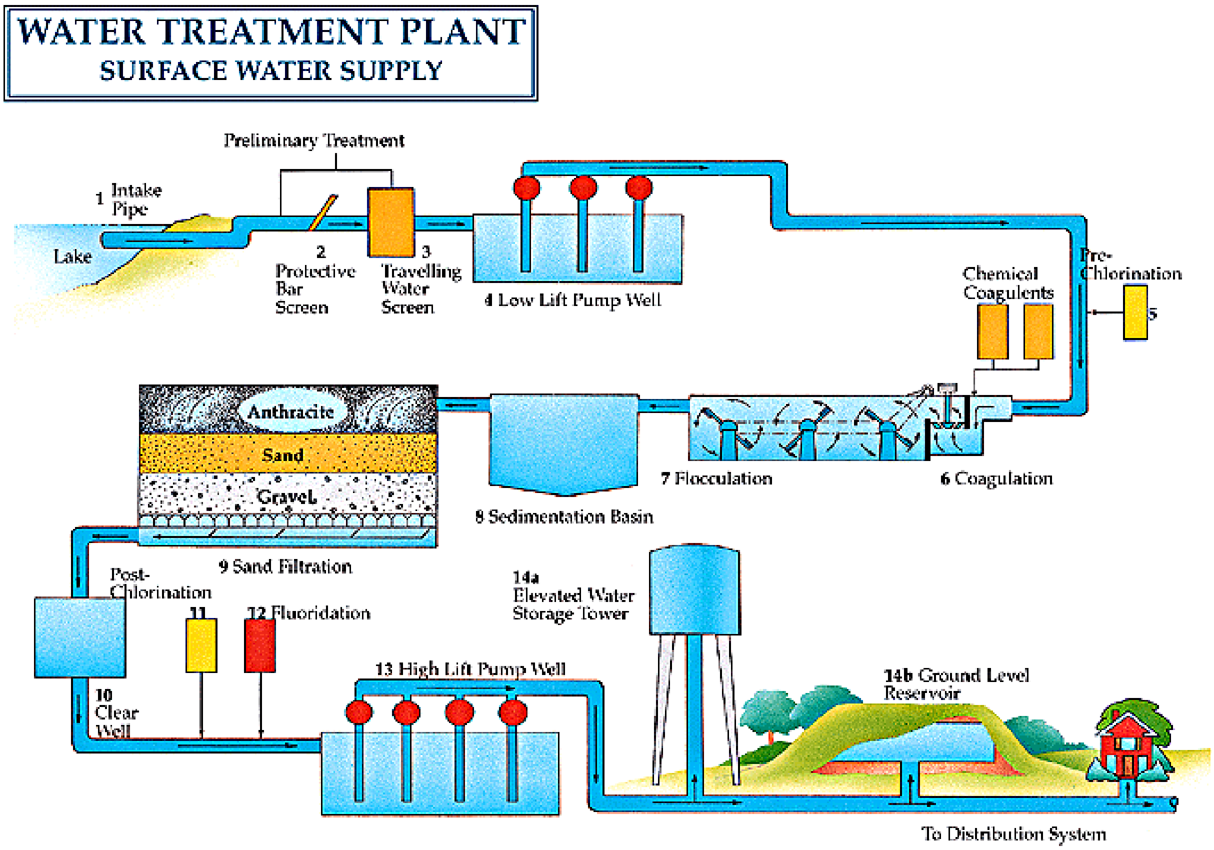


Figure 3: Water Treatment Plant, (Fleming, 2018)

The following stage is the pre-oxidation and primary disinfection phases, which are the Chemical Coagulants and Pre-chlorination. The purpose of this stage is to treat the taste and odor of the water by using disinfectants and oxidants. The type of disinfectants and oxidants used depends on the original water quality and characteristics.

Coagulation is then performed is done through rapidly adding electrochemical charges that help small particles in the water to collide together to form a "floc". The next step is "Flocculation", which is slowly mixing the water to add turbulence, which causes the small "flocs" to come together and form large pieces. The large particles become heavy, and after reaching the sedimentation tanks where the water is less turbulent, it settles. The settled particles are removed from the sewage system.

The purpose of the Media Gravity Filtration is to further purify the water by screening the water over several layers. The first layer is "Anthracite," which is granular activated carbon. The second layer is sand, and the third one is gravel or synthetic material. The water in the clear well is used to backwash the above-mentioned filters.

A secondary disinfection process is implemented using supplemental chlorine in order to disinfect the water at the farthest point in the plant. Fluoridation is then performed to raise the fluoride concentration in water. Finally, the treated water is pumped by a high lift pump to be distributed either to other pump stations or to reservoirs or elevated water storage tower.

2 . 3 . 2 Wastewater Systems

The wastewater network is the inverse of water networks in the essence that it starts with the actual pipes network and ends with the wastewater treatment plant, unlike the water networks, which begin with the treatment plant. The first component is the sewage piping network, which collects sewage from different users. Sewage can be either domestic or industrial. Industrial sewage, in some cases, is partially treated at the source depending on some specifications that are required by the Egyptian Code. The next component is manholes, which exist along the line. The sewage is collected at Sewage Pump stations to be pumped to the Force Main. Finally, the Force Main is to pressurize the sewage in order to reach another wastewater pump station or the wastewater treatment plant.

2 . 3 . 2 . 1 Types of Wastewater Treatment

In general, not all wastewater needs to be treated before discharging it to a disposable location; moreover, there are multiple levels of treatments. Sewage can be pumped to lagoons, which is open land designed for the disposal of such waste. It can also be pressurized by force main to a pump station along the way to reach another Force Main and another pump station, etc., in order to reach a specific place of treatment. Sewage can be treated to many extents, one of which is to be "Grey Water," which is used in irrigation of fruitless trees and plants which is not exposed to human interaction. Some wastewater treatment plants can purify water to the extent that it becomes potable water. In some countries, they have networks for treated water to be used in the flushing system of toilets as well.

2 . 3 . 2 . 2 Wastewater Treatment Process

Wastewater consists of three primary sources: domestic wastewater, industrial wastewater, and rain or stormwater. Domestic wastewater and rainwater directly discharge into the sewage system; however, industrial wastewater should be treated first at its origin before discharged into the sewage system as, in most cases, it contains pollutants that can not be treated by ordinary wastewater treatment plants.

The wastewater treatment consists of three main stages: primary treatment, secondary treatment, and tertiary treatment. The first step of the primary treatment is to remove the solids from the influent sewage water by letting them go through screens. The rest of the effluent is collected into a large settling tank or a "grit chamber" where solids are to settle in the bottom to be removed. The rest of the flow is moved to another basin, which is called the "primary clarifier," which is usually a circular tank that again allows sedimentation of solids and large particles. The primary clarifier usually has a rotating rod that skims the oil and grease waste floating on the water surface. The scraped waste is removed from the digester. The solids collecting from the bottom of the basins are directed based on their format to one of three destinations: a digester, a sludge press, or a drying bed.

The wastewater is then directed to weirs, where it is further purified and oxygenated to facilitate the biological reactions, which is the secondary stage of treatment. After removing the solids, the water is collected into an aeration basin. Activated sludge is to infiltrate air into the water to stimulate microorganisms (microbes and protozoans) to further treat the wastewater by consuming the remaining pollutants in the water. The microorganisms are consumed by time and die. After they die, they collide together and form clumps. The water is then moved to another sedimentation basin in order to get rid of those clumps. A portion of the sludge is returned to the aeration tanks as food to the microorganisms, which is called "return activated sludge". The final step is to apply chlorination in order to remove harmful substances and bacteria. De-chlorination is then performed to reduce the toxicity of the treated water.

A stage called "bio-solid treatment" is performed on the sludge in digesters tanks, which are heated tanks to reduce the volume of the sludge. It also helps in getting rid of the odor and the organisms that can pollute the environment. Unlike aerobic tanks, the digesters are anaerobic in nature, which means that it is free of oxygen. Byproducts resulting from the digesters are ammonia, hydrogen sulfide and methane gas, as shown in Figure 4.

At this point, the treated water can be discharged into a river or a reservoir; however, some plants have the third stage of treatment called tertiary treatment. It can be chemical, physical, or biological treatment. Chemical treatment can be done by adding alum to precipitate the phosphorus, while physical treatment can be done by filtering the water through anthracite coal, sand, and gravel. Finally, Biological treatment can be done by moving the water through plants that naturally absorb excess nutrients and solids.

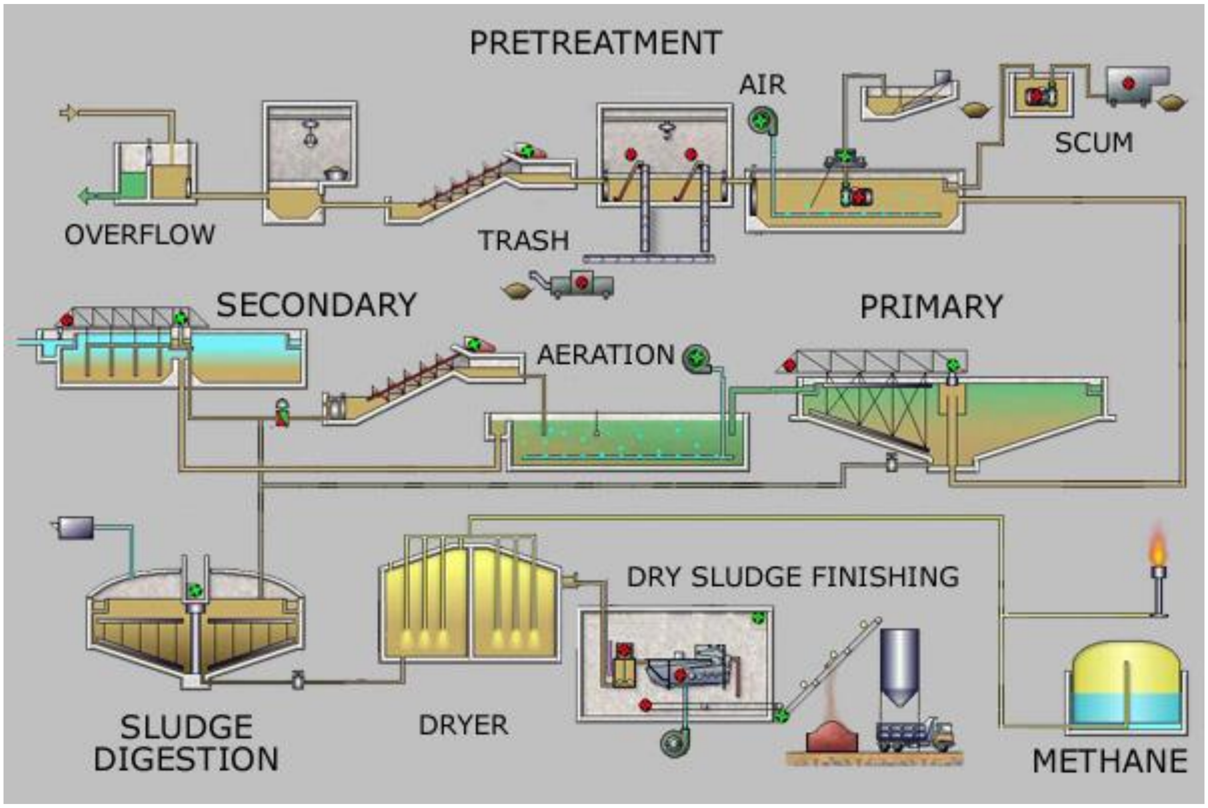


Figure 4: Wastewater Treatment Plant, (Mondal, 2018)

2 . 4 The Sanitation Egyptian Code

2 . 4 . 1 Overview

Egypt is a developing country that is known for a rapid rate of increase in its population. The water and wastewater projects are given priority in developing the strategic infrastructure plan and have been allocated almost 4.2 billion Egyptian Pounds of its state general budget in 2015. The water supply and sanitation coverage of Egypt is almost 56 percent only; 83 percent of which in urban areas and 17 percent in rural areas (The World Bank, 2015).

The key factor of the design of water and wastewater networks is to determine the capacity of the project and the expected discharges. The Egyptian Code has given detailed steps to be able to calculate current and forecasted discharges in cities and villages of concern. The following report will: explain the Egyptian Code methods of discharge calculation, discuss the different treatment options, and provide examples of the standard components of water and wastewater projects.

2 . 4 . 2 Design Parameters

2 . 4 . 2 . 1 Population Versus Demand

Infrastructure mega projects are very complicated projects which require many feasibility studies and experts' feedback in order to determine whether it will fulfill a public need or not. Strategic projects usually are planned over several phases. Due to their long-term nature, they are phased based on the demand at a particular stage. For water and wastewater treatment projects, the demand is highly correlated to the population size. Cities with a higher population are more likely to need larger treatment plants and maybe one or more pump stations. In order to be able to make such a decision of how many treatment plants are needed or what is the capacity of each one of them, first, it is essential to be able to estimate the demand and the population status.

2 . 4 . 2 . 2 Population Forecast

In general, there are three stages of the growth of the population in a particular area. The first stage is the beginning and prosperity. In this stage, the population is at a growing rate of increase. The second stage is normalization, where the population curve slows down and starts to increase with much lower rates. The last stage is saturation, where the population is no longer rising in this specific area.

Based on the above, experts have been able to form mathematical equations which determine the estimated future population in areas of study. Those forecasted equations allow the government to decide on the phasing part of water and wastewater mega projects and enable designers to forecast the capacity of the networks.

Each stage of the above three stages has a different equation to be able to forecast the population at which. During the first stage, the equation used in the Egyptian Code is called the "geometrical Increase Equation". The equation used by the Egyptian Code to calculate the population during the second stage is called the "Arithmetic Increase Equation", and finally, the equation used for the last stage is called the "Decreasing Rate of Increase Equation". The Three equations are shown below:

$$ln\, P_n = ln\, P_1 + K_g\,(t_n - t_1)$$

Equation 1: Geometrical Increase Equation, (The Egyptian Code (Ministerial Decree no. 52), 1998)

$$P_n = P_1 + K_a\,(t_n - t_1)$$

Equation 2: Arithmetic Increase Caption, (The Egyptian Code (Ministerial Decree no. 52), 1998)

$$P_n = S - (S - P_1)\, e^{-K_d\,(t_n - t_1)}$$

Equation 3: Decreasing Rate of Increase Equation, (The Egyptian Code (Ministerial Decree no. 52), 1998)

Where:

P_n: is the Population targeted by the Project.

P_1: The current population based on the Central Agency for Public Mobilization and Statistics (CAPMAS).

K_g: The geometric rate of increase (Increasing Rate)

K_a: The arithmetic rate of increase (Constant Rate)

K_d: The decreasing rate of increase

S: The Saturation Limit

$(t_n - t_1)$: The project lifetime

Based on the above relationships, the population growth curve for any area is shown in Figure 5, which illustrates the graphical representation of the three stages of population growth. The curve is increasing at an increasingly rapid rate at the beginning stage, and then it starts growing at a constant rate in the second stage. After a while, the area becomes close to the saturation limit, where the rate of increase is decreasing until it is close to the saturation limit.

Table 4 shows another method to anticipate the forecasted population, which is by mapping the targeted city based on the anticipated land use. The Egyptian code introduces a method to be applied to the different land uses in order to obtain a range of the expected population per hectare of land. This method does not account for the gradual growth of the population as the equations above; however, it provides a quick and relatively accurate method of calculating the design capacity.

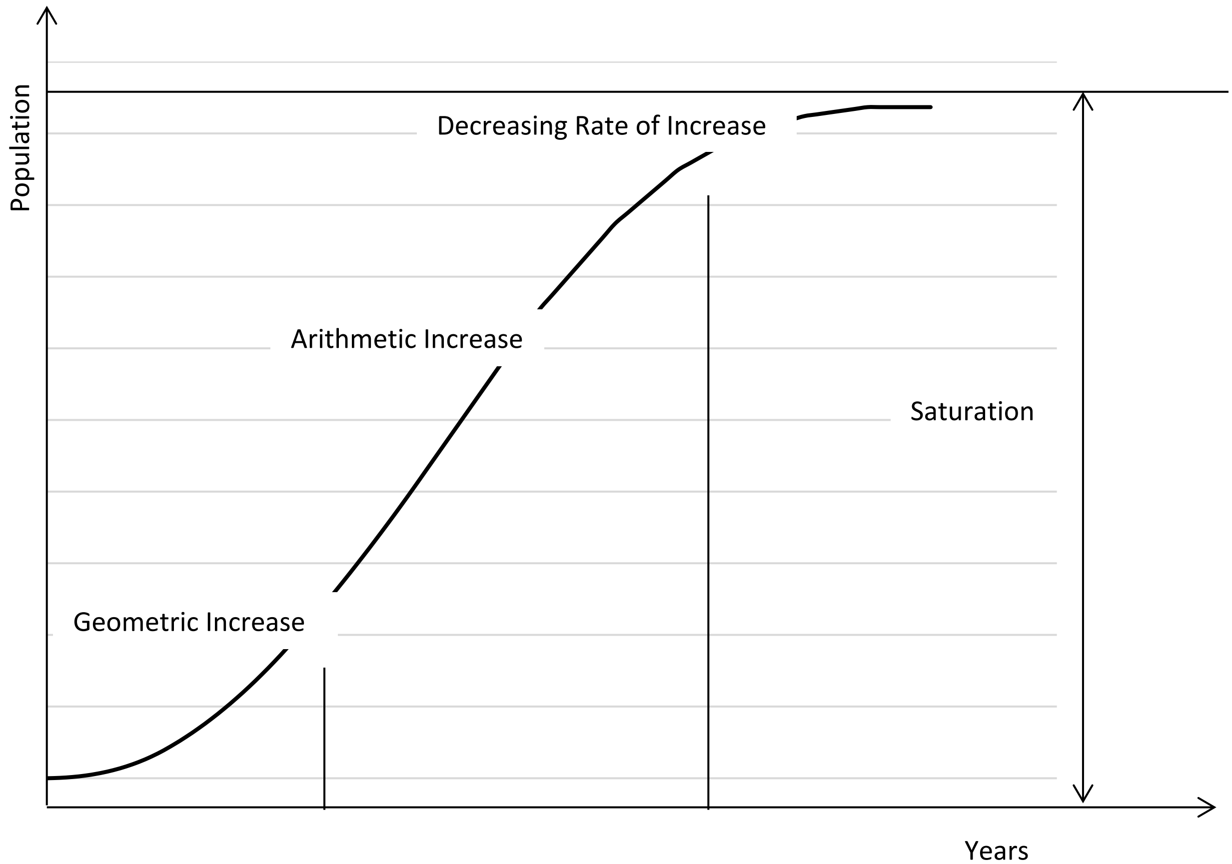


Figure 5: The Population Growth Curve, (The Egyptian Code (Ministerial Decree no. 52), 1998)

The code introduces another two methods, which are the "Graphical Extension Method" and the "Graphical Comparison Method". The "Graphical Extension Method" is simply applied by drawing the above population growth curve for the current population and extending it in order to anticipate the future population. On the other hand, the "Graphical Comparison Method" is by drawing the population growth curve for a city similar to the city of study, and by comparing both curves, the future population can be inferred to the city of study.

Table 4: Population vs Land Use, (The Egyptian Code (Ministerial Decree no. 52), 1998)

Land Use	Population (capita per hectare)
First Class Villas	20 -50
Second Class Villas	50 - 100
Low populated residential buildings	100 - 250
Medium populated residential buildings	250 - 700
High populated residential buildings	700 - 1200 or more
Commercial Areas	50 - 75
Industrial Areas	20 - 30

2 . 4 . 2 . 3 Project Phasing

As explained above, it takes a considerable amount of time for a population of a city to reach saturation. Hence, it is not very efficient to construct a whole network and plants to serve the saturation capacity at the early stages of population growth. It is very important to anticipate the population in order to be able to design the different phases of the project to fit the population demand at a certain time.

The Egyptian code divides the design stages into two stages. The first stage is from 15 to 30 years, which gives a total design stage of 30 to 50 years, depending on the population growth rate.

2 . 4 . 2 . 4 Project Capacity

In order to be able to calculate the design capacity, the code gives methods to anticipates the discharge. Those methods are based on many factors. The first factor is land use; a residential area differs from an industrial area in terms of the discharged material nature. Moreover, the discharge amount varies based on the climate. Table 5 shows the average discharges anticipated in both summer and winter.

Table 5: Seasonal Average Discharges (Q), (The Egyptian Code (Ministerial Decree no. 52), 1998)

Season	Factor of the Average Q
Summer	1.2 - 1.3
Winter	0.7 - 0.8

2 . 4 . 2 . 5 Treatment Plant Discharge Calculation

The final stage of water and wastewater network design is to determine the discharge or the capacity of the plant. Based on the above information, the designer can evaluate the forecasted population of the area of concern and, based on which will determine the capacity and discharges anticipated for the design area. At this stage, detailed specifications for each stage of the treatment and the network are provided.

2 . 5 Egyptian Sanitation Infrastructure Projects

According to the Egypt Network for Integrated Development (ENID), the formalization of the sanitation services in Egypt is traced to the second half of the nineteenth century where a group of European investors has established a company that serves the water sector in

Cairo and Alexandria. On the Eastern governorates of Port Said, Suez, and Ismailia, the Suez Canal Company was the primary source of water service. The first Egyptian institution to be established to serve the water sector was the General Organization for Potable Water, which has been operating since 1956 in Delta and the canal governorates. It was not until the 1980s that the Egyptian government established a single institution to serve as the sole provider for water and wastewater services in Egypt which is the National Organization for Potable Water and Sanitary Drainage (NOPWASD), (Egypt Network for Integrated Development, 2015).

According to the USAID website, USAID started working in Egypt in the 1970s. The poor water and wastewater qualities have become very severe that it affected health life in many rural areas. Diseases spread widely, such as Diarrhea and rheumatism due to contact with polluted untreated wastewater. From the 1970s till now, USAID has provided funds for Egypt with a value of almost 3.5 billion dollars. Statistics show a drop of 80 percent in the rate of diseases caused by polluted water and infant mortality rates, (Water and Sanitation, 2020).

In 2004, the Holding Company for Water and Wastewater (HCWW) was established, where the objective of the new company is to address the poor quality of the service provided. In order to do that, a number of local companies are to be developed in each of the governorates to work on the water and wastewater services closely. The Egyptian Water Regulatory Agency was also established by the government during the same year in order to have an independent organization that regulates the performance of the company, (Egypt Network for Integrated Development, 2015).

In 2004, the percent coverage of urban areas of sanitary services was 56% compares to only 4% in rural areas. Even with tremendous efforts and funds in 2010, the percent coverage in rural areas has only increased to be 13%, which represents the coverage of 603 villages out of a total of 4670 villages. The 2010 government plan was to be able to raise the percent coverage of urban areas to 100% and rural areas to 20% by the year 2012, which has not been met at the time. Moreover, statistics show a great unbalance between the water services and the sanitation services, which is represented by the huge difference between the water and wastewater network lengths of 146,000 km and 39,000 km only, respectively. Table 6 shows the daily quantities of water and wastewater consumed in a million meters cubed per day. This huge difference is reflected in the below statistics, which shows the daily consumption of water is about 24 million m3/day, where only 16 million m3/day is collected at wastewater networks. Unfortunately, only 10 million m3/day are treated, (Egypt Network for Integrated Development, 2015).

Table 6: Daily Quantities of Water and Wastewater

Type	Quantity (million m^3/day)
Water Produced	24
Wastewater Collected	16
Wastewater Treated	10

A study conducted by the Ministry of Housing, Utilities & Urban Communities has shown that the amount of investment needed to be able to reach 100% coverage of sanitation services in rural areas of Egypt is 300 billion Egyptian Pounds based on 2021 money value without accounting for the inflation, (MHUUC, 2021)

There are many sanitation projects that are taking place in the region. Some of them are funded domestically or by international funding agencies. Table 7 shows the current USAID activities in Egypt with regard to the sanitation sector. Three major initiatives are currently in progress, which are the North Sinai Initiative and Egypt Utilities Management.

Table 7: Current USAID Activities in Egypt, (Water and Sanitation, 2020)

Project	Duration	Fund Amount	Agreement
North Sinai Initiative: - Drilling of deep wells - Construction of desalination Plants - Potable Water Transmission and Distribution Lines - Water Reservoirs	October 2014 till September 2020	$50 million	Bilateral Agreement
Construction Monitoring - Technical and oversight support to USAID's staff in monitoring, implementing, and finalizing projects procured and managed by the Government of Egypt: Assiut, Beni Suef, Luxor, North Sinai, Sohag	July 2015 till September 2020	$1.5 million	Bilateral Agreement
Egypt Utilities Management: - Improving sanitation in rural areas such as Beni Suef, Assuit, Sohag, Luxor, and Aswan	October 2014 till June 2018	$30 million	Bilateral Agreement

The World Bank has funded and is currently funding many sanitation projects, as well. Table 8 shows all the sanitation projects funded by the World Bank in the past two decades, (Project and Programmes in Egypt, 2016).

Table 8: The World Bank Sanitation Projects in Egypt

Project Title	Project ID	Amount (M USD)	Status	Approval Date
AF to Sustainable Rural Sanitation Services Program	P166597	300	Active	21-Sep-18
Sustainable Rural Sanitation Services Program for Results	P154112	550	Active	28-Jul-15
Regional Coordination for Improved Water Resources Mgt. & Capacity	P130801	1.05	Active	17-Jul-12
EG-Enhanced Water Resources Management	P118090	6.68	Active	5-Jul-12
Integrated Sanitation& Sewerage Infrastructure Project – Phase 2	P120161	200	Active	30-Jun-11
Alexandria Coastal Zone Management Project	P095925	7.15	Active	29-Apr-10
EG - Sanitation	P119805	9.49	Closed	7-Dec-09
Integrated Sanitation& Sewerage Infrastructure Project – Phase 1	P094311	120	Closed	20-Mar-08
Egypt-Alexandria Development Project	P094229	100	Closed	18-Sep-07
West Delta Water Conservation and Irrigation Rehabilitation Project	P087970	145	Closed	21-Jun-07
Egypt-Integrated Irrigation Improvement and Management Project	P073977	120	Closed	3-May-05

The currently active projects are five projects. The first one is the Sustainable Rural Sanitation Services Program for Results, which was expected to finish by December 2023 with a total project cost of 550 million US dollars. The project targets 769 villages that suffer from discharging untreated wastewater in canals. The Project targets seven governorates: Beheira, Dakahliya, Sharkiya, Damietta, Giza, Menoufya, and Gharbiya. The total cost needed to address those governorate needs is 2.8 billion dollars, of which the World Bank is providing one billion dollars in phases. The first phase cost is 550 million dollars. The financing method used is Program for Results (P4R), which links the performance of the project to the fund installments, (Sustainable Rural Sanitation Services Program for Results, 2021).

The second project, which is the Regional Coordination for Improved Water Resources Management and Capacity, is an international program that serves as the first phase: Lebanon, Jordan, Morocco, and Tunisia, and as the second phase Egypt. The Egyptian grant amount is 1.05 million dollars. The grant shall be released based on a yearly amount of 0.2 million dollars for four years, 2013 till 2016, and 0.25 million dollars in the fifth year 2017, (Regional Coordination for Improved Water Resources Mgt. & Capacity, 2016).

Egypt Integrated Sanitation and Sewerage Infra 2 is another active sanitation project that is financed by the World Bank. The financing mechanism used is Specific Investment Loan (SIL), with a total of 200 million dollars. The project is divided into three objectives. The first one is to establish a wastewater infrastructure system in a number of villages in Menoufia and Sharkiya. The Second objective is to provide the same for Assiut and Sohag. The third objective is to support the HCWW and NOPWASD in the project management processes of the project, including the implementation phase, the monitoring phase and the evaluation and supervision phase, (G-Integrated Sanitation & Sew. Infra. 2, 2016).

2 . 6 Global Funding Methods

Developing countries are highly dependent on external funding methods in order to finance mega infrastructure projects, (Roy *et al*, 2010). Public funds rarely cover the large pool of crucial infrastructure projects as they are, in most cases, limited and insufficient, (Shane *et al*, 2009). Hence, a need for financial institutions that provide funds is required. The world bank group, regional development banks, export credit agencies, and other bilateral and multilateral institution are the different form of financial institutions which provides funding at lower interest rates than conventional commercial banks.

2 . 6 . 1 The World Bank Group

The world bank provides long-term loans and short-term loans; it also provides consultancy services to borrowing countries. The world bank group consists of five organizations: "the International Bank for Reconstruction and Development (IBRD), the International Development Association (IDA), the International Finance Corporation (IFC), the Multilateral Investment Guarantee Agency (MIGA) and the International Centre for Settlement of Investment Disputes (ICSID), (The World Bank, 2016). Table 9 summarizes one of the techniques used by the World Bank in selecting the different countries to receive their loans and the responsible organization to be dealt with, (Boas & McNeill, 2003). Only three of the above five institutions provide loans to developing countries which are: the IBRD, the IDA, and the IFC, (Nelson, 2015). The three institutions are interested in providing loans to mega infrastructure projects; moreover, the IFC is concerned with lending and providing equity investments in the private sector, which aims to construct infrastructure projects under project finance agreements such as the public-private partnerships agreements.

The International Bank for Reconstruction and Development (IBRD) is the leading institution in the world bank group. The institution consists of 189 members; each constitutes a different country. The board of the bank consists of 25 members, which is divided into five pre-selected members and 20 elected members. As provided above, the bank offers loans for middle-income and creditworthy countries. Since 1946, the IBRD provided loans of 500 billion dollars' worth of loans. The bank succeeded in maintaining a AAA credit rating since the late 1950s; it also generates enough revenues to cover its operational expenses and transfer annual funds to the International Development Association (IDA) for the sake of poorer countries, (The International Bank for Reconstruction and Development, 2016).

As seen in Table 9, the International Development Association (IDA) is providing funds for the poorest countries. According to the IDA website, IDA provides funds for 77 countries with a total worth of 19 billion dollars, according to the latest statistics of 2015. IDA presents long-term loans that reach 30 to 40 years with zero or very low-interest charges that cover only administrative costs of the agency, (The International Development Institution, 2016).

Table 9: World Bank Institutions Lending Mechanism

Borrower Country	**Per Capita Income**	**Lenders**
Middle-Income Countries	$1506-$5445	IBRD
Poor Countries (Credit-Worthy)	-	
Poorest Countries	Less than $885	IDA (Interest-Free Loans)

In 2012, The World Bank Group had three financing mechanisms along with some bank guarantees as shown in Figure 6. In 2013, the bank had a new policy with three financing instruments only that shall incorporate the guarantees which are the Investment Project Financing (IPF) the Program for Results (P4R) and the Development Policy Lending (DPL). The later was renamed to be the Development Policy Finance (DPF) which shall deal with policy based loans only. The IPF shall deal with Investment projects while the P4R shall be a combination of both options, (The World Bank Group, 2019).

Current policy architecture

	Instruments					
	Investment Project financing	**Program-for-results Financing**	**Development policy lending**	**Guarantees**		
Financing mechanism	loans, credits or grants	loans, credits or grants	loans, credits or grants	Partial risk guarantee (PRG)	Partial credit guarantee (PCG)	Policy-based guarantee (PBG)
What it supports	Investment projects	Investment and expenditure programs	Policy and institutional reforms	Investment projects	Investment projects	Policy and institutional reforms
Eligible countries	IBRD, IDA	IBRD, IDA	IBRD, IDA	IBRD, IDA	IBRD	IBRD

Proposed policy architecture

Instruments		
Investment Project Financing	**Program for Results Financing**	**Development Policy Financing**
Loans, credits, grants or guarantees	Loans, credits or grants	Policy-based loans, credits, grants or guarantees
Investment projects	Investment and expenditure programs	Policy and institutional reforms
IBRD, IDA	IBRD, IDA	IBRD, IDA

Figure 6: Funding Policies used by the World Bank Group, (The World Bank Group, 2019)

2 . 6 . 2 Regional Development Banks

Regional development banks, as its name denotes, are banks that finance projects that usually lie within their regions. The four major banks are The Inter-American Development Bank, the African Development Bank, the Asian Development Bank, and the European Bank for reconstruction and development. Table 10 shows the four development banks and the corresponding borrowers and the amount of loans for 2015.

Table 10: Regional Development Banks, (Nelson, 2015)

Regional Bank	Borrowers	2015 Commitment
The Inter-American Development Bank	Middle-income governments, some creditworthy low-income governments, and private sector firms in the region	12.65 Billion USD
The African Development Bank	Middle-income governments, some creditworthy low-income governments, and private sector firms in the region	4.64 Billion USD
The Asian Development Bank	Middle-income governments, some creditworthy low-income governments, and private sector firms in the region	10.23 Billion USD
The European Bank for Reconstruction and Development	Primarily private sector firms in developing countries in the region, also developing country governments in the region.	10.75 Billion USD

Figure 7 and Figure 8 show the distribution of funds per year from 2000 till 2015. The figures separate the concessional financial assistance from non-concessional financial aid. The concessional financial aid usually has more extended grace periods and may be given at lower interest rates than the ones provided by the market, unlike non-concessional loans, which are provided at the market interest rates, (Nelson, 2015).

2 . 6 . 3 Export Credit Agencies (ECA)

Export credit agencies (ECA) are another global funding organization that is poorly broadcasted compared to other bilateral and multilateral organizations such as the world bank and the development banks. According to Gianturco, ECAs cover 800 billion dollars

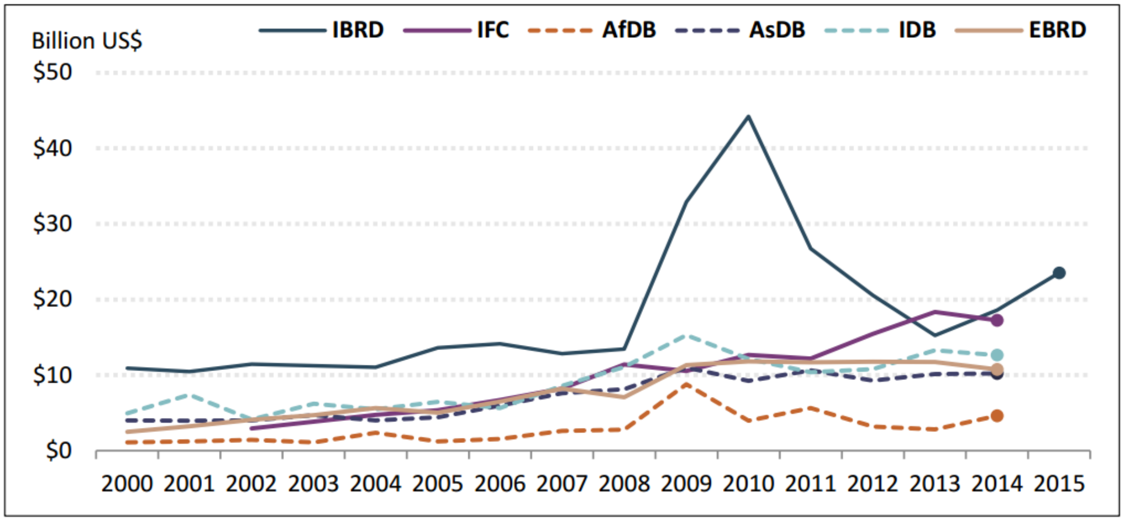


Figure 7: Non-Concessional Financial Aid, (Nelson, 2015)

of funding methods such as loans, guarantees, and insurances. This is much larger than all bilateral and multilateral institutions. The world bank group and the development banks

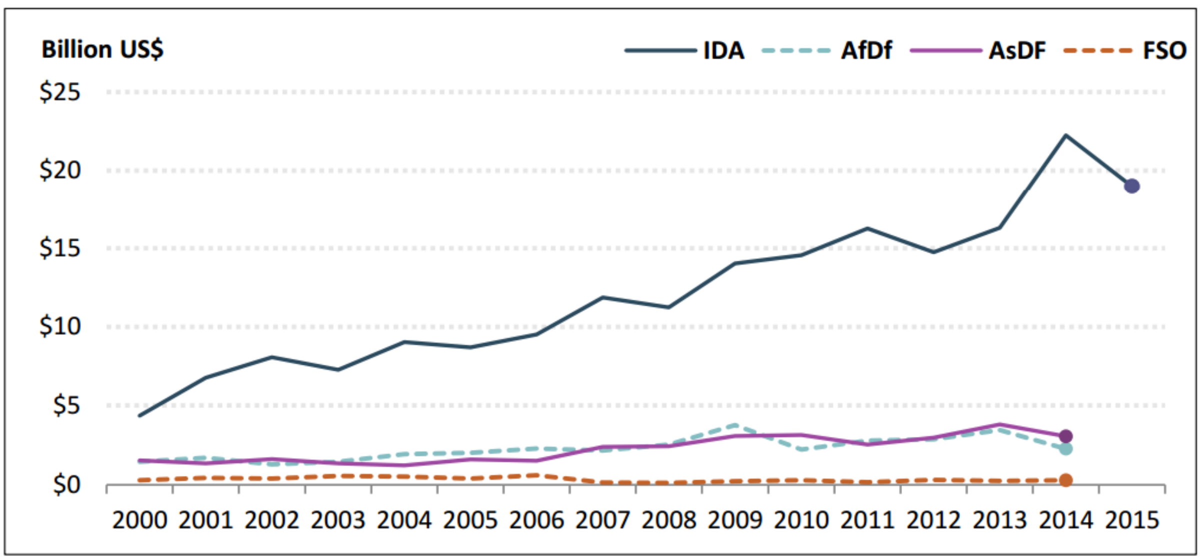


Figure 8: Concessional Financial Aid, (Nelson, 2015)

are traced to the 1940s, which is much recent than ECAs, which are traced back to 1906. There exist 200 agencies in the world located in 100 countries. Gianturco defines ECAs as: “a highly specialized bank, an insurance company, finance corporation, or dependency of the government, offering loans and/or guarantees, insurance, technical assistance etc., to support exporters, covering both commercial and political risks related to export sales, with the backing or approval of the national government, and dedicated to supporting the nation's exports," (Gianturco, 2001).

Most ECAs are of a governmental origin, yet at the end of the 20th century, more private ECAs have come into the picture. ECAs are found in both developed and developing countries, yet they are much needed in developing countries due to many reasons. One of which is the resistance of the local commercial banks to offer loans at reasonable low-interest rates and longer loan terms. Moreover, banks usually offer a smaller amount of credit due to their unawareness of international markets and the lack of reliable information. In Africa, the African Export-Import Bank (AFREXIM) is a regional export credit agency that is established in 1993 to support exports in the African region. The bank is developed by the African Development Bank (AFDB). This ECA aims to overcome the problems of the local commercial banks, (Gianturco, 2001).

The only limitation for using the ECA method of funding is that it requires a direct exporting relationship between the giving country and the developing country. In other words, mega projects require major exporting funds. Turbines, power stations, treatment stations, etc. require multimillion-dollar investment. ECAs typically finance those kinds of exports with terms that vary from 5 to 10 years and can be extended to more than 12 years in certain mega projects. Power, transport, and telecommunications are major mega projects that attract the attention of ECAs because they involve a massive amount of exports. One of the significant contract clauses, in this case, is to limit the exports of all the equipment and devices from the ECA country of origin.

The only drawback of the ECA method of funding is that it usually does not support the most deprived countries, unlike the International Development Association (IDA). One of the main acceptance criteria for ECA funding is the assurance of repayment. Hence, extensive studies are made to ensure that the project feasibility study is actually reflecting the expected revenues and expenses for the project.

There are two types of ECA loans. The first type is "direct lending," which is directly getting the loan from the export credit agency. The second type of ECA is "financial intermediary loans," which is getting the loan through an intermediate bank, which means that the ECA will lend a local commercial bank, and the bank will lend the beneficiary organization.

2 . 7 Results-Based Finance (RBF)

2 . 7 . 1 The Development of RBF Mechanism

"Results-Based-Finance" is a funding mechanism that has been used by many financial institutions, including the institutions mentioned above and many others as well. In 2012, a press release was issued by the World Bank Group Board of Executive to announce the beginning of using "Results-Based-Finance" funding mechanism, (The World Bank Group, 2012). The funding mechanisms are a reflection of the bank mission to eliminate poverty and boost prosperity.

According to Clist, the "Results-Based-Finance" mechanism has also been used by the Asian Development Bank (ADB), Norwegian Agency for Development Cooperation (NORAD), Department of Foreign Affairs, Trade and Development (DFATC) in Canada, Danish International Development Agency (DANIDA) in Denmark and KFW

Development Bank in Germany, (Clist, 2018). "Results-Based-Finance" mechanism has also been used in Ghana and Tanzania, (Janus, 2014).

2 . 7 . 2 RBF Aim and Achievements

The "Results-Based-Finance" mechanism aims to provide countries with the means to improve their managing techniques after the period of the lending institution's involvement ends. Instead of giving the loan amount to the borrowing country at the beginning of the project and collecting the interest after some time, in the "Results-Based-Finance" mechanism, the loan disbursements are not released unless the borrowing government achieves tangible results. The concept used is to ensure that the borrowing country is motivated to achieve the results of the project in an efficient matter. This approach increases the accountability of the sector to meet the needs of the service beneficiaries and address the system's weaknesses, (Oxman & Fretheim, 2009).

Late disbursements will result in increasing the funding gap in the project cashflow. In other words, the government shall need to secure more funds from its treasury and may also result in delaying the project due to the lack of finances, especially in developing countries where funds are not abundant. When mega public projects start to exceed the allocated budget, the decision shall be either to stop the projects or to minimize their scope of works. In the case of the "Results-Based-Finance" scenario, the descoping is not one of the acceptable alternatives, and projects shall be forced to stop instead. Hence, it is crucial to carefully plan the results in a manner to ensure that the project shall not run out of budget at any point in time.

The funding mechanism has proven its efficiency. According to the World Bank statistics, the mechanism has been used for 99 projects up until April 2019, with a total value of 40.3 Billion American Dollars, (The World Bank Group, 2019). In 2015, the bank published a report which includes the different operations executed using the "Results-Based-Finance" mechanism in order to assess its effectiveness, (The World Bank, 2015). Figure 9 reflects 18 approved projects during the year 2015. The figure shows the expected disbursed loan amount versus the actual disbursed amount. As shown from the figure, the two curves are very close to each other's, which reflects the effectiveness of the implementation of the "Results-Based-Finance" mechanism in the above projects. The borrowing countries have succeeded in achieving the required results within the timeframe stated in the agreement.

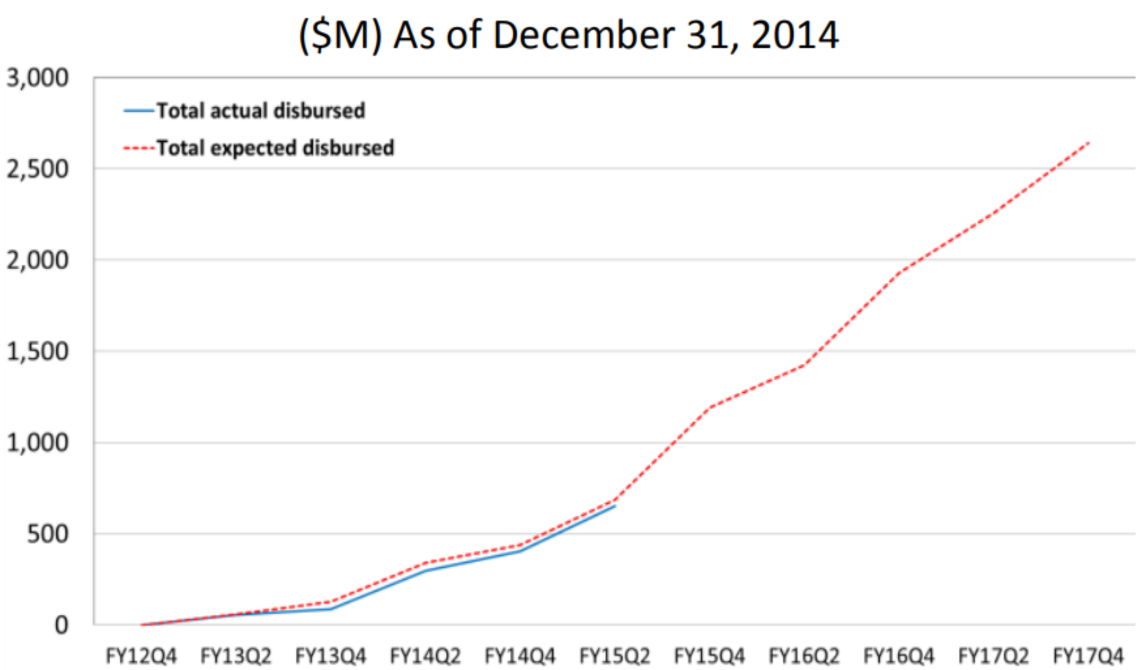


Figure 9: Actual vs Expected "Results-Based-Finance" Loan Disbursements, (The World Bank, 2015)

2 . 7 . 3 RBF Lessons Learned

Results-Based Finance has been used by many countries, as stated above, to fulfill different objectives. Linking disbursements to achieving results provides an incentive to the borrower to ensure the efficiency of the functions and processes within the targeted organization. This makes it useful to many fields that go beyond the construction field. Below is a survey of a number of projects that resolve to the RBF mechanism and proves its efficiency when it comes to boosting the performance of the borrower institution and enhancing the quality of the project outputs.

RBF mechanism has been used by both developed and developing countries. RBF has been used for projects in Australia, Canada, Denmark, Germany, Ireland, New Zealand, Scotland, and the United States, (Grittner, 2013). On the other hand, RBF has been more useful for developing countries, as shown below.

Mozambique is a developing country in Africa that suffered from civil war for many decades, which results in a deterioration in the health sector. Mortality rates have risen, and a need for intensive reform has grown. A result-based finance program has begun in 2013, which aims to enhance the processes within the Central Medical Store in Mozambique. Spisak *et al* have developed a review that studies the effectiveness of the RBF approach in the above program. Interviews were conducted with 33 officials from both the borrowing country and the lending institution. Data were collected and analyzed. The institution has shown continuous improvement against the performance indicators defined in the agreement. According to Spisak *et al*, RBF has proven to be effective in strengthening the supply chain and teamwork innovation, (Spisak, et al., 2016).

Beane *et al* have also discussed the effectiveness of RBF in the health sector of low- and middle-income countries. Beane *et al* outlined three main types of RBF mechanisms that have been used by the World Bank, which are: Performance-Based Financing (PBF), Performance-Based Contracting (PBC), and Conditional Cash Transfers (CCT). The difference between the above method is based on the entity collecting the disbursements. In the case of Performance-Based Financing, the entity is the service provider against the service provided. As for the Performance-Based Contracting, the payment is not fixed and subject to increase or decrease depending on the service provided. The last type is Conditional Cash Transfers, where the entity receiving the incentives (which can be financial or not) is the beneficiaries of the service, (Beane, Hobbs, & Thirumurthy, 2013).

RBF mechanism has also been used in India (rural road projects worth 1.5 billion USD), Pakistan (Punjab education sector project worth 350 million USD), and Ethiopia (health development goals worth 100 million USD). The above projects have proven their efficiency in meeting the required disbursement linked indicators and achieving the results on time, (Brien & Kanbur, 2013).

Another success story has been recorded in Zambia despite many obstacles, such as the high turnover rate of government officials and the split of ministries. Zambia has shown remarkable results when achieving the required results by the RBF programs, (Friedman *et al*, 2016). Soeters *et al* have also demonstrated examples of RBF projects in the Democratic Republic of Congo and presented other examples of successful projects in and Rwanda, (Soeters *et al*, 2011). Further papers have discussed successful RBF in Cambodia, (Ir, et al., 2015), Malawi, (Wilhelm *et al*, 2016), Benin, (Antony, Bertone, & Barthes, 2017), and Rwandan, (Klingebiel *et al*, 2019).

Unlike the health and education sectors, the RBF applications in the sanitation sector are relatively limited, (Tremolet, 2011). According to Tremolet, traditional financing instruments have been used in sanitation mega infrastructure projects, although they were not very efficient. The problem with conventional methods is the decision to allocate the funds to which project. In the case of RBF, the funds are assigned to the most needed project first to achieve the required results. Moreover, responsibilities, in the case of traditional loans, are not defined as they are defragmented among different key players, while in the case of RBF, incentives are aligned towards a bigger goal that is set from the early start. For instance, in sanitation projects, funds are usually allocated to treatment rather than providing remote areas with access to proper wastewater disposal systems, (Tremolet, 2011).

Due to its limited applications in the sanitation sector, RBF sanitation projects have suffered from budget overruns and other failure reasons. Jones *et al* surveyed a number of sanitation projects in order to identify the reasons beyond their failure and provide solutions to avoid them in the future. One of the projects used in the study was a rural sanitation nationwide project located in India. The results required 68% coverage in 2012, while the Indian government struggled to increase the coverage from 31% in 2001 to only 22% in 2011 (one year before the required result). Jones *et al* stated that the reason for failure included a rapid increase in population, which was estimated to be 8.3 million additional beneficiaries from 2001 to 2011. Other reasons were identified, such as: "low political priority, flawed monitoring, distorted accountability and career incentives, bureaucratic inertia and corruption," (Jones *et al*, 2013).

2 . 8 Mega Projects Packaging

Because of the complex nature of mega projects, the project managers usually decompose the project into packages in order to assign each package to a distinctive project team. There are different techniques used to decompose the scope of the project into smaller fragments, most of which are done manually by planning engineers with the assistance of the project manager. According to the Construction Owners Association of Alberta, in the absence of an appointed construction contractor, the packaging should be done by the construction management team of the project owner, (COAA, 2013). Pellegrino (2018) defines a work package as “an executable construction deliverable that defines in detail a specific scope of work in a particular construction work area,” (Pellegrino, 2018). From the above definition, it is noted that work packages are fragments of the scope of work that are independent of each other. In other words, work packages cannot overlap. On the other hand, according to Ibrahim *et al.*, packaging can be done by breaking down the scope of work into a hierarchy of work packages that are unique and measurable, (Ibrahim *et al*, 2009). Each of the packages shall be assigned to a different party to be able to monitor and control the deliverables required.

One of the essential facts in the packaging process is timing. Safa *et al.* (2017) state that the packaging process typically takes place in the pre-construction phase of the project. Hence, after the packages are awarded to potentially responsible parties, it is hard to assess the effectiveness of the packaging process. Safa *et al.* (2017) have developed a “comprehensive construction value packaging system (CVPS),” which ensures that the packaging process can be audited and assessed from the early beginning till the closing stage of the project, (Safa *et al*, 2017).

Gardner (2006) lists in his paper the different advantages of the work packaging process. One of the main advantages is being able to define the cost elements of the project. Breaking down the project into smaller fragments makes it easier to realize cost drivers and to be able to quantify them precisely. Moreover, the fragmentation process also enhances the planning and scheduling of the project by recognizing the sequence of specific activities required in each of the packages. Besides, being able to understand the different execution techniques proactively is one of the significant advantages of the packaging process, which by default, reduces the probability of changes in the scope later on in the project, (Gardner, 2006).

For mega sanitation projects, the decomposition criteria can vary and can be done on many levels. For example, one of the levels can be the facility type: the treatment plant, the pump station, or the network of pipes. Another level can be the treatment technology used. In general, not all wastewater needs to be treated before discharging it to a disposable location. In the treatment plant, there are multiple levels of treatment. Sewage can be pumped to lagoons, which is open land designed for the disposal of such waste. It can also be pressurized using a force main to a pump station along the way to reach another Force Main and another pump station, etc., in order to reach a specific treatment location. Sewage can be treated to many extents, one of which is to be "Grey Water," which is used in irrigation of fruitless trees and plants which is not exposed to human interaction. Some wastewater treatment plants can purify water to the extent that it becomes potable water. In some countries, they have networks for treated water to be used in the flushing system of toilets as well.

The wastewater treatment type can also be one of the packaging techniques as it consists of three main stages: primary treatment, secondary treatment, and tertiary treatment. Primary treatment can also be defined using physical operations such as screening or sedimentation. Other treatment technologies are chemical and biological operations, which constitute disinfection, dichlorination, and others. The technologies are summarized in Table 11.

Packaging can also be affected by the choice of a specific delivery method. In mega sanitation projects, the scope can be categorized into piping networks, pump stations, and wastewater treatment plants. Choosing whether to go with the traditional delivery method (design-bid-build) or any other delivery method such as the (bid- design-build) can affect the decision of selecting the content of one package. For example, a subsection of the scope that shall be executed with the design-build delivery method should not be grouped with another subsection that shall be using the traditional delivery method.

Table 11: Treatment Technologies

Physical Unit Operations	Chemical Unit Operations	Biological Unit Operations
Screening	Chemical Precipitation	Activated Sludge Process
Comminution	Adsorption	Aerated Lagoon
Flow Equalization	Disinfection	Trickling Filters
Sedimentation	Dichlorination	Rotating Biological Contactors
Floatation	Other Chemical Applications	Pond Stabilization
Granular-medium Filtration		Anaerobic Digestion
		Biological Nutrient Removal

According to Hosseini *et al.* (2016), the most commonly used delivery methods are the design-build method, the design-bid-build method, and the construction management method, (Hosseini, et al., 2016). Mahdi and Alreshaid (2005) have discussed the advantages and disadvantages of selecting one of the delivery methods over the other using an analytical hierarchy process. They stated that the selection of the method could be made through a number of criteria in order to reach the best outcome for both public and private owners. The ultimate goal is to achieve the best value for money, (Mahdi & Alreshaid, 2005).

The WBS is another method of packaging as it divides the scope of the project into smaller, manageable packages that can each be allocated to a different contractor, consultant, or design-build contractor. Hassanein and Moselhi (2004) have developed a model that produces the work breakdown structure of a project automatically. They defined a number of aspects that the model has respected while doing the packages allocation, such as the resource availability and the impact of weather on productivity, (Hassanein & Moselhi, 2004). They have also worked on developing a model to optimize both time and cost in linear projects such as many kilometers of piping networks in case of mega sanitation projects, (Moselhi & Hassanein, 2003).

Another aspect to consider while packaging is the location. Olivieri *et al.* (2018) has stated the advantages of using a "location-based management system: which includes better performance and optimized use of resources, (Olivieri, Seppanen, & Granja, 2018). Kenley and Seppanen (2009), the later was a co-author in the previous paper, have worked on a location-based mechanism for scheduling where they introduced the concept of "location production." They developed a location breakdown structure (LBS) in order to define the tasks performed at a distinct location. The mechanism is hierarchal in terms that the positions at the upper level of the breakdown structure contain the data of the subsidiary locations, (Kenley & Seppanen, 2009). This concept shall be of benefit in the model of this paper as the location of the data is a significant factor when trying to divide the scope into packages.

Moreover, to guarantee the success of prospective packages, the decision-makers need to carefully study the market and define the key players in each specialty (i.e., consultants, contractors, and design-build contractors). The packages need to be designed in a way to fit the capabilities of the market players. Alzahrani and Emsley (2013) state that construction projects' success is highly dependent on some aspects of the contractor performing the works. They conducted a questionnaire survey to come up with the most critical success factors that affect the performance of a contractor. Some of the factors that influenced the success of the project are "the adequacy of labor and plant resources" and "quality policy," which should be taken into consideration when preparing the size of the packages in case of this paper, (Alzahrani & Emsley, 2013).

2 . 9 Meta-Heuristic Optimization Algorithms

There exist many optimization techniques that have been used by researchers to reach the optimum solution for their problems. One of the famous techniques is the heuristic method for solving problems, which usually deals with one problem, while the meta-heuristic method provides much faster solutions than traditional methods, (Suh, Park, & Kim, 2011). The word "heuristic" means "to find" in the Greek language, (Pena , 2019). Meta-heuristic methods use computer software to provide a near-optimal solution when an exact solution can be found by traditional methods. The genetic algorithms (GA) method is one of the meta-heuristic optimization techniques that imitate the biological evolution process. The method depends on the "survival of the fittest" concept where new generations are formed from the parents (population), and the best individuals (solutions) survive (the fittest). Individuals can also be mutated or combined in order to obtain a better solution. The selection is made by having a fitness equation, which is the objective function. GA continues to evolve in several iterations wherein each iteration, a selection is made to choose the best/fittest individuals. The survival from one iteration shall be the population of the following one. The population is represented by chromosomes, and the solutions are called individuals or phenotypes. Terminologies such as "traits", "allele", "locus", and genome" are used to describe the features of the individuals, (Sivanandam & Deepa, 2008). In most cases, the coding of the problem is done using the binary system representation, yet some computer software has been developed where the encoding process is embedded and done automatically.

Genetics Algorithms methods have been used in the construction field in many applications. Planning is a very important division in construction management, where lanners usually depend on their expertise when developing schedules of works. Faghihi *et al* have used the GA technique to determine the optimum construction sequence of a building. They used the building information model approach to develop a 3D model for the different elements in a building; then, the concept of the genetic algorithm was used in order to determine the sequence of construction. The constraints provided were to make the building structurally stable at all times. They tested the validity of the model over 21 different buildings. The model was able to develop the optimum schedule for each of the cases provided, (Faghihi, Reinschmidt, & Kang, 2014).

Fang and Ng have also used genetic algorithms in producing a model that optimizes the precast concrete logistics. The model simulates the relationship among the supplier, the warehouse, and the construction site. The model shall provide a schedule of deliveries and flow of materials among the three stops, which minimize any errors that may occur due to subjective judgments. The model works by defining the optimum delivery time that will lead to the lowest cost, (Fang & Ng, 2019). The same technique used by Fang and NG was applied by Sonmez and Bettemir and GA was able to reach a near-optimal combination between time and cost of a project, (Sonmez & Bettemir, 2012).

The time-cost tradeoff has been one of the famous applications of genetic algorithms technique, (Agdas *et al*, 2018). The trad-off here is between the duration of the project and the indirect costs, which are proportionate to the project duration. In order to minimize cost, activities durations need to be reduced, which is done through increasing crew sizes and resources in general. The increase in resources shall add to the cost of the project, which is a vicious circle of trying to reduce costs to end up with additional costs. The genetic algorithm method is used in order to reach the optimal combination between activities duration and project cost. Ammar has enhanced the above technique by adding the effect of the time value of money by considering the discounted cashflows instead, (Ammar, 2011). On the other hand, Aladini *et al* have also considered the time value for money in the time-cost trade-off problem. They have made a comparison between the original cashflow of the project and the discounted one. They found that the discounted cashflow has given more optimum results than the original one, (Aladini, Afshar, & Kalhor, 2011).

The time-cost tradeoff was also the concern of Senouci and N. Eldin, where they used the genetic algorithms technique in resource scheduling in order to minimize both the duration and the cost of a project. Resource leveling can be very tricky when involving a large number of activities, yet the model presented in their paper was able to manage a wide range of activities and still yields the near-optimum solution as anticipated, (Senouci & N. Eldin, 2004).

Another commonly used application for GA methods is the site layout problem. Mawdesley *et al* have highlighted the importance of planning the temporary facilities in the site layout as it can have a great effect on the project cost. It also may lead to time delays as a result of poor site layout planning. Hence, Mawdesley *et al* have developed a model that determines the location of temporary facilities in the site layout with the aid of genetic algorithms concepts. The GA part shall simulate the cost of relocating the facilities along the project timeline and calculate the scenario with the lowest cost possible, (Mawdesley, Al-Jibouri, & Yang, 2002).

Deniz *et al* have also used GA in reducing the environmental impact of construction operations. The framework developed takes account of the time and the cost of construction in addition to the environmental impact as well. The model was developed with the aid of non-dominated sorting genetic algorithms II and MATLAB. The paper concluded that the framework was very useful in predicting the optimum construction operations in the planning phase, yet the authors showed a concern with regards to the amount of data the model can analyze. They recommended developing a tool that can process a more massive amount of data, (Deniz, Zhu, & Ceron, 2012). In 2016, another group of researchers had used the non-dominated sorting genetic algorithms as well, yet they have eliminated the limited number of activities constraints by developing an automated system. El-Abbasy *et al* have created a system that manages multiple projects simultaneously in order to get the optimum objective, which optimizes time, cost, and profit as well, (El-Abbasy, Elazouni, & Zayed, 2016).

Fathi et al used the same non-dominated sorting genetic algorithms technique. The researchers have developed a model that helps with the selection of the most optimum line of credit to finance a construction project. The objective of the model is to achieve the highest profitability while meeting the projects' financial requirements. They design a hypothetical case in order to test the model, which proved to be giving effective results and selecting the optimum solution, (Fathi & Afshar, 2010).

Financing mega projects or multiple relatively small projects is another application of the genetic algorithms method. The selection among which projects should be financed, especially when dealing with large companies that manage multiple projects at the same time, can be very complicated. Abdel-Khalek *et al* have worked on the net cashflow resulting from a combination of multiple projects in order to optimize the financing required. Delay in financing a certain project may lead to major problems and sometimes penalties, which is an additional burden to other projects in the company. The model of the study has been validated and proven to effectively optimize the financing schedule of the case study used, (Abdel-Khalek *et al*, 2011).

2 . 10 The Unified Modeling Language Applications in Construction Management

2 . 10 . 1 . 1 Unified Modeling Language (Object-Oriented)

UML stands for "Unified Modelling Language". As its name denotes, it is a unified language used among computer engineers when developing computer software programs. It is "unified," as many professionals understand it. The language itself was invented in the nineties, where computer engineers aimed to have a common language when developing complex software programs in order to be able to divide tasks while grasping the bigger picture. According to Miles and Hamilton, "a model is an abstraction of the real thing," which means that when modeling software, the designer tries to eliminate any irrelevant or unimportant details, (Miles & Hamilton, 2006). UML presents models in a way that states only important information and eliminates any confusing information. This is why it is relatively easy for non-professional programmers to understand the diagrams developed by the UML technique.

The object-oriented nature of the language means that the model is divided into several modules or objects. Each module contains attributes and methods. The attributes define the module, such as giving it a name or an identification number. The methods, also called the operations, define the function of the object or the module. Finally, the arrows among the modules define the communication and relationships between the different objects.

The UML Language consists of several diagrams such as the Use Case Diagram, Activity Diagram, Class Diagram, Object Diagram, Sequence Diagram, Communication Diagram, State Machine Diagram, and Deployment Diagram. The diagrams used in a certain model depend on the purpose of the model. Table 12 shows the different uses of a number of UML diagrams. The Use Case Diagram is usually used for modeling processes between different users. It models a set of scenarios done by an actor. The actor can be a human, a robot, or any other system. The cases or the scenarios are linked to the actors responsible for them. The whole model is acting with the boundaries of the system. The Activity Diagram is similar to the construction schedule as it maps the sequence of activities and the overlapping among them, while the Sequence Diagram is more concerned with the order of occurrence of the events. The Sequence Diagram describes the messages between the different actors through a timeline of events. Finally, the Class Diagram describes classes or objects and the interrelationships among them.

Table 12: UML Charts Types and Uses

Diagram Type	**Uses**
Use Case	Interaction between system and users. Mapping requirements of the system.
Activity	Sequence and overlapping of activities
Class	The relationship between classes, interfaces, and types
Sequence	A timeline showing the order of the objects interactions
Communication	How the different objects communicate with each other's
State Machine	Showing the lifetime of an object and events affecting it
Deployment	The methods of system deployment

2 . 10 . 1 . 2 UML and the Construction Management Field

Because of the practicality and simplicity of Unified Modelling Language, many researchers in the construction management field have used it to model their frameworks. A number of UML applications in the construction management field are shown in this section.

Aayici and Aouad have come up with a model that facilitates the communication process among the different parties during the different phases of a construction project. They used the Use Case Diagram in their paper to explain the scope of the model. The diagram included the different parties or "actors" involved in the model, such as the planner, the contractor, the architect and other stakeholders. The diagram was very useful to add to the comprehensibility of the model as it demonstrates the scenarios requiring communication between the different parties of the project, (Arayici & Aouad, 2005)

Perng and Chang have used the Use Case Diagram in order to model the government construction procurement process. The authors modeled the relationship between the users, the database, and the administrator for data mining purposes. The model aims to improve the effectiveness of the current practices and provides an opportunity to access the international community, (Perng & Chang, 2004).

The Use Case Diagram was also used by another construction management research that was written by Chong *et al*. Chong *et al* have developed an application for sharing the knowledge among the construction management professionals. They have proven that one of the key reasons that construction infrastructure projects are behind schedule and overbudget, is the lack of management. In order to guarantee proper management practices, a model was developed and demonstrated via the UML. The authors have also used the Class Diagram to store the knowledge base communication into a database, (Chong, Uden, & Naaranoja, 2007).

The Class Diagram was also used by Cheng and Wu. Their research aims to develop a new tool called "Evolutionary Support Vector Machine Inference Model (ESIM)," which is a merge between two existing tools, which are "fast messy Genetic Algorithms (fmGA)" and "Support Vector Machine (SVM)". UML was then used in order to create an "Evolutionary Support Vector Machine Inference System (ESIS)". The purpose of the Class Diagram in the research was to demonstrate the validation process of the new system by defining the classes along with their attributes and operations, (Cheng & Wu, 2009).

Harish and Skibniewski have developed a Sequence Diagram to model the change order process on a construction site. Harish and Skibniewski stated that the time and effort of the different parties in a construction project are wasted due to written communication chains on site. They suggested that communication is conducted via information technology. One of the processes modeled is the change order process. The Sequence Diagram is suitable for such cases as it gives a complete outline of the process and the sequence of approvals and events, (Hiremath & Skibniewski, 2004).

2 . 11 Contribution to the Body of Knowledge

The results-based finance (RBF) method is a relatively new funding method. From the literature, RBF is commonly used in the health and education sector more widely than in the sanitation sector. The applications found in the sanitation sector are somewhat limited. Very few papers were found that have to do with the implementation of the RBF method in the sanitation sector in developing countries. This research aims to encourage both lending institutions and borrowing governments to pursue the RBF approach by trying to simplify the packaging of the management process.

RBF method is different than the traditional lending methods where the lending institutions provide the money at the beginning of the project and collects principal and interest payments along the way. The cashflow in the case of RBF projects is very complicated as the borrowing country is financing the project at the beginning and then collecting disbursement. The lack of know-how or the limited experience of government officials makes decisions more subjective and may harm the benefits of the project stockholders.

Such complex projects require substantiation documents to be submitted to the lending institutions. One of the important requirements is the appropriation cashflow of the project, which ensures that the government shall be able to fulfill its financial obligations under the contract. The appropriation cashflow shall be constructed based upon the sequence of the projects in the schedule.

In order to develop the schedule, the packaging is usually done via experience and is subject to misjudgment. In the case of RBF projects, the case shall be dealing with multiple projects which require extra efforts in order to reach the near-optimal combination. The literature has proven the efficiency of the meta-heuristic optimization algorithms, especially the genetic algorithms tool. Hence, this research shall employ different meta-heuristic optimization techniques in order to come up with an automated packaging technique that shall ensure that the optimization of the project durations meets the required milestones and reduce the funding required from the borrowing government. In the literature, researchers have determined the packaging technique by considering factors that have to do with the project itself, such as the category of work and the location of the works. However, in this research, the packaging shall also consider the available market and the key companies to be considered for each of the packages. The research does not only aim to produce the packages but also suggests the key resources that shall be executing the package. Consequently, the funding gap between the disbursements received from the bank, and the cash-out financing of the different projects shall be minimized.

CHAPTER 3 : METHODOLOGY AND MODEL DEVELOPMENT

This thesis aims to assist with the process of packaging mega infrastructure sanitation projects. The objective of the model is to optimize the packaging process by minimizing the funds required by the borrowing government to execute the mega infrastructure project. In order to be able to do that, first, the life cycle cost of the project needs to be analyzed carefully to come up with the key cost components. Then, an appropriation cost estimate needs to be defined, which is the cost estimate that is prepared for the sake of defining the cash-in and cash-out at an early phase of the project development. The appropriation cost estimate is required by most of the funding agencies in order to define the worthiness of the project of loans or grants.

Moreover, the appropriation cost estimate allows the financial advisors to be able to identify the funding gaps in the project cashflow. Cashflows and schedules are two integral components of a project management plan. They profoundly affect each other's and needs to be connected. The model provides a default schedule that can be used in case of early feasibility studies and an option to add a detailed schedule as well. The model shall use the cost and time information and performs a trade-off between them in order to reach the optimum combination that shall automatically generate the packages of the project in a way that optimizes the project cashflow. The packages shall be assigned to different players in the field, such as contractors, consultants and design-build contractors. The main goal shall be to minimize the amount of funds required from the borrowing government.

3 . 1 Research Methodology

3 . 1 . 1 The RBF Results and Funds Flow

The results-based finance mechanism is an unusual mechanism that needs to be fully defined in the model to be able to track the results, to record them, and to claim for the corresponding disbursements or funds. The results-funds cycle in the project is a repetitive evaluation process along the project life cycle. Results are assessed and verified for the funds to be transferred to the borrowing government.

Figure 10 shows an example of the results and funds flow among the parties of the project. A case study of a mega sanitation project that is located in Egypt shall be used to verify the constructed model. The Government of Egypt (GoE), represented by the Ministry of Finance (MoF), shall be the borrowing country. It has signed a results-based finance loan agreement with the World Bank, which is the international funding agency. The project is executed via several contractors and consultants who are hired through the water and wastewater authorities. In Egypt, the Holding Company for Water and Wastewater (HCWW) is responsible for the guidance and regulation of the Water Sanitation Companies (WSCs).

The agreement has required a formation of a Project Management Unit (PMU), which shall be established by the Ministry of Housing, Utilities, and Urban Communities (MHUUC). The PMU shall be responsible for the execution of the sanitation program. Moreover, PMU shall be engaged along with the Egyptian Water Regulatory Agency (EWRA) in the reporting system, as shall be explained later. It shall prepare an action plan with the aid of the WSCs located in the different areas of the project. It shall also supervise and follow-up on the contractors' and consultants' procurement processes.

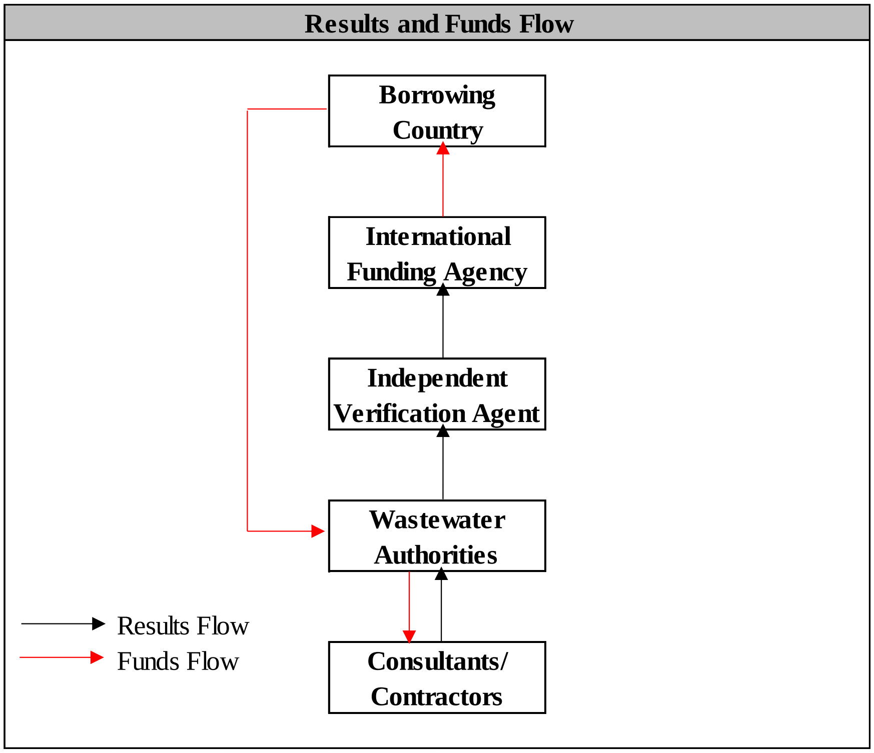


Figure 10: An Example of Results and Funds Flow in RBF Projects

The Independent Verification Agent (IVA) is an independent party that is engaged by the Ministry of Housing, Utilities and Urban Communities (MHUUC) in order to verify the results achieved. The Water Sanitation Companies (WSCs) shall help the IVA to prepare and provide verification reports to certify the achievement of the Disbursement Linked Indicators (DLIs). DLIs are a way to measure and quantify the results required from the borrowing country. The IVA hiring process is shown in Figure 11.

Figure 10 shows the flow of information about the achieved results from the contractors/ consultants to the HCWW and the WSCs. They provide the PMU with information to prepare reports to the IVA and EWRA in order to certify the achievement of a certain DLI in the results. The certification report shall be sent to the lending institution, which shall result in releasing the corresponding loan disbursement to the approved DLI. The funds are given back in a reversed order through the Ministry of Finance (MoF), which is the financial representative of the borrowing government.

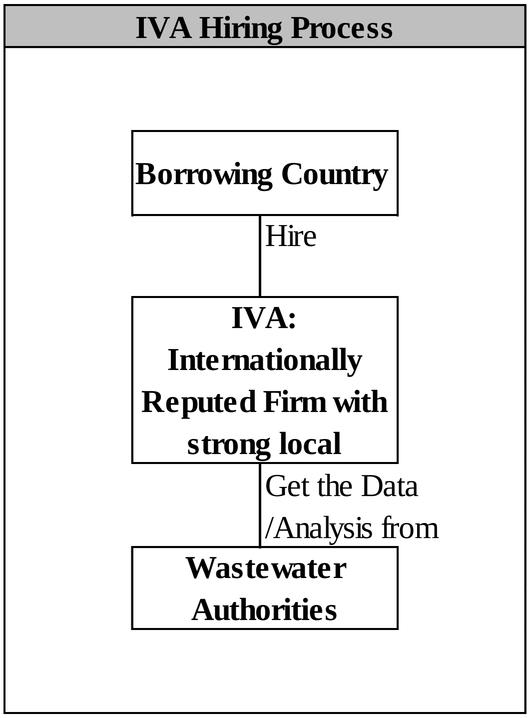


Figure 11: IVA Hiring Process

3 . 1 . 2 The RBF Verification Protocol

The results-based finance mechanism is all about the verification protocol of the results achieved. Without a properly followed protocol, the whole mechanism is jeopardized. Figure 12 details the verification protocol used in the projects opting for the RBF mechanism.

As shown in the figure, the water authorities represented in the case study by the Water Sanitation Companies (WSCs), and the wastewater authorities represented by the Holding Company for Water and Wastewater (HCWW), the Implementation Support Consultants (ISCs), and the regulatory institutions represented by the Egyptian Water Regulatory

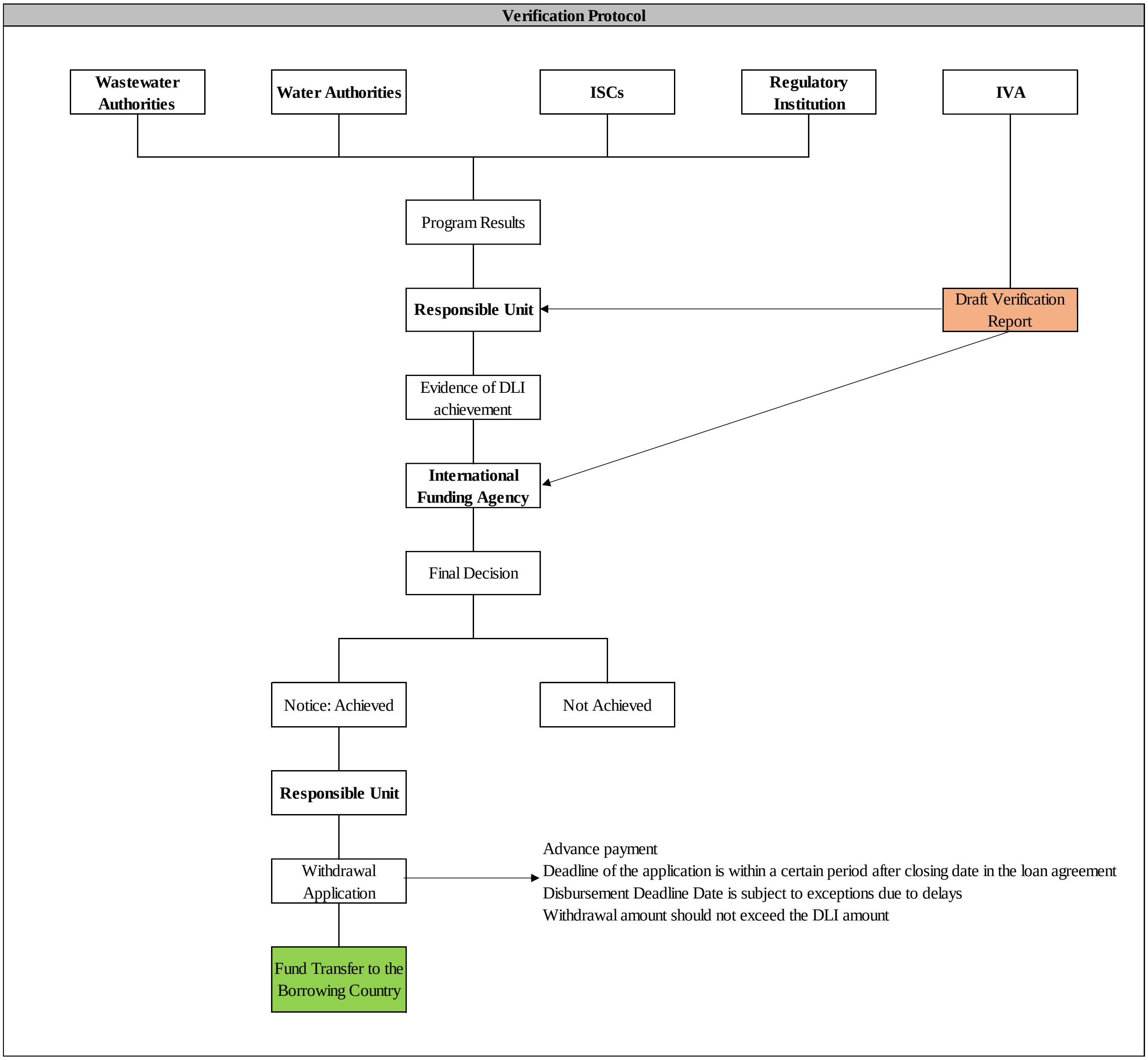


Figure 12: Verification Protocol

Agency (EWRA) work together to report the program results achieved to the responsible unit represented in the Project Management Unit (PMU). The PMU, along with the international funding agency (the World Bank), receives a Verification Report from the Independent Verification Agent (IVA) that confirms the above results and provides evidence of achievement. The international funding agency then gives the final decision on whether the results are achieved or not. If the results are not achieved, the cycle repeats until the results are achieved. In case the agency confirms that the results are actually achieved, a notice shall be sent to the responsible unit in order to prepare the Withdrawal Application.

The Withdrawal Application is a payment application to request the amount of the DLI corresponding to the results verified by the IVA report. The amount of the Withdrawal Application should not exceed the amount specified for the DLI, but it may request an advance payment to be released prior to the DLI achievement. The percentage of the advance payment is specified in the conditions of the contract. Once the DLI is achieved, the corresponding advance payment is recovered from the withdrawal application. The borrowing country may request another advance payment for the following DLI, given that at any point in time, the total amount of advance payment (not recovered) shall not exceed the sum specified in the conditions of the contract. In case the DLI is not achieved by the time stated in the contract, the advance payment shall be refunded to the bank immediately unless an acceptable justification is delivered to the bank. In the case study, a grace period of six months after the closing date is granted to submit the last Withdrawal Application.

The Funds Transfer process is shown in Figure 13. After the verification protocol is executed, and the Withdrawal Application is submitted, the international funding agency shall transfer the funds to the financial representative of the borrowing government. In the case of the given example, the funds are transferred to the Central Bank of Egypt. The Ministry of Finance (MoF) shall transfer the money to the MHUUC which, with the PMU authorization, shall be transferred to the different implementation parties. The funds related

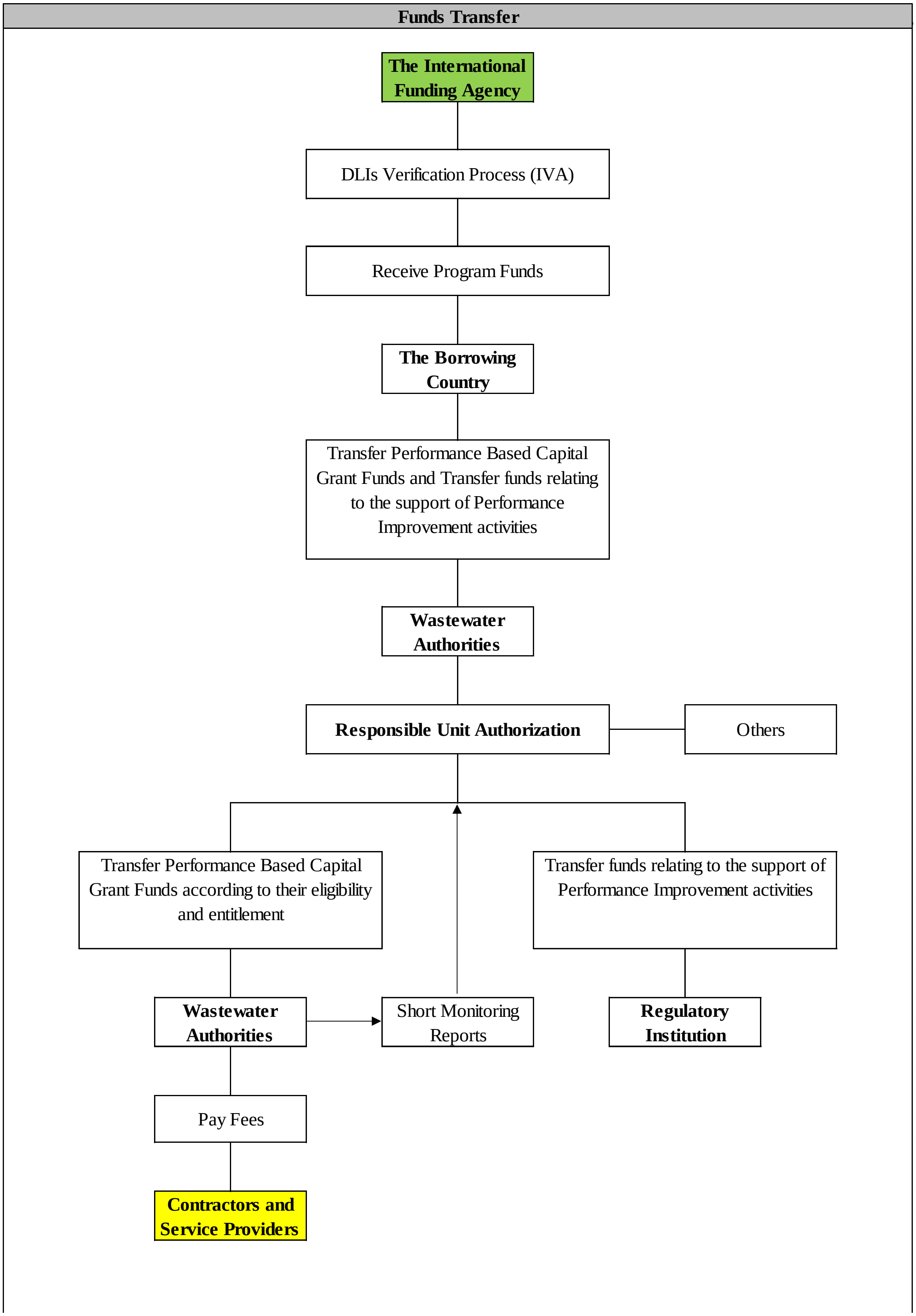


Figure 13: Funds Transfer

shall be transferred to the HCWW.

On the other hand, the funds relating to the execution of the networks, pump station, and treatment plants shall be transferred to the Water Sanitation Companies (WSCs). The form of the funds transferred in the second case shall be treated as performance-based grant funds, as it shall not be paid back again to the MHUUC. The grants are paid against regular short monitoring reports that show the performance of the WSCs. Finally. The WSCs shall pay the executing companies of contractors and consultants.

3 . 1 . 3 The RBF Monitoring and Evaluation Process

The effectiveness of the monitoring and evaluation process in any project is the key reason behind the success of the project. In results-based financed projects, the monitoring and evaluation process is even more crucial as it is the only method to assess the achievement of the results required. Hence, when drafting the contract documents, the reporting system of the monitoring and evaluation process needs to be clearly defined and detailed. Each report should have a creator and a destination. It should also have a clear description of the contents and the expected outputs. Moreover, the time intervals of the submissions should be explicitly mentioned in the contract documents.

In a results-based financed project, many institutions are usually involved in the monitoring and evaluation protocol. The borrowing government alone may have a number of representatives that cover the social, financial, environmental, economic, political, and technical aspects. Hence, the reporting system can have many levels and layers that include a number of parties. Figure 14 shows an example of the monitoring and evaluation levels. The first set of reports are developed by the ISCs on a daily basis to report the different

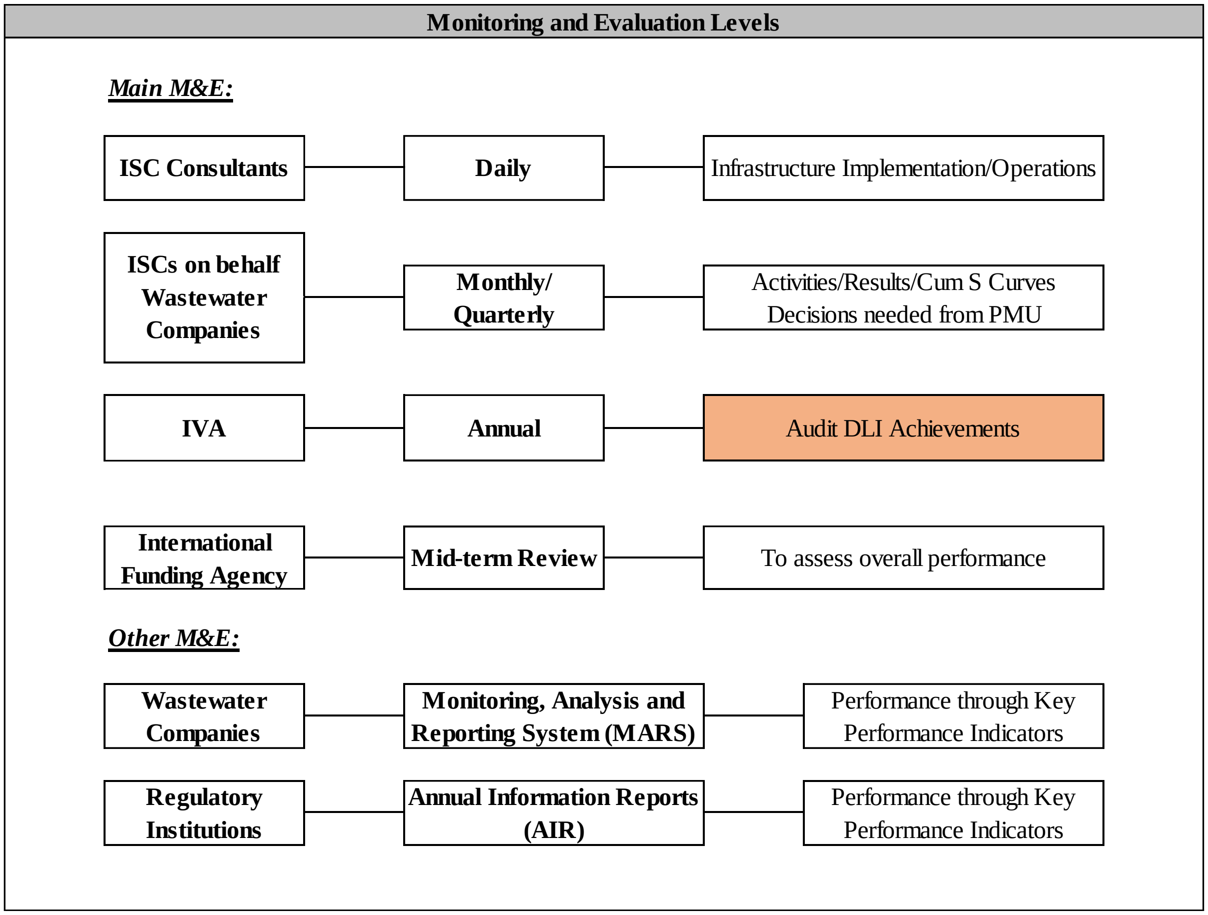


Figure 14: Monitoring and Evaluation Levels

infrastructure implementation operations. The ISCs draft similar monthly and quarterly reports on behalf of the wastewater companies that include the activities performed results achieved, information about the costs incurred, and any approvals or decisions required from the responsible unit. Another report is annually required from the IVA to report the status of each of the disbursements linked indicators. Finally, the international funding agency is required to prepare a report in the middle of the execution period to assess the overall performance of the implementing wastewater companies.

The wastewater companies perform another level of reports to receive performance-based grants. The Monitoring Analysis and Reporting System (MARS) contains key performance indicators (KPIs) to measure the performance of the implementing agencies. A similar set of reports called the Annual Information Reports (AIR) are submitted by the regulatory institutions to measure the performance of the implementing institutions as well.

Figure 15 shows the different reports required by the wastewater companies. At the beginning of the project, the wastewater companies are required to submit an action plan showing their ability to complete the required DLIs on time. A program operation manual shall be developed to follow-up on the different protocols and processes in the project. Wastewater companies are also required to submit on an annual basis: an annual capital

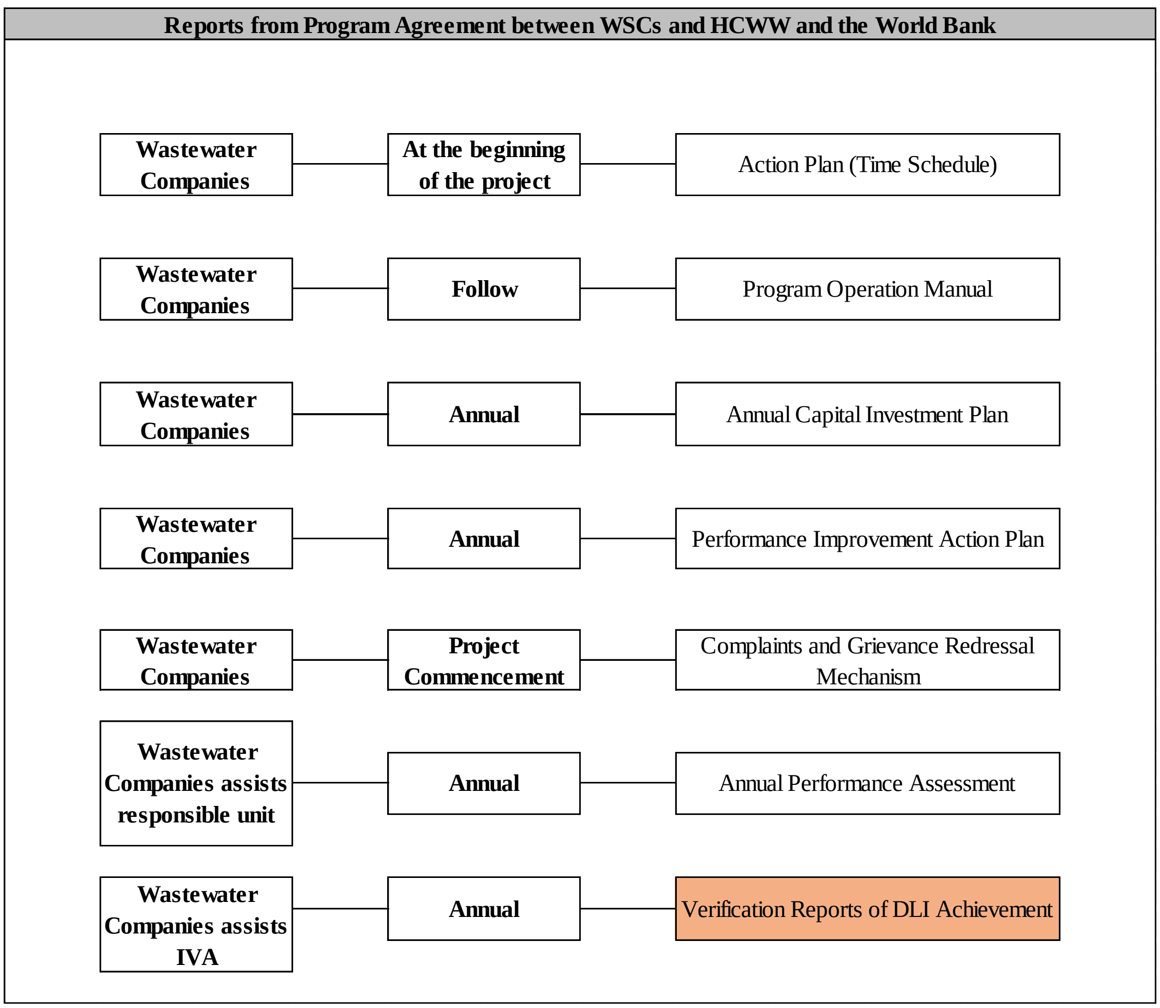


Figure 15: Reports from Program Agreement

investment plan and a performance improvement action plan. Moreover, they shall assist the responsible unit and the IVA in preparing an annual performance assessment and the verification report of DLIs Achievement, respectively.

3 . 2 Model Development

3 . 2 . 1 Costing and Scheduling of RBF Projects

The model suggested in this dissertation aims to optimize the cashflow of the RBF project by minimizing the required funds from the borrowing country. In order to draw the cashflow diagram of any project, the project schedule should be prepared and cost loaded in order to define the cash-in collected and the cash-out required at any point in time.

The first step is to define the parameters and components affecting the costs. Data are collected to aid in understanding all the variables affecting the cost. A database of a number of wastewater projects in Egypt is compiled in order to define the main cost categories, cost components, assumptions, and adjustments required.

Documents are collected, which include (if possible): project scope, tender documents, contract documents, proposals, operational documents, implementation reports, and appraisal documents. The purpose of collecting those documents is to understand the project decision making steps entirely, to define the required data by each of the funding agencies and to list the available funding types available (i.e., grants, loans, etc.).

The above documents are to be studied in order to define independent variables shown in the below table:

Table 13: Dependent and Independent Variables

Dependent Variables	**Independent Variable**
Construction Cost (CC)	Project Land Area (A)
Operation and Maintenance Costs (OMC)	Treatment Plant Capacity (P)
	Level of Treatment (V)
	Piping Network Length (L)
	Number of Household Connection (H)
	Number of Manholes (M)
	Project Type (T)
	Project Delivery Method (DM)
	Project Contract Type (CT)
	Bidding Strategy (BS)
	Geographical Location (G)
	Commencement Year (D)
	Funding Strategy (F)

The land area is directly proportionated with the land cost. In general, the land cost can be one of the highest cost components, especially in large cities. Hence, the geographical location is also essential, as finding land in largely populated cities in Egypt can constitute a problem for decision-makers. Even in rural areas, the land can be of great importance to local farmers and should be identified carefully. The treatment capacity and type are also important as larger WWTPs require more space than small ones. They also require more advanced technologies, which can profoundly affect the cost of the plant. Treatment types can be divided into primary, secondary and tertiary. Primary treatment can also be defined using physical operations such as screening or sedimentation. Other treatment technologies are chemical and biological operations, which constitute disinfection, dichlorination and others. The most famous technology is the activated sludge process, which is used in many Egyptian treatment plants.

The above variables are to be used in order to forecast the life cycle cost of the project. The main components of the life cycle cost for a wastewater treatment plant are investment cost, operation cost, cost of finance, sale price, taxes, indirect cost, and miscellaneous items. The investment cost is mainly the land acquisition and the construction cost. The operation costs are divided into fixed cost, maintenance cost and variable cost. Examples of the variable cost are the cost of electricity, the cost of chemicals, and the sludge treatment cost. The cost of finance is divided into interest charges, fees of financial institutions and salaries of related personnel. The sale price is the revenue of the service provider.

On the other hand, a set of assumptions and adjustments are usually defined when trying to analyze the above cost categories. Assumptions may include the equity to debt ratio targeted, which can be calculated based on the finds available for the project and the allocated budget within the government treasury. Another assumption to be made is the minimum attractive rate of return acceptable for the project "MARR" for both the government and the investors. Other contractual aspects need to be defined, such as payment terms, retention, margins, project extensions, variation orders, payment delays, cost of capital and other unknown factors at that stage. Moreover, the lifecycle cost of a project is usually demonstrated using many presentation modes. For example, the operation costs are typically presented in terms of their annual worth (AW). Hence, adjustments also need to be made for inflation, discount rates, foreign exchange rates and the like.

The life cycle cost of the project is translated into an “appropriation cost estimate,” which is one of the main requirements of most of the funding agencies. The appropriation cost estimate aims to provide as accurate as possible a forecast cost estimation in the form of a cashflow analysis for the duration of the mega project. This appropriation cost estimate shall be a combination of smaller cashflows for each part of the project (i.e., the treatment plant, the network, household connections, etc.).

Project cashflows are made for each project in a customized way. The circumstances and factors affecting each project can be classified into general factors and factors specified to each project. The financing terms vary for each project. Loans are directly associated with each project and may have different agreement terms, so assumptions need to be made. Due to all of the above, the level of accuracy of the appropriation cost estimate is jeopardized. At this stage, the cost estimator looks at things globally since this estimate is usually done at an early stage of the project planning. The estimate should be made to determine the value of the project at the time of execution, not at the time of the estimate.

The sole aim of the appropriation cost estimate is to draw the cash-in and cash-out curves to define the funding gaps, which are the areas with negative net cashflow. The first step in defining the funding gap is through plotting the cash-in and cash-out of the project. As mentioned before, since mega wastewater projects usually constitute a number of sub-projects such as the treatment plant and the piping network, the cashflow shall be a combination of smaller cashflows. The process can be illustrated using Figure 16. The cash-in includes the initial equity and the progress payments while the cash out includes the different cost components including the subcontractors (S/C) and the indirect costs (IC).

As shown in Figure 16, the difference between the cash-in and the cash-out of the project is the funding required. The cashflow shall define precisely the required amounts and durations of the negative cashflows.

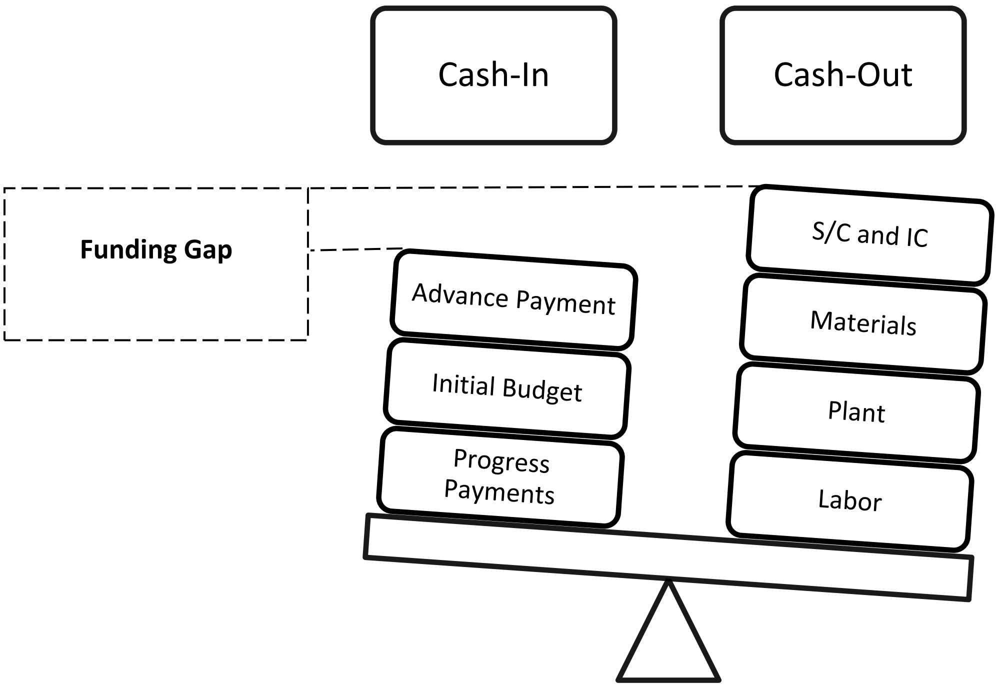


Figure 16: Funding Gap

3 . 2 . 2 The Packaging Timing

As stated in the literature, the packaging process occurs during the pre-construction phase of the project. Since "Results-Based-Finance" is an exceptional tool, the timing of the packaging process can be tricky. Figure 17 shows an example of the typical sequence of a "Results-Based-Finance" project. As shown in the figure, the first official step is signing the Loan Agreement between the lending institution and the borrowing country. The Program Agreement is what defines the implementing entities within the country institutions that will be responsible for the execution of the program. The Responsible Unit is formulated to be responsible for the implementation of the project. An independent

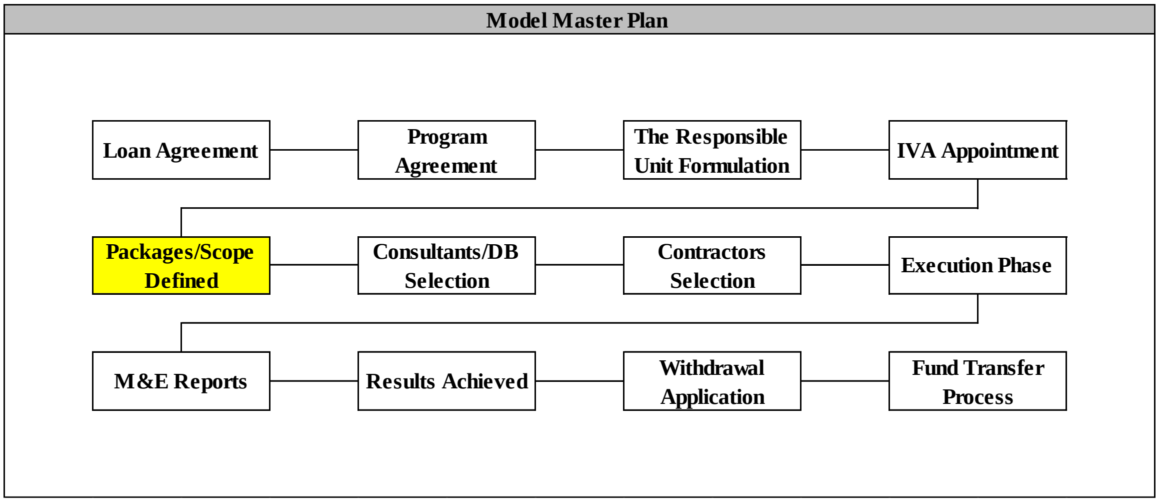


Figure 17: RBF Master Plan

verification agent (IVA) is then appointed to verify the achievement of the required results for the loan to be disbursed accordingly to the borrowing country, (Leoning & Tineo, 2012). At this stage, the packaging process starts in order to be able to assign the different packages of the scope to the party responsible for it. Depends on the nature of the package, it can be assigned to a design consultant, a contractor, or a design-build contractor, who is usually the case for wastewater treatment plant. During the execution phase, monitoring and evaluation reports are developed by the different entities in the project, while the IVA confirms the achievement of the results required. The borrowing country initiates the withdrawal application process where the lending institution approves the IVA recommendation and releases the loan disbursements through a fund transfer protocol that is agreed upon beforehand.

3 . 2 . 3 The Model Planning

The model, in general, consists of four phases, Figure 18. The Agreement Phase, where all contractual parties are defines. Major inputs are extracted from both the Loan Agreement and the Program Agreement. The Procurement phase is where the packages are formulated

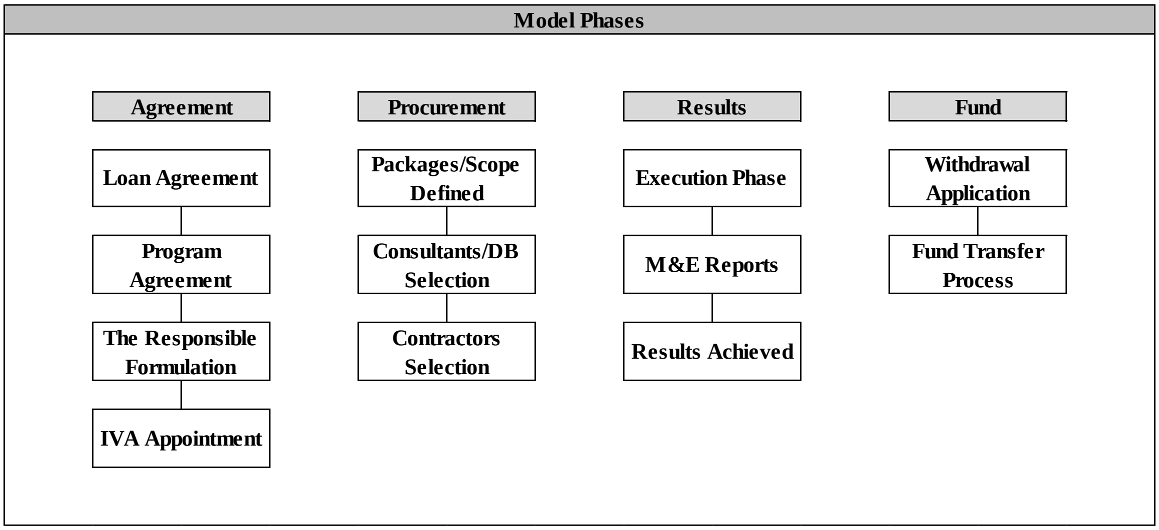


Figure 18: Model Phases

and assigned to the competent executing companies: contractors, consultants and design-build contractors. The packaging process is similar to the Knapsack Problem. Each of the executing companies shall have a maximum allowable project size depends on the cost and time limitations. The packages shall be selected in a way to optimize the timing of execution and the funds required from the borrowing country at any point in time.

After defining the timing of the packaging process, the methodology of decomposition needs to be determined. The most crucial step is to identify the model parameters and components. The first step in any research is to collect data that aids in understanding all the variables, which leads to the required results. A database of the different decomposition criteria is compiled in order to define the main constraints, assumptions and adjustments required.

In general, decomposition can be done in terms of many factors such as the facility itself, whether it is the wastewater treatment plant, the pump station, or the piping network itself. It can also be decomposed in terms of the physical location of the facility, such as the cluster, the village or the zone. In addition, the funding mechanism used is one of the important factors, such as the traditional method "design-bid-build" or the "design-build" method. The system used, such as the technology used for the treatment, can also affect the packaging decomposition criteria. The rationale behind the package standardization module is shown in Figure 19.

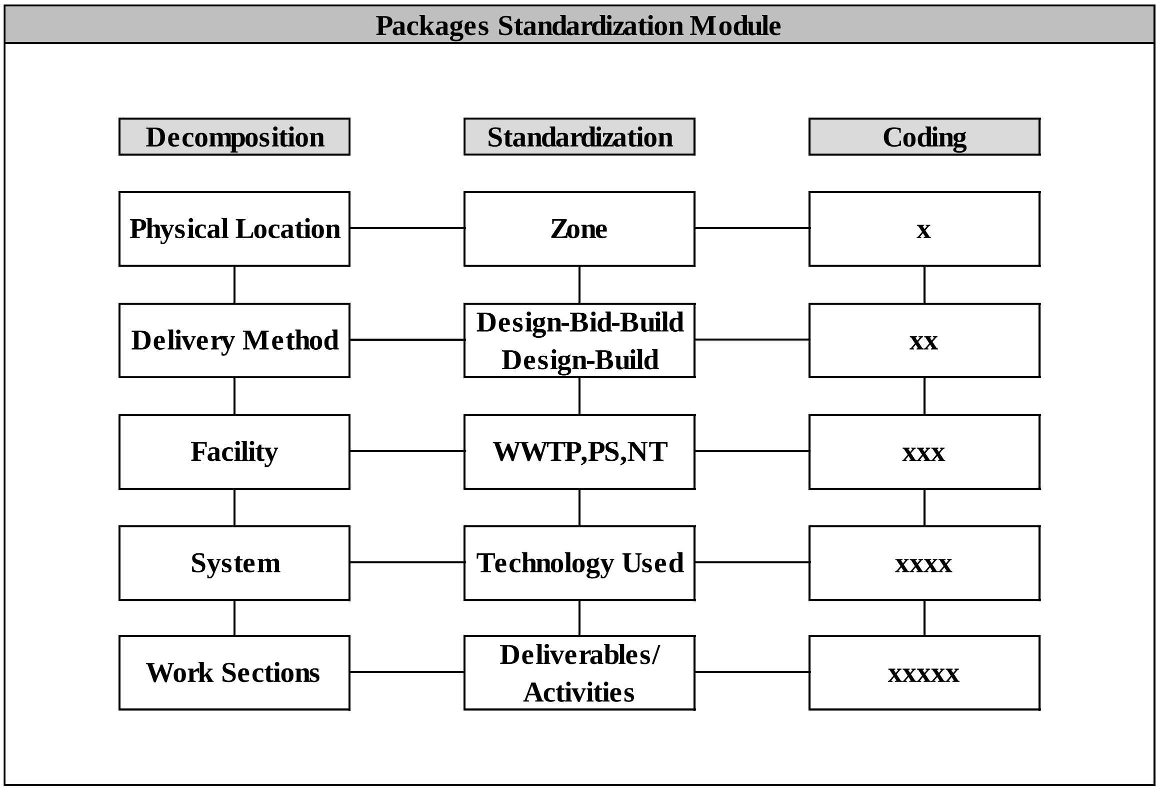


Figure 19: Packages Standardization Module

Figure 20 shows the flowchart of the suggested model. The flowchart demonstrates the packages assignment module and the rationale behind the decomposition process, and when to stop decomposing the scope much further. The decision of whether to decompose the package much further or to stop decomposing shall be determined by the question of whether the optimum packaging scenario has been reached. The model shall suggest an initial packaging scenario. The model shall proceed with the scheduling module to determine the timing of the results achieved in order to incorporate it in the fund flow module, where the timing of the different loan disbursements is calculated.

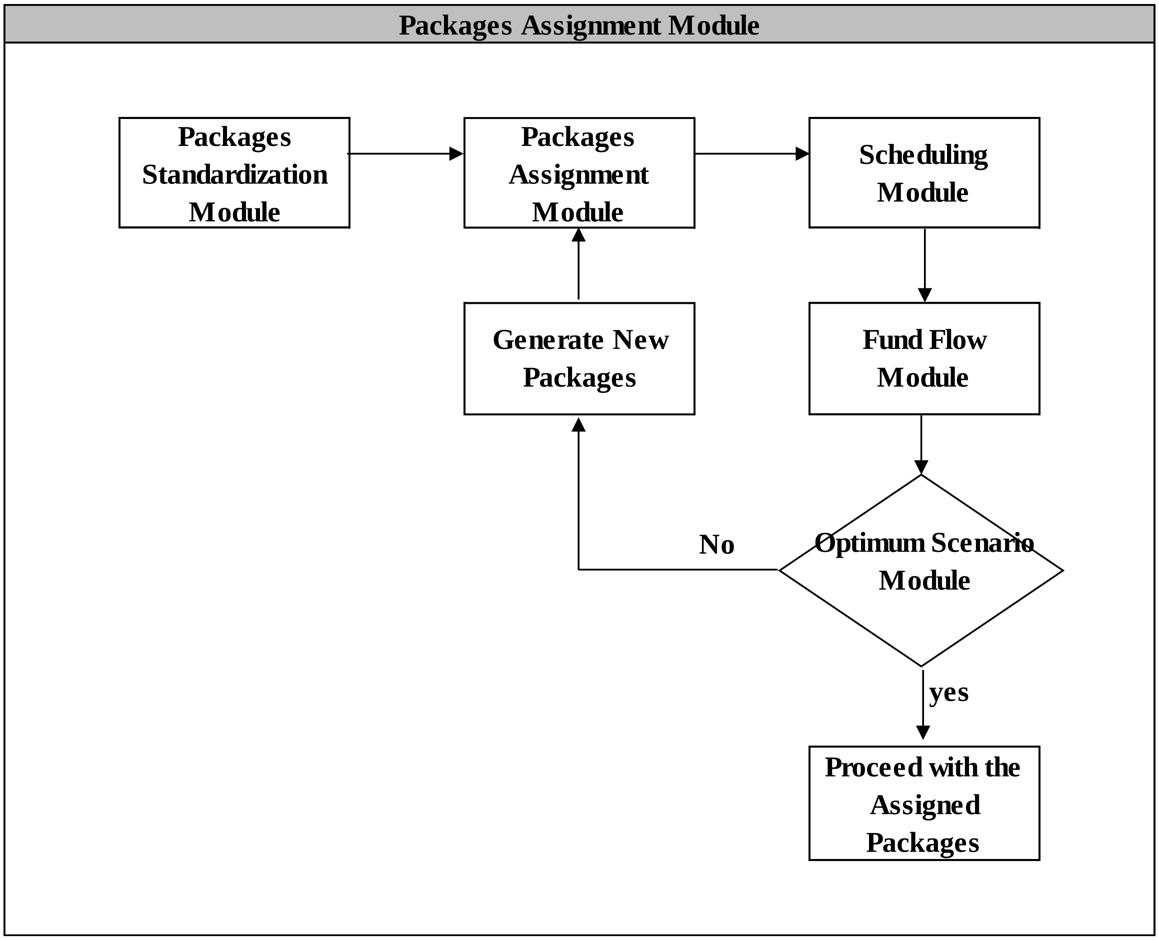


Figure 20: The Model Flowchart

Several iterations shall be performed in order to ensure that the optimum scenario has been reached. The definition of the optimum scenario is the scenario, which minimizes the funding gap. In other words, the borrowing county has to finance the project stages in order to achieve the required results and receives the loan disbursements. The faster the disbursements are received; the fewer funds are required to be secured by the government.

3 . 2 . 4 The UML Charts

As shown in the section 2.10, the Unified Modelling Language (UML) is proven to be suitable for many applications in the construction management field. It is an object-oriented language that enables the model to focus on the logic beyond the modeling technique. One of UML's most significant advantages is the ability to visualize the flow of informatics within the model. The objects within the model have a number of attributes and methods which define the object purpose.

Moreover, the objects have stored values and operations that occur within the object itself or by communicating with another object. The lines and arrows between the different objects represent the relationships between the different objects. Those relationships can be in a number of formats such as inclusion, extension, inheritance, generalization, etc. In this model, three types of UML diagrams were used, which are the Use Case Diagram, the Sequence Diagram and the Class Diagram to model the different processes in the model.

The constructed model developed in this research aims to automate the packaging process in a typical sanitation mega project, which is funded using the "Results-Based-Finance" mechanism. The objective is to minimize the funding gap. This means achieving the results early on in the project in order to receive the loan disbursements as soon as possible. This will reduce the amount of fund that needs to be secured by borrowing countries to finance the project.

In order to validate the suggested framework, a case study of a mega sanitation project located in Egypt is selected to implement the constructed model. The lender institution is the International Bank for Reconstruction and Development. The Egyptian Government has been trying to perform several reforms in the sanitation sector. Despite the several projects completed, the progress has been hindered by slow implementation and inflated construction costs and poor quality, (The World Bank, 2015). The Egyptian Government has signed an agreement with the World Bank in order to be able to finance the required objectives. One of the main advantages of the "Results-Based-Finance" is to motivate the government to enhance the old systems in order to achieve the required results within the time frame and the quality agreed in order to receive the loan disbursements.

The first phase of the "Results-Based-Finance" mechanism is the formalization of the project agreements. Figure 21 depicts the agreements within the mega project. The Use Case Diagram shown has a number of actors that has a corresponding actor in the case study used: The international funding agency (The World Bank), the borrowing country (the Government of Egypt), the regulatory authorities represented by the Ministry of Housing and the Utilities and Urban Communities (MHUUC), The program Implementing Entities which are the Water Sanitation Companies (WSCs) and the Holding Company for Water and Wastewater (HCWW). Typically, there are two agreements (use cases). The first one is the Loan Agreement, which is between the international funding agency and the borrowing country. The relationship between the borrowing country and the regulatory authorities is inheritance; as its name denotes, it is a relationship between a child, and a parent as the regulatory authorities are derived from the borrowing country. The same applies to the relationship between the water and wastewater companies and the Program Implementing Entities in the Program Agreement Use Case. The main Use Cases have subcases that shall deploy the following diagrams to proceed with the model.

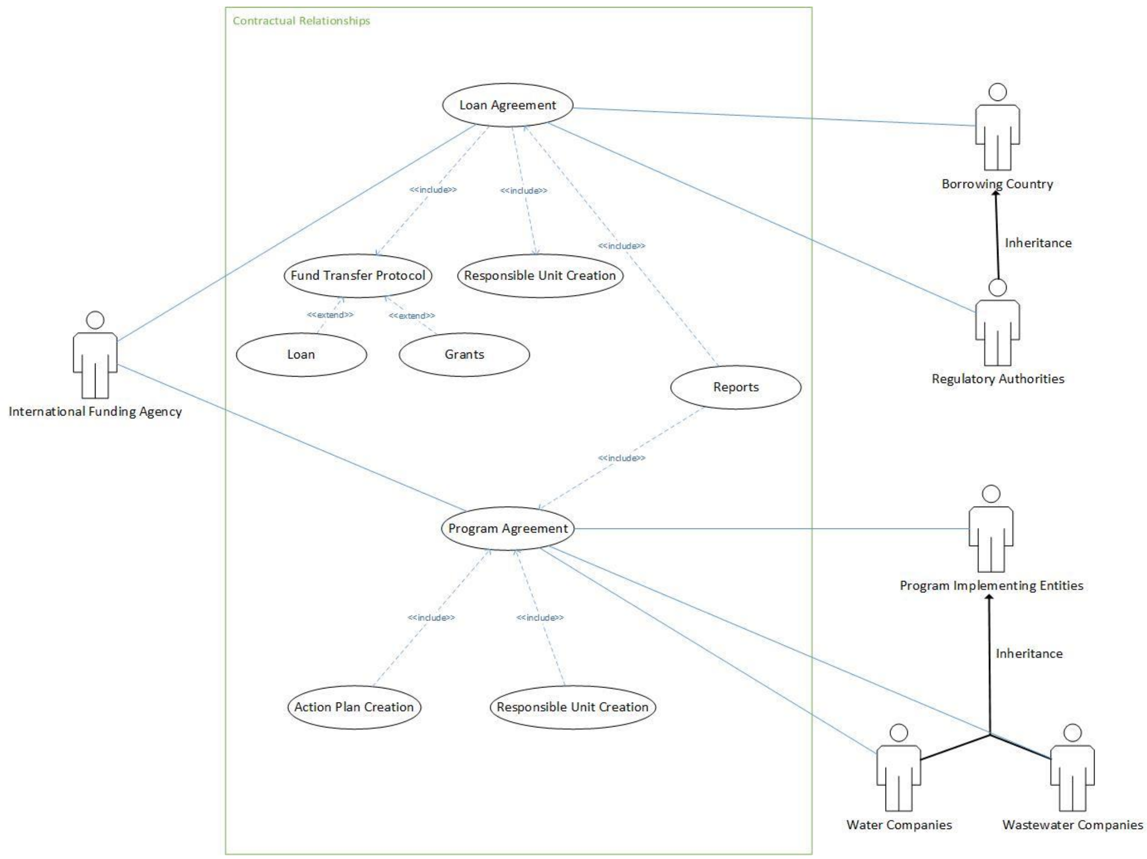


Figure 21: Use Case Diagram for the Project Agreements

The following step is to start the packaging process. The algorithm shown in Figure 22 illustrates the automated process of the package formulation. The model shall have nine classes: the user interface class, the user class, the scope class, the scope details class, the coding class, the optimization class, the work packages class, the decoding class, and the permissions class. Each one of the above classes has attributes and methods illustrated in the diagram; the user class shall be the class that represents the data entry of the users of the software. The inputs shall be through another class, which is the user interface class. This class shall have a number of screens that shall be used for the data entry and the display of the different outputs.

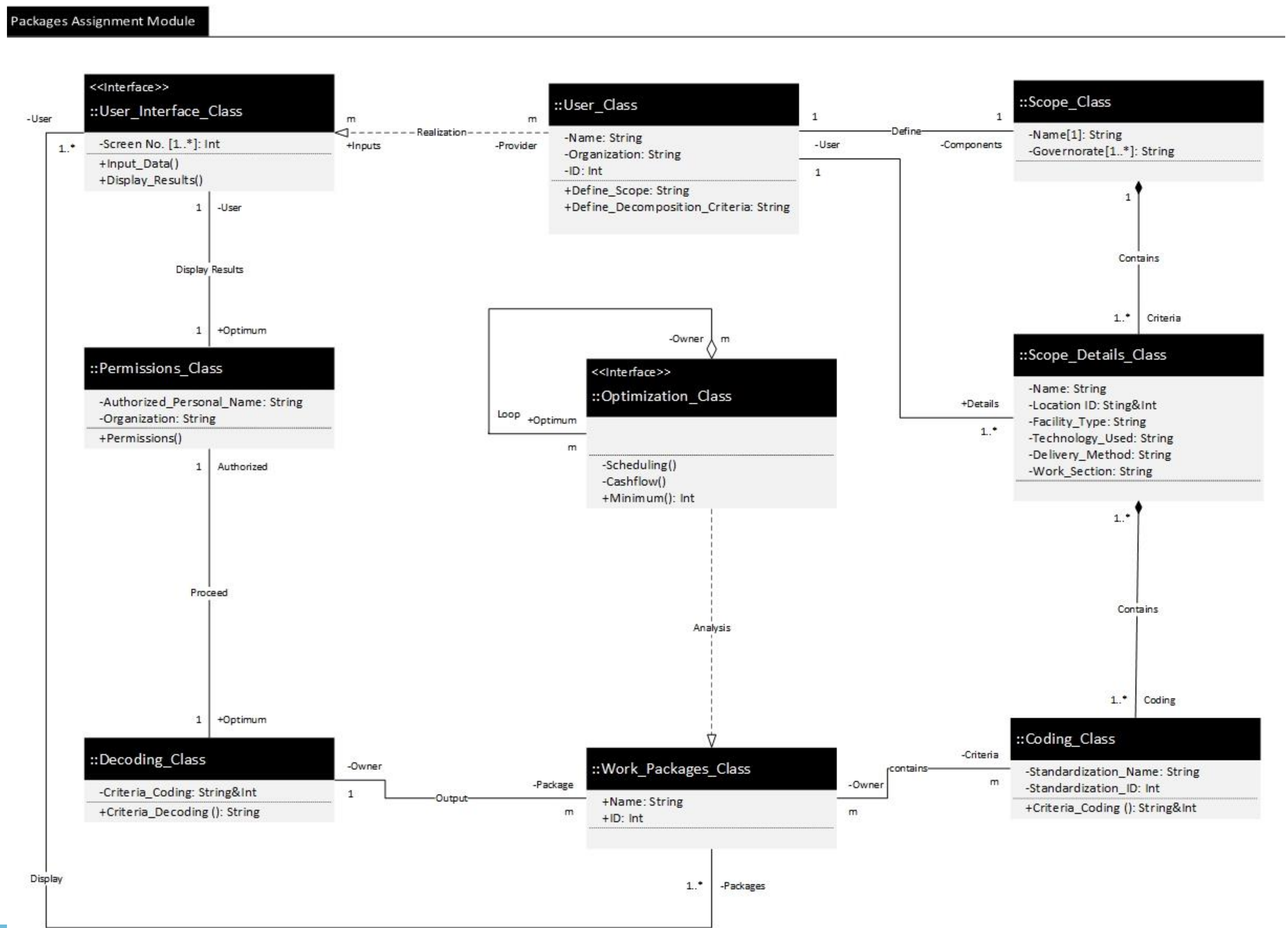


Figure 22: Class Diagram for the Automated Packaging Process

The original scope of the project shall be realized through the scope class, while the decomposition criteria shall be seized through the scope details class. At this stage, the different decomposition criteria shall be coded via the coding class in order to be able to standardize the optimization process. After reaching the optimum work packages, decoding shall be performed via the decoding class, and after getting the required permissions, the results shall be displayed via the user interface class.

The optimization class shall be responsible for assessing the optimum combination of work packages. This class shall deploy another type of diagrams, which shall be responsible for the results verification process. In order to ensure that the combination of the package is the optimum combination, the project shall simulate the different phases of the RBF projects in order to assess the funding gap required.

A loop shall be generated to deploy the Sequence Diagram in Figure 23 in order to select the optimum combination that shall minimize the funding gap. Figure 23 is similar to bar charts that construction engineers use to illustrate the sequence of activities within a certain project. The diagram simulates the communication process between the different parties in the project. Messages flow between the sender and the receiver, some of which require a response while the others are asynchronous messages which do not expect a response.

The Sequence Diagram includes new actors such as the Egyptian Water Regulatory Agency (EWRA), which is in the given case study shall be responsible for providing the IVA with data required in the verification process. Another new actor is the Implementation Support Consultant (ISC), which shall provide the PMU with data with regards to the verification process.

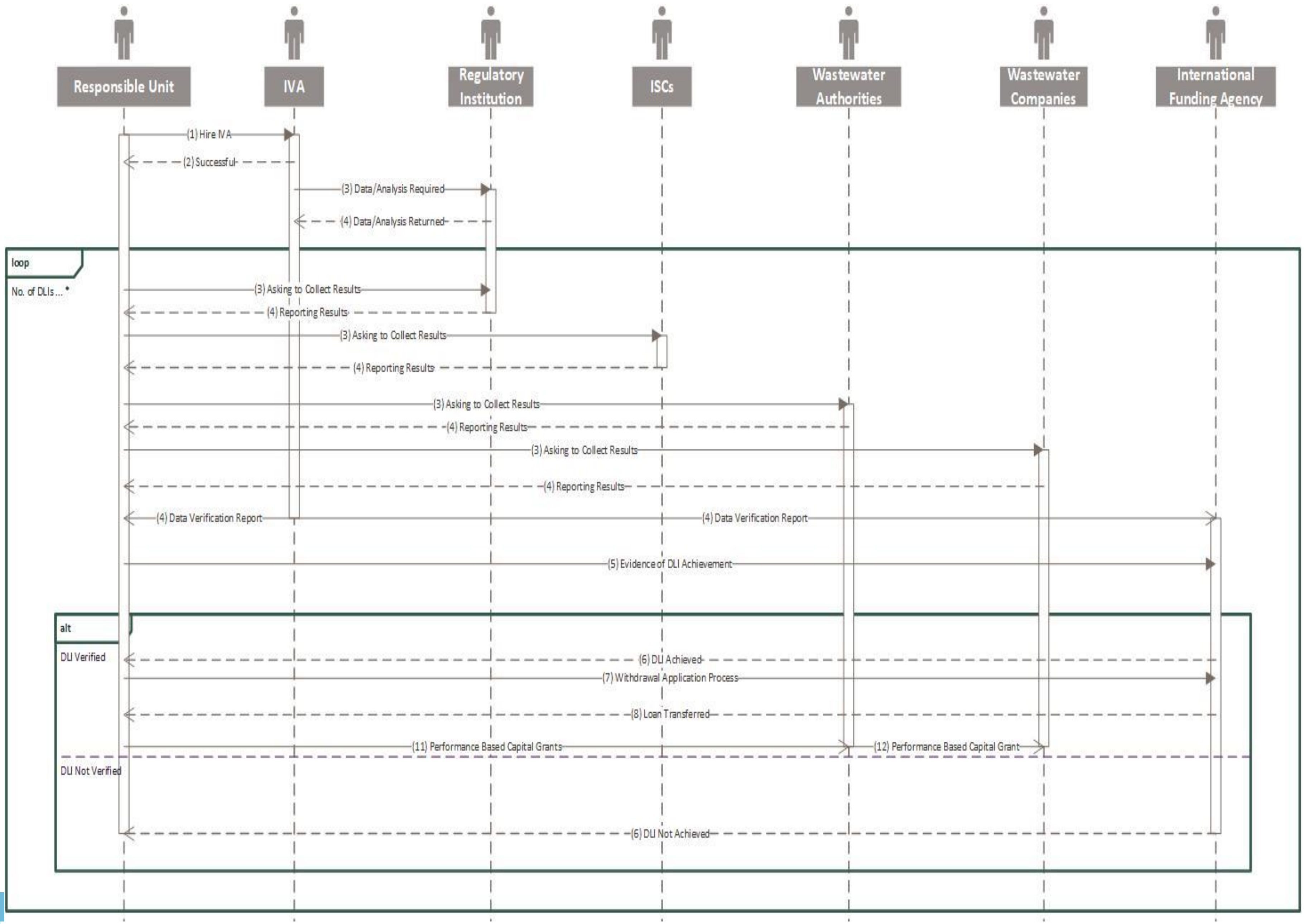


Figure 23: Sequence Diagram for the DLIs Verification Process

After assigning the packages to competent parties, the software shall simulate the verification process, which starts by collecting data from the different parties in the project in order to issue the withdrawal application, which is the formal notice to ask for the different loan disbursements. The key that defines the different results achieved is called the Disbursement Linked Indicator (DLI). The scope of a specific RBF project consists of a number of DLIs which are used as a monitoring tool to track the achieved results. Once a DLI has been achieved, the corresponding portion of the loan is disbursed.

The verification process is initiated by the borrowing country and the IVA, where they prepare verification reports to be submitted to the Bank. The verification process is modeled within a loop system boundary that is defined by the number of DLIs in the project. The Bank shall decide whether the DLI is achieved or not achieved.

The process is depicted by the system boundary lines at the bottom area of the Sequence Diagram with the annotation "alt" at the left upper corner. "Alt" denotes that an "either-or" relationship where only one of the two alternatives shall be applied.

The outputs from the Sequence Diagram shall be reported to the Class Diagram in order to incorporate the financial data in the optimization process. After several runs, the model shall be able to produce the most optimum scenario for the packaging process of the project, which minimizes the funding gap of the project through three options: by reducing the peak value of the negative cashflow curve, by normalizing the negative cashflow curve, or by a combination of the previous two options.

CHAPTER 4 : MODEL VERIFICATION

The model explained earlier is implemented using a group of computer-aided software. The model consists of a number of modules that shall be discussed in detail. The modules are constructed via Microsoft Excel, Visual Basic for Applications (VBA) programming language, and Palisade's Decision Tools Suite. The Visual Basic for Applications (VBA) programming language was used in order to make the interface more user-friendly for the government's officials to deal with. The Palisade's Decision Tools Suite is a popular tool for performing optimization processes using the Genetic Algorithms solving technique and sensitivity analysis modules. The model verification has been done through both system checks and sensitivity analysis to ensure that the output of the model is viable.

4 . 1 System Checks

In order to test the methods and techniques used in the proposed model, the outputs of the model have been verified using a number of steps. During the model design stage, the calculations are manually checked along the way. Unified codes are developed to minimize data entry errors. Dropdown menus are used for the same purpose. Error messages are designed to ensure the inputs align with the formatting of the model whenever possible. System checks are compiled at the end of the data entry process to guide the users to the location of the errors.

The cost and the schedule modules are vital modules in the model since time and cost are the foundation for calculating the cashflow diagrams. In order to be able to use such valuable information, as stated in the model flowchart, a coding system needs to be developed. Figure 24 shows an example of the coding system used. The table on the left side shows a coding system for the detailed activities inside one of the sewage pump stations, while the one on the right shows coding for the master schedule of the projects conducted in "Dakahlia". "NT" stands for a network project, "PS" represents a pump station project, while "TP" represents a wastewater treatment plant project. The first three letters of the are name are used as an acronym like in the case of "Dak", which represents the Dakahlia area. On the other hand, clusters or sub-areas are given sequential numbers.

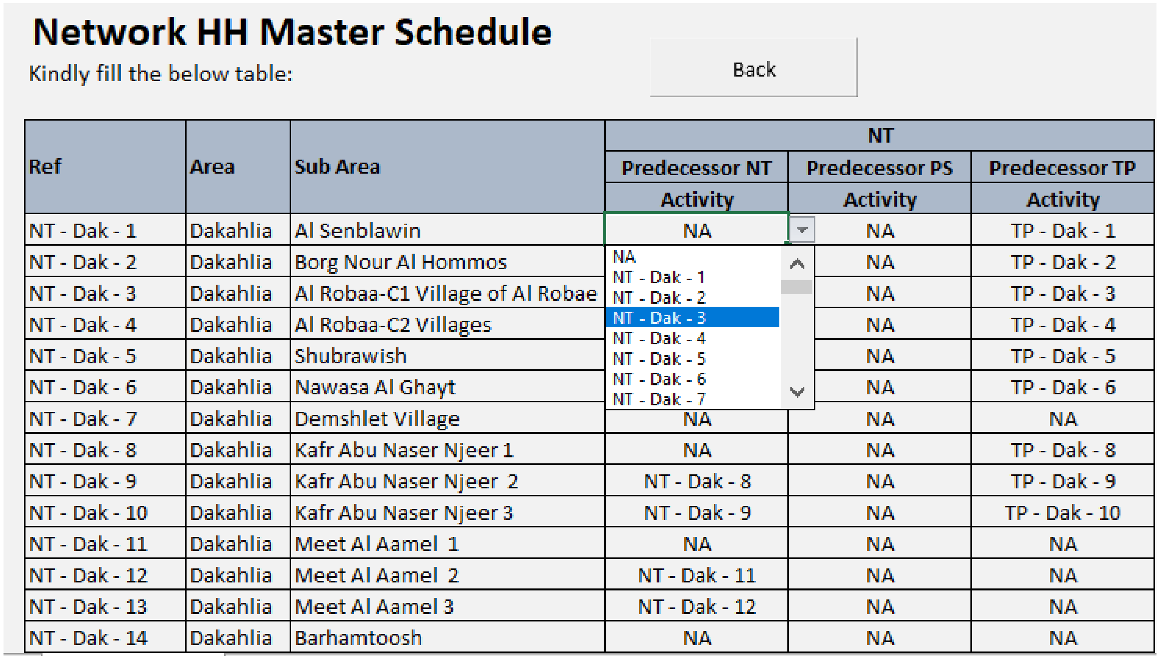
Sewage Pump Station

Code	Activity Description
PS-A-10101	Site Handing Over
PS-B-10101	Site Mobilization
PS-C-10101	Site & Network Survey
PS-C-20101	Permits and Environmental Approvals
PS-D-10101	Geotechnical Test
PS-E-10101	Hydraulic Profile Submittal & Approval
PS-E-10201	P&ID Submittal & Approval
PS-E-10301	General Civil Outline Submittal & Approval
PS-E-10401	General arrangement Layout Drawing Submittal & Approval
PS-E-10501	Geo Technical Report Submittal & Approval

Ref	Area	Sub Area
NT - Dak - 1	Dakahlia	Al Senblawin
NT - Dak - 2	Dakahlia	Borg Nour Al Hommos
NT - Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae
NT - Dak - 4	Dakahlia	Al Robaa-C2 Villages
NT - Dak - 5	Dakahlia	Shubrawish
NT - Dak - 6	Dakahlia	Nawasa Al Ghayt
NT - Dak - 7	Dakahlia	Demshlet Village
NT - Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1

Figure 24: Examples of the Coding System

When referring back to one of the projects, dropdown menus are used to minimize data entry errors (Figure 25). One of the famous programming errors is syntax errors that include a missing character in the model code. In this case, a missing dash or a missing space is crucial to correctly calculate outputs of the model. Hence, dropdown menus minimize this source of errors, as shown in the figure.



Network HH Master Schedule

Kindly fill the below table:

Back

Ref	Area	Sub Area	NT Predecessor NT Activity	NT Predecessor PS Activity	NT Predecessor TP Activity
NT - Dak - 1	Dakahlia	Al Senblawin	NA	NA	TP - Dak - 1
NT - Dak - 2	Dakahlia	Borg Nour Al Hommos		NA	TP - Dak - 2
NT - Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae		NA	TP - Dak - 3
NT - Dak - 4	Dakahlia	Al Robaa-C2 Villages		NA	TP - Dak - 4
NT - Dak - 5	Dakahlia	Shubrawish		NA	TP - Dak - 5
NT - Dak - 6	Dakahlia	Nawasa Al Ghayt		NA	TP - Dak - 6
NT - Dak - 7	Dakahlia	Demshlet Village	NA	NA	NA
NT - Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1	NA	NA	TP - Dak - 8
NT - Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2	NT - Dak - 8	NA	TP - Dak - 9
NT - Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3	NT - Dak - 9	NA	TP - Dak - 10
NT - Dak - 11	Dakahlia	Meet Al Aamel 1	NA	NA	NA
NT - Dak - 12	Dakahlia	Meet Al Aamel 2	NT - Dak - 11	NA	NA
NT - Dak - 13	Dakahlia	Meet Al Aamel 3	NT - Dak - 12	NA	NA
NT - Dak - 14	Dakahlia	Barhamtoosh	NA	NA	NA

Figure 25: Example of Syntax Errors

Another type of programming error is semantic errors, where the wrong types of variables are used. Using a decimal figure instead of an integer one is an example of semantic errors. Figure 26 demonstrates an example of how the model avoids semantic errors by providing error messages. The model shall instantly warn the user when an inputted data is invalid.

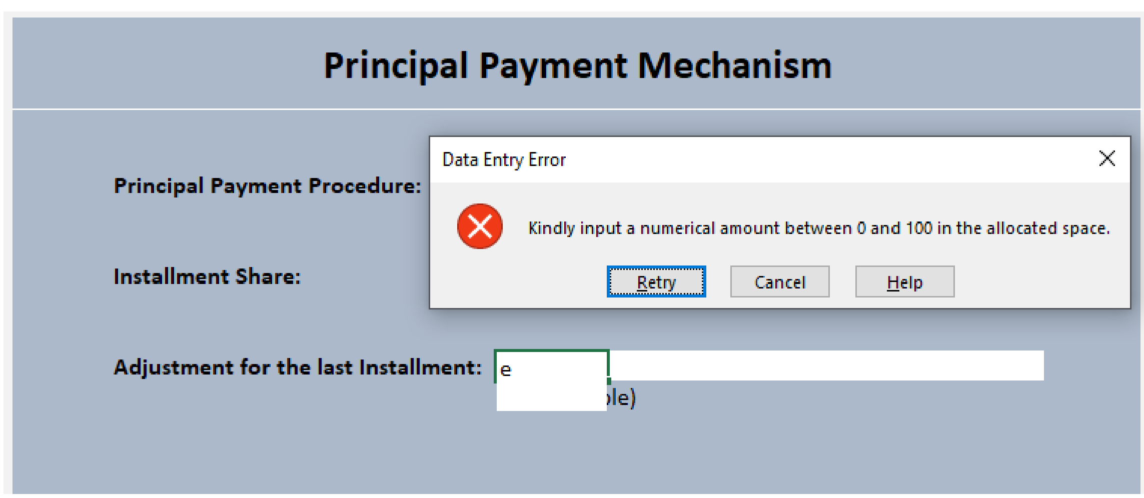


Figure 26: Example of Semantic Errors

Moreover, it shall provide the user with the accepted form of data entry in order to correct the error.

The last type of programming error is logical errors. This type of error is the hardest type to detect since the model shall behave normally without giving any of the above error messages. Logical errors make sense and provide seemingly correct outputs, yet the output data shall not be correct nor accurate. In order to avoid this error category, a "system check" option is added at the end of the data entry process. After the working sheets have finished their work, the user is asked to "run checks" in order to ensure the model is working properly. The system checks work as a validation check for the viability of the model and that the achieved results are based on correct calculations. As shown in Figure 27, there exist several checks. Each of the checks is allocated to one of the user navigations sheets. By checking this screen, the user shall have an idea of the location of possible data entry

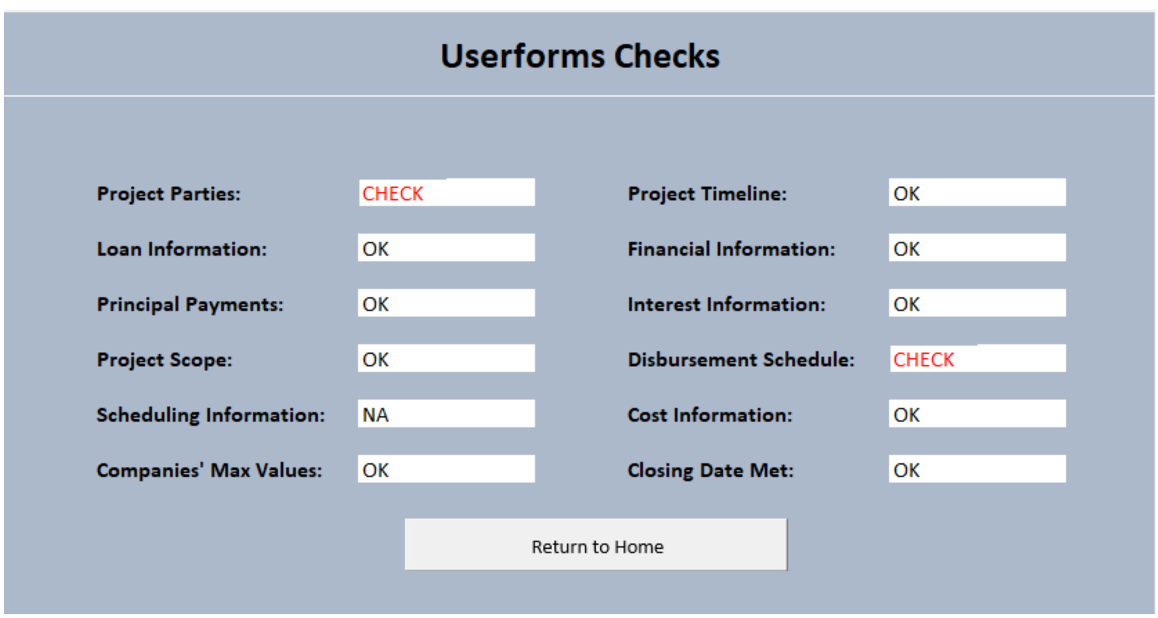


Figure 27: System Checks

errors; hence, the user shall be able to refer back to the location of the error and amend it accordingly.

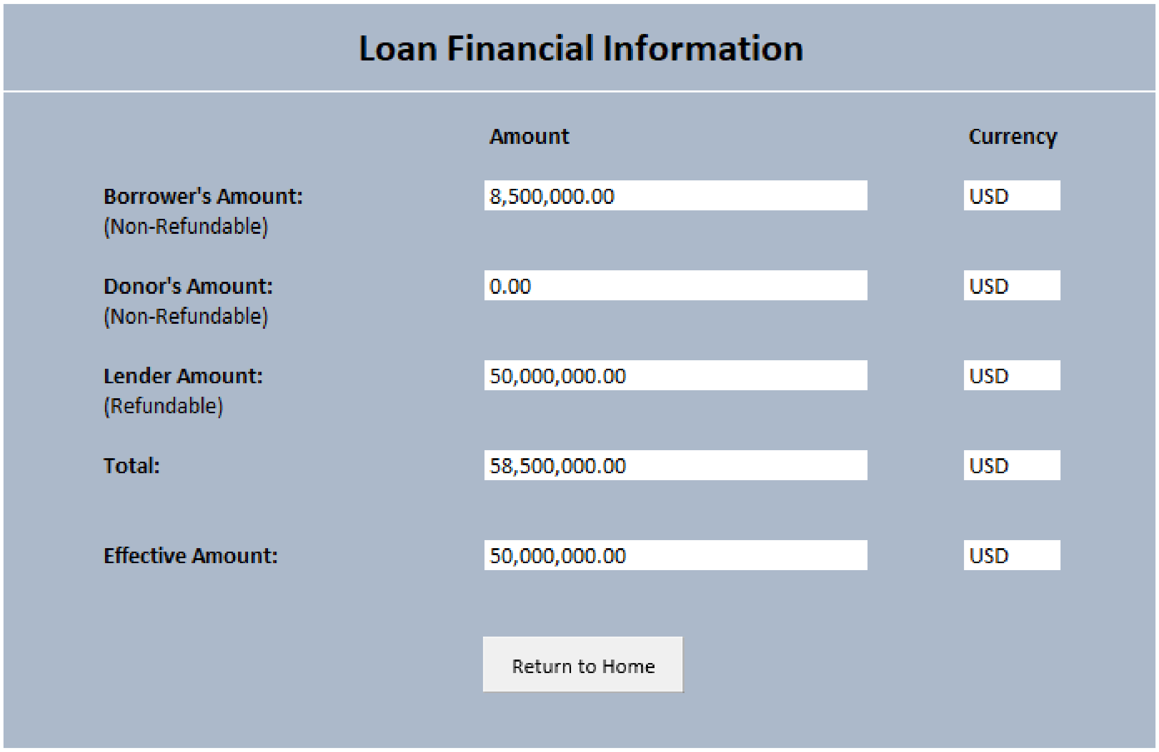
Finally, the model has proven to reduce common programming errors such as syntax errors, semantic errors, and logical errors. The model has applied a number of prevention methods to ensure the reliability of the model outputs. The prevention methods have been tested along the design process of the model and proved their efficiency.

4 . 2 Sensitivity Analysis Module

The sensitivity analysis approach has also been used to verify the model results by analyzing its data. The purpose of the sensitivity analysis approach to ensure that the model shall behave similarly when the input data are varied. In other words, it assesses the stability of the model under modified input conditions. Uncertainty can be quantified using sensitivity analysis. The model is constructed during the early phases of the project agreement, where uncertainty shall have huge implications for many of the decisions made at this stage. The sensitivity analysis approach helps in calibrating the model when needed by emphasizing the effect of varying the different model inputs on the model outputs.

4 . 2 . 1 The Sensitivity Analysis Data

For the purpose of performing the sensitivity analysis, a set of data has been applied to the model in order to perform the sensitivity analysis process. A sanitation results-based financed project has been agreed upon according to the loan data shown in Figure 28. The international funding agency has agreed to a loan with a value of 50 Million USD against a value of 8.5 Million USD to be financed by the borrowing government. The agreed loan shall be released via an agreed scheme of disbursement linked indicators.



Loan Financial Information

	Amount	Currency
Borrower's Amount: (Non-Refundable)	8,500,000.00	USD
Donor's Amount: (Non-Refundable)	0.00	USD
Lender Amount: (Refundable)	50,000,000.00	USD
Total:	58,500,000.00	USD
Effective Amount:	50,000,000.00	USD

Return to Home

Figure 28: Loan Information

The financial information corresponding to the above agreement is shown in Figure 29. The front-end fee shall be 20 percent of the loan value. This shall be deducted at the beginning of the project, unlike the commitment charge that shall be collected periodically against the unwithdrawn loan amount. The commitment charge is expected to be 0.2 percent. A ten percent advance payment is the advance payment set in the contract to be amortized upon achieving the corresponding disbursement linked indicator. The advance payment recovery method is selected from a menu to be "Upon DLI Achievement".

The scope of the project includes constructing house connections, pump stations and wastewater treatment plants. An example of the scope of the house connections is shown in ten areas, as shown in Figure 30. A total of 30,000 are to be designed, constructed and operated by the borrowing government.

Financial Information

The Front-end Fee: 20.00%
Deducted once from the loan amount

The Commitment Charge: 0.20% — Frequency: Semi-annually
Per annum on the unwithdrawn loan balance
Accrue from the Loan Agreement date +60 days

Currency of Payment: USD

Advance Payment: 10%
(If Applicable)

Advance Payment Recovery: Upon DLI Achievement
(If Applicable)

Return to Home

Figure 29: Financial Loan Parameters

Network HH Scope

Kindly fill the below table:

Back

Ref	Area	Sub Area	NT Scope Yes/No	NT Target HH
NT - A - 1	XYZ	Area 1	Yes	4,690
NT - A - 2	XYZ	Area 2	Yes	4,038
NT - A - 3	XYZ	Area 3	Yes	1,063
NT - A - 4	XYZ	Area 4	Yes	1,093
NT - A - 5	XYZ	Area 5	Yes	3,523
NT - A - 6	XYZ	Area 6	Yes	4,900
NT - A - 7	XYZ	Area 7	Yes	1,990
NT - A - 8	XYZ	Area 8	Yes	2,219
NT - A - 9	XYZ	Area 9	Yes	2,219
NT - A - 10	XYZ	Area 10	Yes	4,268

Figure 30: Network Projects Scope

Figure 31 shows the scope of the wastewater treatment plants and their capacities, the technology used, and the expected scope. The capacity of the required plants varies between 5,000 to 10,000 meters cubed per day, while the technologies used in the treatment are activated sludge, stabilization ponds and oxidation ditches. Some of the plants require only an extension to an existing plant, while others are to be constructed from scratch.

WWTPs Scope

Kindly fill the below table: Back

Ref	Area	Sub Area	TP Scope Yes/No	TP Technology Used	TP Target m3/d
TP - A - 1	XYZ	Area 1	Extension	Activated Sludge	5,000
TP - A - 2	XYZ	Area 2	Extension	Stabilization Ponds	10,000
TP - A - 3	XYZ	Area 3	Yes	Stabilization Ponds	10,000
TP - A - 4	XYZ	Area 4	Yes	Stabilization Ponds	10,000
TP - A - 5	XYZ	Area 5	Yes	Stabilization Ponds	7,500
TP - A - 6	XYZ	Area 6	Yes	Oxidation Ditches	10,000
TP - A - 7	XYZ	Area 7	No	Stabilization Ponds	7,500
TP - A - 8	XYZ	Area 8	Extension	Stabilization Ponds	7,500
TP - A - 9	XYZ	Area 9	Extension	Activated Sludge	5,000
TP - A - 10	XYZ	Area 10	Extension	Activated Sludge	5,000

Figure 31: Wastewater Treatment Plants Scope

In order to link the above scope to the different loan disbursements, the user shall input a disbursement linked indicator schedule to specify the scope required against the value of the disbursement. Figure 32 shows the detailed information for the disbursement process. for example, after completing the design of 4,500 house connections by June of 2016, an amount of 1.8 Million USD shall be released to the borrowing country. The schedule shall

Design, Construction and Operation DLIs Schedule:

Kindly fill the below table: Back

Criteria	Units	Total	01-Jun-16	01-Jun-17	01-Jun-18	01-Jun-19	01-Jun-20
Final Output Required (HH):	**#**	**167,000.00**	**0.00**	**10,000.00**	**40,000.00**	**50,000.00**	**67,000.00**
Disbursement Trigger:							
Design %	%		15%	40%			
Design	#	**16,500.00**	4,500.00	12,000.00			
Construction %	%						
Construction	#	**30,000.00**		7,000.00	4,000.00	10,000.00	9,000.00
Operation %	%		0%	20%	20%	20%	20%
Operation	#	**6,000.00**		1,400.00	800.00	2,000.00	1,800.00
Disbursement Amount After Verification							
For Design	**USD**	**5,000,000.00**	1,800,000.00	3,200,000.00			
Amount per new connection HH	**USD**	**0.00**	1,500.00	1,500.00	1,500.00	1,500.00	1,500.00
For Construction	**USD**	**45,000,000.00**	0.00	10,500,000.00	6,000,000.00	15,000,000.00	13,500,000.00
Total Amount	**USD**	**50,000,000.00**					

Figure 32: DLIs Schedule

be the basis used by the model to prepare the cash in portion of the cashflow schedule along with other inputted data.

The following step is to prepare the schedule module. The user shall input any existing relationship between the projects specified in the scope, as shown in Figure 33. Dependencies are a vital step when preparing schedules. Also, they constitute an indirect constrain when performing the optimization process.

Network HH Master Schedule

Kindly fill the below table:

Back

Ref	Area	Sub Area	NT		
			Predecessor NT Activity	Predecessor PS Activity	Predecessor TP Activity
NT - A - 1	XYZ	Area 1	NA	NA	TP - A - 1
NT - A - 2	XYZ	Area 2	NA	NA	TP - A - 2
NT - A - 3	XYZ	Area 3	NA	NA	NA
NT - A - 4	XYZ	Area 4	NT - A - 3	NA	NA
NT - A - 5	XYZ	Area 5	NA	NA	TP - A - 5
NT - A - 6	XYZ	Area 6	NA	NA	TP - A - 6
NT - A - 7	XYZ	Area 7	NA	NA	TP - A - 7
NT - A - 8	XYZ	Area 8	NA	NA	NA
NT - A - 9	XYZ	Area 9	NT - A - 8	NA	NA
NT - A - 10	XYZ	Area 10	NT - A - 9	NA	NA

Figure 33: Dependencies between Projects

The user shall also provide the estimated design and construction durations, as shown in Figure 34. As shall be explained in the following chapter, the model has a built-in schedule

Network HH Durations

Kindly fill the below table:

Back

Ref	Area	Sub Area	NT Duration	
			Design Days	Construction Days
NT - A - 1	XYZ	Area 1	30	300
NT - A - 2	XYZ	Area 2	24	241
NT - A - 3	XYZ	Area 3	15	150
NT - A - 4	XYZ	Area 4	30	302
NT - A - 5	XYZ	Area 5	28	276
NT - A - 6	XYZ	Area 6	25	245
NT - A - 7	XYZ	Area 7	18	176
NT - A - 8	XYZ	Area 8	27	267
NT - A - 9	XYZ	Area 9	29	294
NT - A - 10	XYZ	Area 10	20	198

Figure 34: Design and Construction Durations

that may guide the user with regards to the durations; however, the user may choose to enter pre-estimated figures to prepare schedules, as shown in Figure 35 .

Network Construction Master Schedule Bar Chart

Activity	Activity De	Total Duration	ES	EF	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17	Jan-18	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
NT - A - 1	Area 1	330	2-Oct-16	28-Aug-17						■	■	■	■	■	■	■	■	■	■													
NT - A - 2	Area 2	265	20-Sep-16	12-Jun-17					■	■	■	■	■	■	■	■	■															
NT - A - 3	Area 3	165	1-Jun-16	13-Nov-16	■	■	■	■	■	■																						
NT - A - 4	Area 4	332	14-Nov-16	12-Oct-17							■	■	■	■	■	■	■	■	■	■	■											
NT - A - 5	Area 5	304	12-Oct-16	11-Aug-17						■	■	■	■	■	■	■	■	■	■													
NT - A - 6	Area 6	270	20-Sep-16	16-Jun-17					■	■	■	■	■	■	■	■	■															
NT - A - 7	Area 7	194	22-Sep-16	3-Apr-17					■	■	■	■	■	■	■																	
NT - A - 8	Area 8	294	1-Jun-16	21-Mar-17	■	■	■	■	■	■	■	■	■	■																		
NT - A - 9	Area 9	323	22-Mar-17	9-Feb-18											■	■	■	■	■	■	■	■	■	■	■							
NT - A - 10	Area 10	218	10-Feb-18	15-Sep-18																						■	■	■	■	■	■	■

Figure 35: Network Construction Bar Chart

An example of the prepared schedules is shown in Figure 35, which represents a construction bar chart for the network projects. the preparation of the schedule is very important in order to be able to calculate the project cashflow schedule accordingly. The user shall also input the costs of the projects. Figure 36 shows an example of a cost table that belongs to the wastewater projects in the program. The individual costs shall be distributed along the project time schedule to prepare the project cashflow.

WWTPs Cost

Kindly fill the below table:

Back

Ref	Area	Sub Area	TP Construction Cost USD
TP - A - 1	XYZ	Area 1	4,740,500
TP - A - 2	XYZ	Area 2	3,142,500
TP - A - 3	XYZ	Area 3	1,571,250
TP - A - 4	XYZ	Area 4	1,571,250
TP - A - 5	XYZ	Area 5	4,713,750
TP - A - 6	XYZ	Area 6	2,285,000
TP - A - 7	XYZ	Area 7	1,000,000
TP - A - 8	XYZ	Area 8	1,571,250
TP - A - 9	XYZ	Area 9	1,571,250
TP - A - 10	XYZ	Area 10	1,571,250

Figure 36: WWTPs Cost Information

The project cashflow schedules shall be explained in detail in the following chapter; however, the sole purpose of the cashflow schedule is to obtain the data with regards to the funding gap. In other words, the purpose is to identify the period with negative cashflows in order to determine the amount of funds to be financed by the government. The model shall optimize a summation of two figures. The first figure is the maximum amount needed to be financed by the government at a certain point in time, which shall be the negative peak of the cumulative cashflow curve. The next figure is the net present value of all negative cashflows in order to normalize the negative peak curve and distribute the values along the execution period in a way to collect the DLIs as early as possible. The results of the optimization process are shown in Figure 37. As shown in the figure, the model has minimized the maximum negative fund required by the government by almost 11 percent, while it minimized the net present value of all negative cashflows by 6.5 percent.

NPV for the Negative Cahflow Required		
Before Optimization	$	(31,387,656.67)
After Optimization	$	(29,348,491.12)
Difference	**$**	**(2,039,165.55)**
% Optimized		**6.50%**
Maximum Government Fund Required		
Before Optimization	$	(29,412,585.62)
After Optimization	$	(26,093,547.13)
Difference	**$**	**(3,319,038.49)**
% Optimized		**11.28%**
Combined		
Before Optimization	$	(60,800,242.30)
After Optimization	$	(55,442,038.25)
Difference	**$**	**(5,358,204.04)**
% Optimized		**8.81%**

Figure 37: Optimization Results

4 . 2 . 2 Financial Parameters Sensitivity Analysis

In order to figure out the effect of the input data on the above results, a sensitivity analysis was performed using one of Palisade's Decision Tools Suite, which is the Top Rank software. The software measures the effect of varying a number of inputs to the output results, which is, in this case, the maximum funds required by the borrowing government at a certain point in time. The inputs include the financial parameters and the packaging selection process. As shown in Figure 38, a total of 23 inputs are varied.

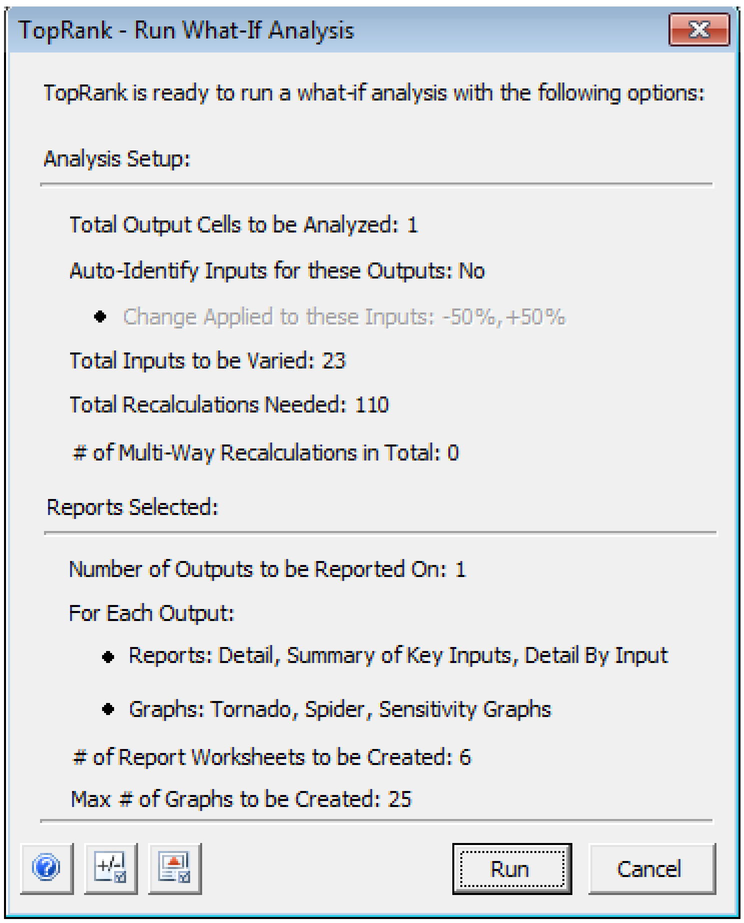


Figure 38: Top Rank Model Definition Window

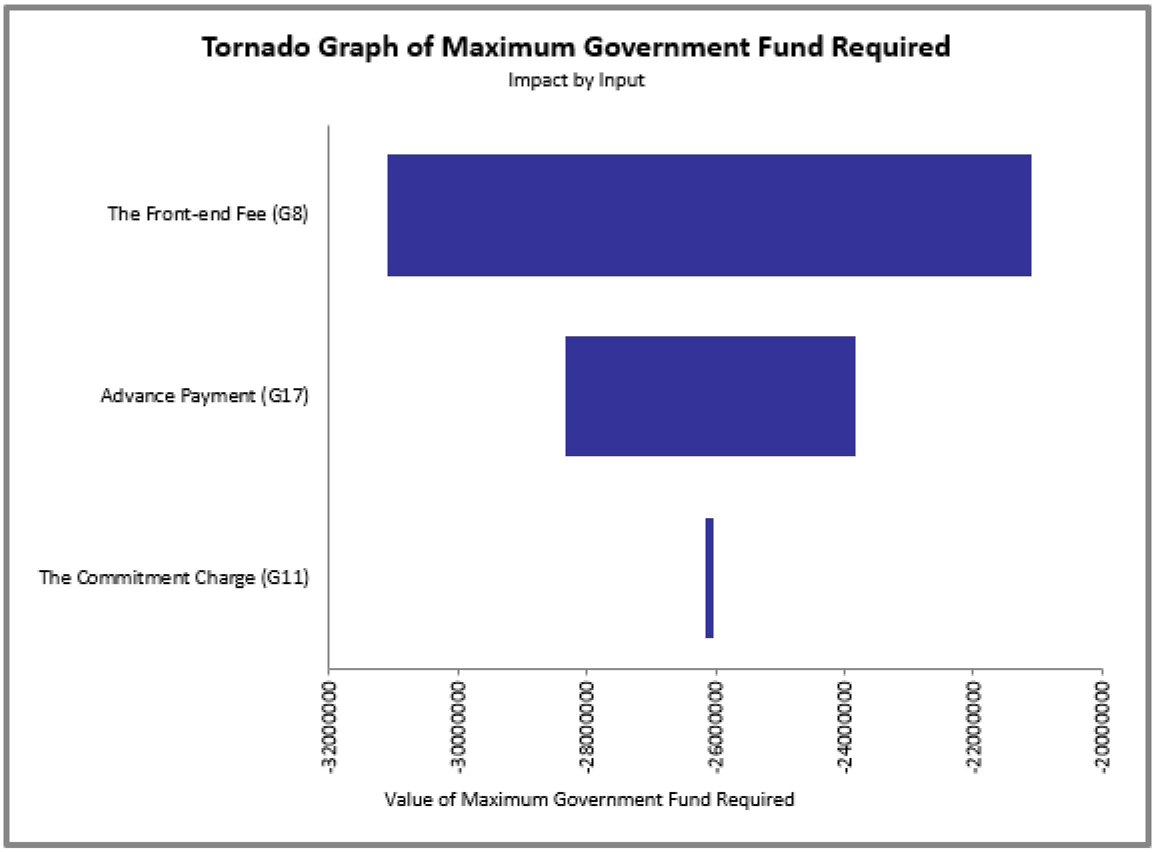
The sensitivity analysis module has been executed in two steps. The first group of inputs varied is the financial parameters, including the front-end fee, the commitment charge and the advance payment. The model has been adjusted to perform the variance along ten steps ranging between positive 50 percent and negative 50 percent. All possible scenarios are shown in Figure 39.

What-If Analysis Detail for All Inputs and Outputs All Iterations								
			Input Variation			Output Variation Maximum Government Fund Required		
Input Name	Cell	Step	Value	Change	Change (%)	Value	Change	Change (%)
The Front-end Fee (G8)	G8	1	0.1000	-0.1000	-0.5000	(21,093,547.13)	5,000,000.00	19.16%
		2	0.1222	-0.0778	-0.3889	(22,204,658.24)	3,888,888.89	14.90%
		3	0.1444	-0.0556	-0.2778	(23,315,769.35)	2,777,777.78	10.65%
		4	0.1667	-0.0333	-0.1667	(24,426,880.47)	1,666,666.67	6.39%
		5	0.1889	-0.0111	-0.0556	(25,537,991.58)	555,555.56	2.13%
		6	0.2111	0.0111	0.0556	(26,649,102.69)	(555,555.56)	-2.13%
		7	0.2333	0.0333	0.1667	(27,760,213.80)	(1,666,666.67)	-6.39%
		8	0.2556	0.0556	0.2778	(28,871,324.91)	(2,777,777.78)	-10.65%
		9	0.2778	0.0778	0.3889	(29,982,436.02)	(3,888,888.89)	-14.90%
		10	0.3000	0.1000	0.5000	(31,093,547.13)	(5,000,000.00)	-19.16%
The Commitment Charge (G11)	G11	1	0.0010	-0.0010	-0.5000	(26,043,547.13)	50,000.00	0.19%
		2	0.0012	-0.0008	-0.3889	(26,054,658.24)	38,888.89	0.15%
		3	0.0014	-0.0006	-0.2778	(26,065,769.35)	27,777.78	0.11%
		4	0.0017	-0.0003	-0.1667	(26,076,880.47)	16,666.67	0.06%
		5	0.0019	-0.0001	-0.0556	(26,087,991.58)	5,555.56	0.02%
		6	0.0021	0.0001	0.0556	(26,099,102.69)	(5,555.56)	-0.02%
		7	0.0023	0.0003	0.1667	(26,110,213.80)	(16,666.67)	-0.06%
		8	0.0026	0.0006	0.2778	(26,121,324.91)	(27,777.78)	-0.11%
		9	0.0028	0.0008	0.3889	(26,132,436.02)	(38,888.89)	-0.15%
		10	0.0030	0.0010	0.5000	(26,143,547.13)	(50,000.00)	-0.19%
Advance Payment (G17)	G17	1	0.0500	-0.0500	-0.5000	(28,343,547.13)	(2,250,000.00)	-8.62%
		2	0.0611	-0.0389	-0.3889	(27,843,547.13)	(1,750,000.00)	-6.71%
		3	0.0722	-0.0278	-0.2778	(27,343,547.13)	(1,250,000.00)	-4.79%
		4	0.0833	-0.0167	-0.1667	(26,843,547.13)	(750,000.00)	-2.87%
		5	0.0944	-0.0056	-0.0556	(26,343,547.13)	(250,000.00)	-0.96%
		6	0.1056	0.0056	0.0556	(25,843,547.13)	250,000.00	0.96%
		7	0.1167	0.0167	0.1667	(25,343,547.13)	750,000.00	2.87%
		8	0.1278	0.0278	0.2778	(24,843,547.13)	1,250,000.00	4.79%
		9	0.1389	0.0389	0.3889	(24,343,547.13)	1,750,000.00	6.71%
		10	0.1500	0.0500	0.5000	(23,843,547.13)	2,250,000.00	8.62%

Figure 39: Financial Parameters Sensitivity Analysis

In order to visualize the above data, a tornado graph is plotted using the data at the bottom of Figure 40. The tornado graph consists of a number of rectangles where each rectangle represents a different variable. The rectangle with the longest width represents the input variable with the highest impact on the output data. As shown in the figure, the front-end

TopRank - Tornado Graph
Performed By: Amira Shalaby
Date: Monday, July 01, 2020 12:41:46 AM
Model: 2020.07.01 PhD Model
Output: Maximum Government Fund Required (D8)
Base Value: -26093547.1324444



What-If Analysis Summary for Output Maximum Government Fund Required
Top 3 Inputs Ranked By Change in Actual Value

			Minimum			Maximum		
			Output		Input	Output		Input
Rank	Input Name	Cell	Value	Change (%)	Value	Value	Change (%)	Value
1	The Front-end Fee (G8)	G8	(31,093,547.13)	-19.16%	0.3	(21,093,547.13)	19.16%	0.1
2	Advance Payment (G17)	G17	(28,343,547.13)	-8.62%	0.05	(23,843,547.13)	8.62%	0.15
3	The Commitment Charge (G11)	G11	(26,143,547.13)	-0.19%	0.003	(26,043,547.13)	0.19%	0.001

Figure 40: Financial Parameters Tornado Graph

fee has the highest impact on the funds required from the borrowing government, while the commitment charge has the lowest impact.

Another method to present the above results is using a spider graph, as shown in Figure 41. While the tornado graph shows only a range of the possible outcomes of varied inputs, the tornado graph provides lines that represent the behavior of the output results when varying the inputs. To interpret the data of the sensitivity analysis, the line with the steepest slope has the largest impact on the output results. Again, the front-end fee is the input that highly affects the amount of funds required by the borrowing government.

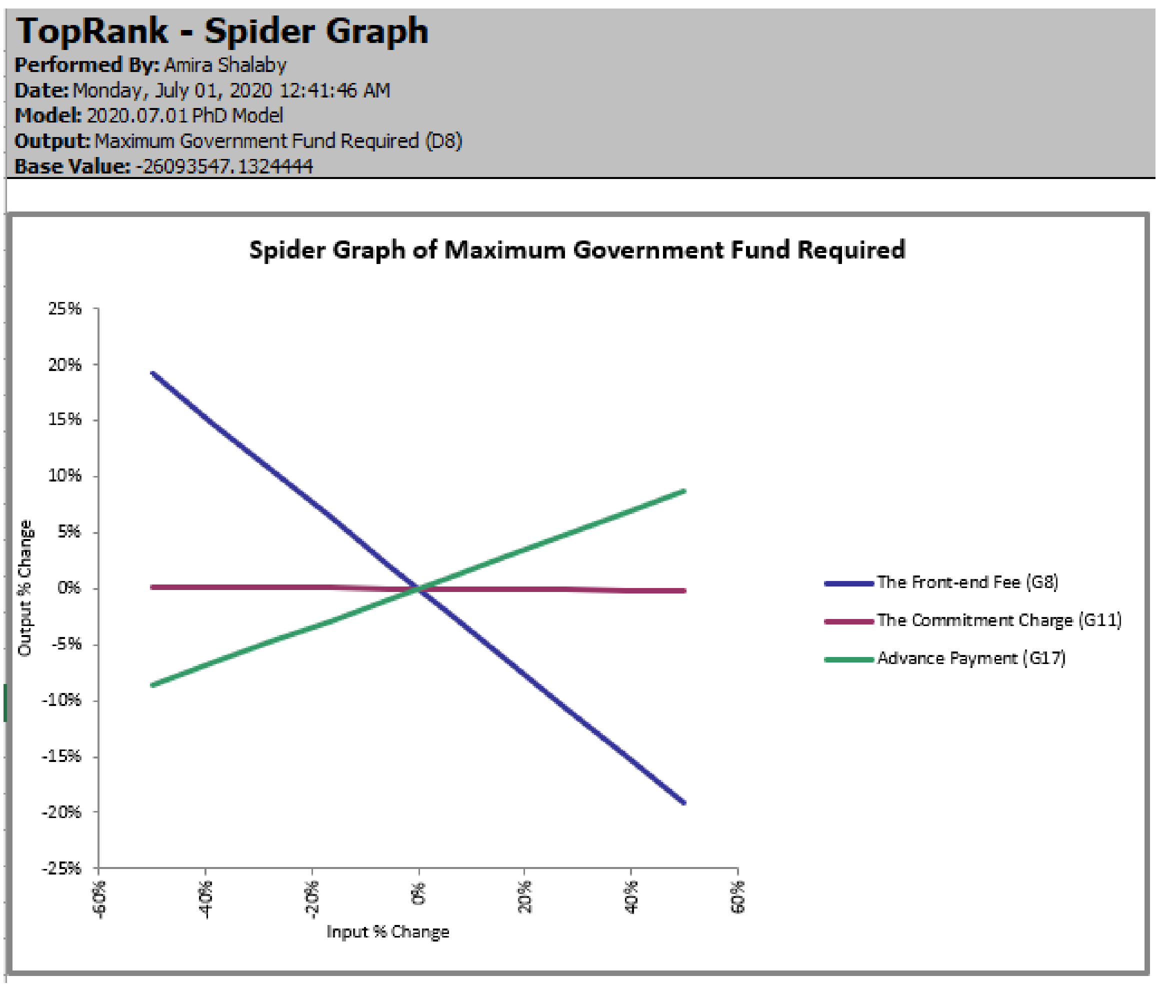


Figure 41: Financial Parameters Spider Graph

4 . 2 . 3 Packages Selection Sensitivity Analysis

The second step of the sensitivity analysis module is to perform the sensitivity analysis by varying the selection of the packaging scenarios, along with the financial parameters varied earlier. The different packaging scenarios are varied by varying the allocation of the different executing companies, including contractors, consultants and design-build contractors.

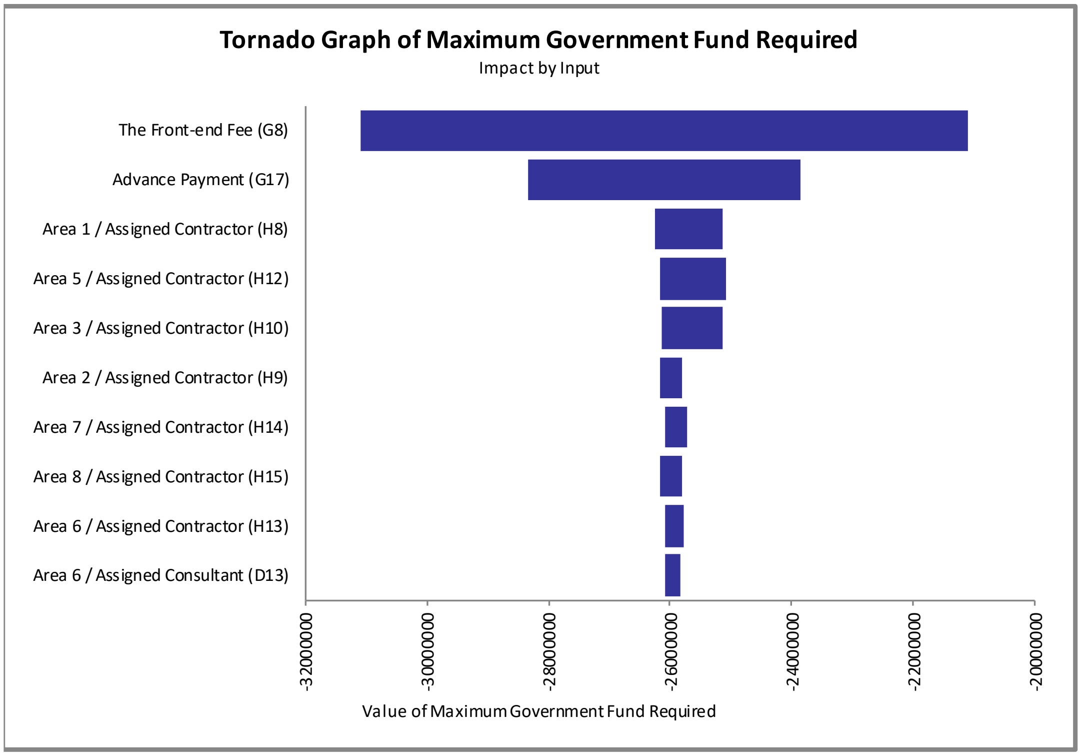
The sensitivity analysis module definition has been set to choose the 10 top parameters affecting the output results. Figure 42 shows the tornado graph of the top 10 parameters. The front-end fee and the advance payment financial parameters remain to be on top of the inputs that affect the funds required from the government, which is totally justifiable due to their timing on the cashflow schedule.

The following top-ranked inputs with the widest variance are the contractor assigned to Area 1 followed by the contractor assigned to Area 5, then Area 3. This means that during the packaging process, those areas shall have the highest impact on the funds required from the borrowing government and should be given special attention. The packages containing the above area shall have the highest impact on the funds required from the borrowing country.

Figure 43 shows a spider graph of the ten top-ranked variables. The graph shows the top two ranked inputs with the steepest slope are again the front-end fee and the advance payment. The graph shows a complete representation of the sensitivity analysis values. The following top-ranked inputs are the contractor assigned to Area 1, followed by the contractor assigned to Area 5, then the contractor assigned to Area 3.

TopRank - Tornado Graph

Performed By: Amira Shalaby
Date: Monday, July 01, 2020 12:54:39 AM
Model: 2020.07.01 PhD Model.xlsx
Output: Maximum Government Fund Required (D8)
Base Value: -26093547.1324444



What-If Analysis Summary for Output Maximum Government Fund Required

Top 10 Inputs Ranked By Change in Actual Value

				Minimum			Maximum		
				Output		Input	Output		Input
Rank	Input Name	Worksheet	Cell	Value	Change (%)	Value	Value	Change (%)	Value
1	The Front-end Fee (G8)	Financial	G8	(31,093,547.13)	-19.16%	0.3	(21,093,547.13)	19.16%	0.1
2	Advance Payment (G17)	Financial	G17	(28,343,547.13)	-8.62%	0.05	(23,843,547.13)	8.62%	0.15
3	Area 1 / Assigned Contractor (H8)	NT Durations - Opt	H8	(26,255,772.50)	-0.62%	2	(25,134,850.79)	3.67%	5
4	Area 5 / Assigned Contractor (H12)	NT Durations - Opt	H12	(26,177,899.27)	-0.32%	2	(25,090,260.82)	3.84%	4
5	Area 3 / Assigned Contractor (H10)	NT Durations - Opt	H10	(26,148,068.56)	-0.21%	2	(25,127,745.05)	3.70%	4
6	Area 2 / Assigned Contractor (H9)	NT Durations - Opt	H9	(26,174,117.69)	-0.31%	4	(25,790,222.69)	1.16%	1
7	Area 7 / Assigned Contractor (H14)	NT Durations - Opt	H14	(26,093,547.13)	0.00%	4	(25,715,119.37)	1.45%	1
8	Area 8 / Assigned Contractor (H15)	NT Durations - Opt	H15	(26,164,381.37)	-0.27%	4	(25,791,569.58)	1.16%	1
9	Area 6 / Assigned Contractor (H13)	NT Durations - Opt	H13	(26,093,547.13)	0.00%	4	(25,764,426.48)	1.26%	1
10	Area 6 / Assigned Consultant (D13)	NT Durations - Opt	D13	(26,093,547.13)	0.00%	2	(25,827,365.71)	1.02%	1

Figure 42: Packages Selection Tornado Graph

TopRank - Spider Graph

Performed By: Amira Shalaby
Date: Monday, July 01, 2020 12:54:39 AM
Model: 2020.07.01 PhD Model.xlsx
Output: Maximum Government Fund Required (D8)
Base Value: -26093547.1324444

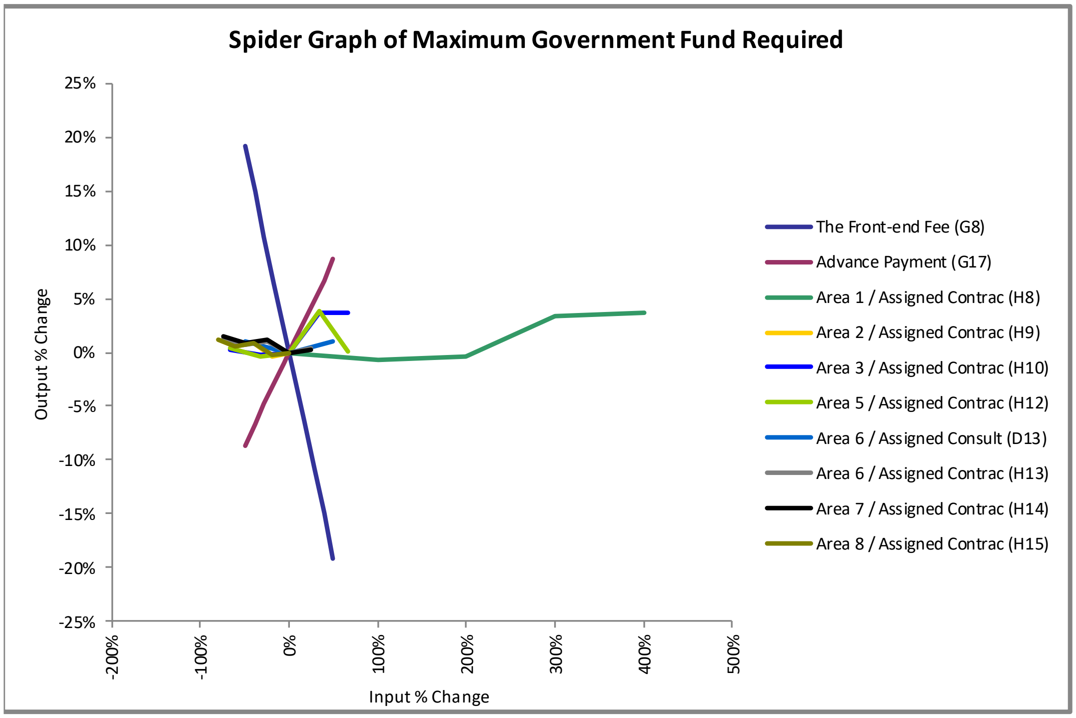


Figure 43: Packages Selections Spider Graph

To conclude, the sensitivity analysis module has helped in measuring the effect of major inputs of the model on the output results. It verified that the model should behave similarly when key inputs are adjusted. It helped in identifying the major areas of improvement when it comes to the packaging selection process. It defined the key inputs that will affect the output results by measuring the effect of individual parameters with respect to other parameters and with respect to the output results.

CHAPTER 5 : MODEL VALIDATION

After verifying the model results, the next step is to validate that the output results are effective and provide a better solution to the packaging problem. The model has several outputs. The key output is the optimum packaging scenario reached via the optimization process described above. The model does not only define the content of the packages, but it develops a complete managing plan of them. It simulates the whole lifecycle of the project in order to be able to ensure the viability of the output results. The model starts as early as the agreements signing phase up until the delivery of the required results, the receiving of loan disbursements, and finally, the repayment of the loan. The model provides detailed schedules for each of the projects' design and construction phases and a complete cashflow showing all the project financial requirements such as front-end fees, commitment charges, advance payments, principal loan amounts, interest paid, and many others. The model also considers the contractual payment terms, retention, margins, expected payment delays, cost of capital, and other unknown factors at that stage. Since the model is to be operated prior to the actual start of the project, adjustments are also made for inflation, discount rates, foreign exchange rates, and the like.

To validate the model, the model results have been compared to a real-life case study in order to measure the effectiveness of the optimization process and the ability of the model to enhance the packaging process and reduce the government funding portion. This comes by measuring the deviation or the variance between the real-life case scenario and the results obtained from the model. The literature review has surveyed the results-based financed (RBF) projects that have taken place in Egypt. For the purpose of the model validation, one of the RBF projects in Egypt is selected to optimize the packaging process by applying the data to the model developed.

The project used one of the financial instruments of the results-based finance approach, which is the program for results (P4R) approach. The program is achieved through the World Bank and aims to strengthen the Egyptian Institutions for better service delivery by providing incentives. The core incentive is linking the loan disbursements to the results achieved, as explained earlier. Moreover, the program aims to shift the government paradigm towards a more decentralized approach by engaging the Water Sanitation Companies (WSCs) in order to enhance their management techniques and services. The parties involved in the project were explained earlier in Section 2.2.5 and shall be explained again in the following sections.

The project consists of a number of objectives/Results Areas that aim to enhance the sanitation sector in Egypt, especially in rural areas. The Egyptian authorities are concerned with enhancing the sanitation system in some of the governorates and constructing a whole system in others. The Delta region contains the poorest twenty-one percent of the Egyptian households, specifically in Dakahliya, Sharkia and Beheira, which was the reason for selecting the three governorates to constitute phase one of the program. The first phase of the project handled three governorates, which are denoted by the title "Area" in the model. Each governorate has a number of clusters, which shall be denoted by the title "Sub-area." The project in each of the sub-areas varies from constructing only the sanitation collection network to constructing pump stations and, in some sub-areas, constructing a treatment plant or rehabilitating/expanding an existing one.

The program objectives can be summarized in three key results areas shown in Table 14. The first results area is to improve sanitation access by ensuring that at least 167,000 household connections are designed, executed, and connected to a proper sanitation system in three governorates (Dakahliya, Sharkia, and Beheira). This shall improve the sanitation conditions of at least 833,000 people living in those governorates. The second results area is to improve operational systems and practices of WSCs by improving service delivery through better planning and operation processes. The last result area is to strengthen the national sector framework, which shall include the structuring of a new tariff system.

Table 14: Results Areas, (The World Bank, 2015)

Results Area	**Description**
Results Area 1: Improved Sanitation Access	About 167,000 new households (about 833,000 people) connected to working sanitation systems in villages and satellites in the three governorates in the Program area
Results Area 2: Improved Operational Systems and Practices of WSCs	Improved capacity, investment planning, operations, and general service delivery of each of the three participating WSCs (Beheira, Dakahliya, and Sharkiya)
Results Area 3: Strengthened National Sector Framework	Improved enabling environment for more sustainable rural sanitation services

The details of the required DLIs may be subject to change during the execution dates of the project based on a restructuring request to be issued by the borrowing government. However, for the sake of the model validation, the data of the case study were inputted in the model in order to test the output results effectiveness.

5 . 1 Model Mapping/Logic

The purpose of the model is to automatically create work packages in a result-based-financed project by simulating the project lifecycle starting from the agreement signing up until the loan repayment schedule at the end of the project. The model complies with a new emerging funding method, which is the Results-Based-Finance method. The funding method is adopted by many regimes in developing countries and has proven its effectiveness, as shown in the literature review. The method is used by many financial institutions such as the World Bank Group and many Regional Development Banks to eliminate poverty and boost prosperity.

The model consists of four phases: the agreement phase, the procurement phase, the results phase, and the fund phase. Each of the phases has several inputs and outputs. The data flow among the different phases of the model is critical in order to ensure the viability of the results obtained. Navigation sheets are sheets that allow the user to move among the different phases of the model. Navigation sheets are the user-interface module that guides the user through the data entry process. The Visual Basic for Applications (VBA) programming language has helped the user go through those phases in a smooth and simplified manner, especially for non-technical users. The user-interface module has created several screens to collect the information required to simulate the four phases of the project. For instance, the agreement phase consists of the loan agreement, the program agreement and information with regards to the Project Management Unit (PMU) formulation, and the Independent Verification Agent (IVA) appointment. The interface is designed to extract important information such as the major contractual agreements, including the major parties such as the bank and the borrower representatives. The interface shall define responsibilities and important financial information such as the interest rates and the loan repayment schedule. The interface shall also contain information from the World Bank protocol with regards to the assessment of the results and the Disbursement Linked Indicators (DLIs). The model also provides information such as the scope required, the executing companies in the market, the project schedule, and cost estimates.

The working sheets are the data processing sheets that shall not be visible to the user. The main purpose of the sheets is to code the scope of work required in a way that simplifies the packaging process. The coding shall be used in order to create different scenarios for the work packages division process. In these sheets, calculations are made for creating schedules, calculating cash-in and cash-out tables, and preparing a detailed cashflow of the project scope. In order to prepare the cashflow, detailed information is calculated with regards to the loan terms and conditions such as the front-end fee, the commitment fee payments, the advance payments against each of the projects. Also, the sheets calculate the loan amortization schedule, which has a distinctive nature as the loan disbursements are linked to the project results. The sheets provide the interest payable and principal loan repayment schedules.

In order to eliminate any data entry or a processing error, system checks are designed along with the model in order to ensure the reliability of the data provided and processed along the way. The system checks purpose is to eliminate any human error. The checks are performed automatically and designed to guide the user to the location of the error. Errors may vary from missing data, wrongly inputted data, or unrealistic data processed.

During the procurement phase of the model, the model shall aid the government officials in order to be able to select the most optimum packaging scenario that will minimize the amount of funds to be paid by the government. In other words, the model shall test several contents of each of the packages in order to reach the most optimum cashflow. The model does only offer the content of each package, yet it provides a clear path of the packages start and finish dates, the cost of each of the projects included, and the executing companies to be awarded the project. The model also divides the packages in a way that optimizes the project cashflow in order to meet the required results of the funding institution, which shall be the trigger of releasing the loan disbursements. In order to achieve that, the model contains optimization sheets that are designed with the aid of Palisade's Decision Tools Suite. The software uses genetic algorithms (GA) as a solving technique. The GA is a meta-heuristic optimization method that had been used for many construction engineering optimization problems, as shown in the literature, and proven its efficiency.

In order to test the validity of the model, data from an ongoing results-based-financed project have been used. In 2012, a press release was issued by the World Bank Group Board of Executive to announce the beginning of using the RBF funding mechanism, (The World Bank Group, 2012). A mega sanitation project located in Egypt is selected to implement the new funding method to it. This project shall serve as a case study for the constructed model. The lender institution is the International Bank for Reconstruction and Development. The Egyptian Government has been trying to perform several reforms in the sanitation sector. Despite the several projects implemented, the progress has been hindered by slow implementation and inflated construction costs, and poor quality, (The World Bank, 2015). The Egyptian Government has signed an agreement with the World Bank in order to be able to finance the required objectives. One of the main advantages of the RBF is to motivate the government to enhance the old systems in order to achieve the required results within the time frame and the quality agreed in order to receive the loan disbursements.

5 . 2 Navigation Sheets

The user-interface module has been constructed using the aid of Microsoft Excel and Visual Basic for Applications (VBA) programming language, (Figure 44). The navigation sheets were designed in a way to be more user friendly to non-technical users. Moreover, it controls the data entry process to ensure minimal errors obtained during the data processing stage. Dropdown menus and built-in formatted calendars are examples of how to control the format of the data entered. In addition, users are guided to pre-constructed data tables to fill in certain information for the same reason.

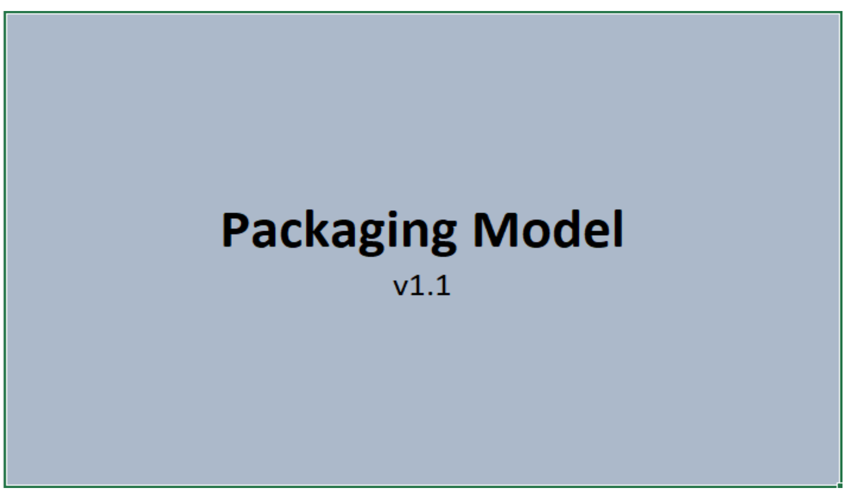


Figure 44: The Packaging Model

Figure 45 shows the homepage of the model, where the user navigates through the different parts of the model through it. The user shall be requested to enter a number of inputs,

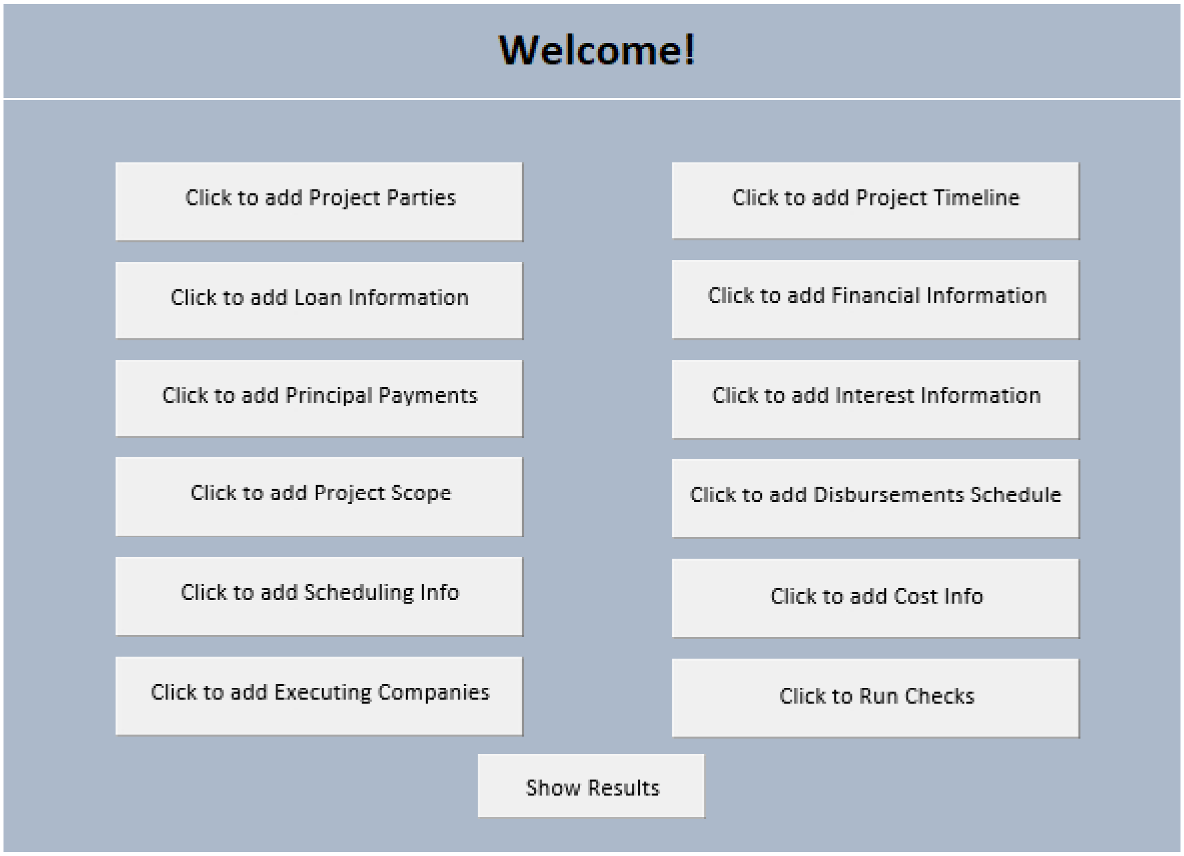


Figure 45: Model Home Page

including information about the signed agreements, important dates, and the expected timeline information. The user shall also be requested to enter some financial information such as the loan amount, payment terms, interest rate, interest cap and floor, principal payments, etc. Moreover, the inputs shall include some information about the scope, project schedule, and cost of items.

When the first button “Click to add Project Parties” is selected, the user shall be direct to the screen in Figure 46. The information reflects the agreement page in both the Loan Agreement and the Program Agreement. The Loan Agreement is the agreement between the international funding agency and the borrowing country. The financial institution is denoted by “Lender” and the borrowing country by “Borrower”. In the provided case study, the lender is the International Bank for Reconstruction and Development (IBRD), and the

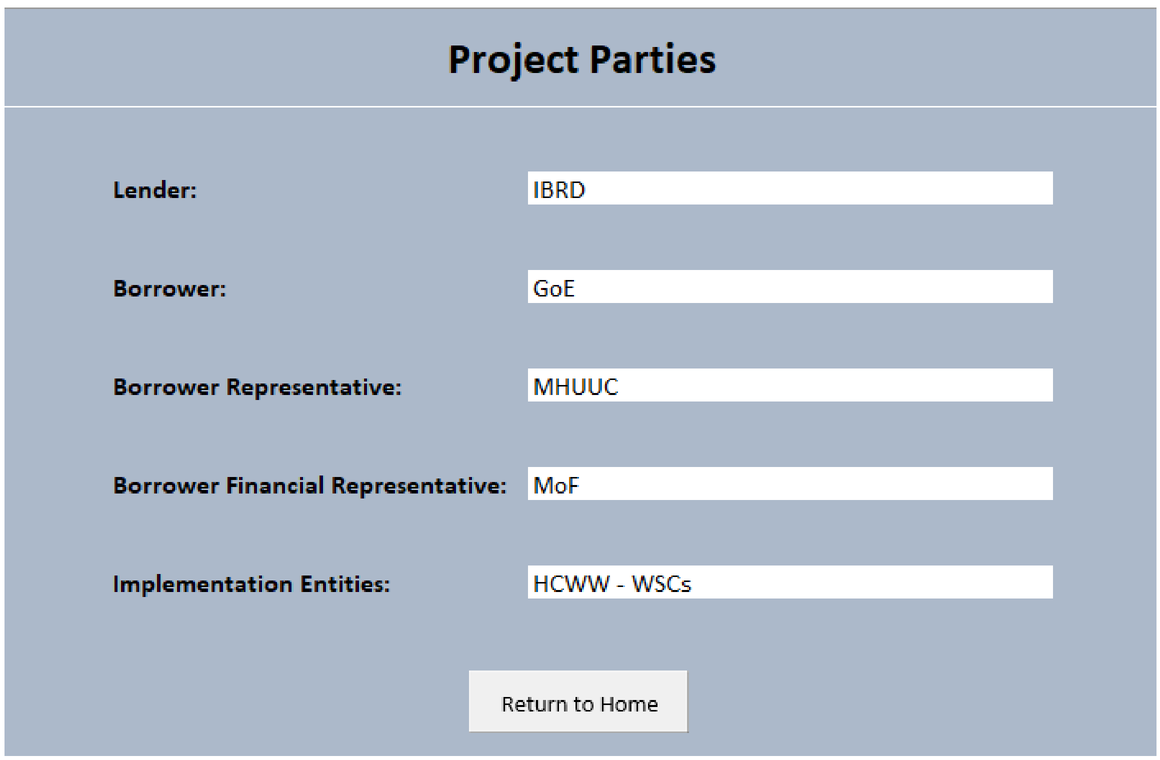


Figure 46: Project Parties

borrower is the Government of Egypt (GoE). Typically, the government shall have representatives from its institutions or ministries. The “Borrower Representative” and the “Borrower Financial Representative” are identified. The “Borrower Representative” is the Ministry of Housing, Utilities, and Urban Communities (MHUUC), and the “Borrower Financial Representative” is the Ministry of Finance (MoF). The Program Agreement is the agreement between the lender and the implementing institutions. The implementing entities shall be the institutions responsible for the operation and execution of the sanitation system in a country. In Egypt, it shall be the Holding Company for Water and Wastewater (HCWW) along with the Water Sanitation Companies (WSCs).

After completing each of the inputs in the different screens, the user shall return to the homepage using the button “Return to Home”. The following screen is to enter the contractual project dates, as shown in Figure 47. The user is requested to enter the

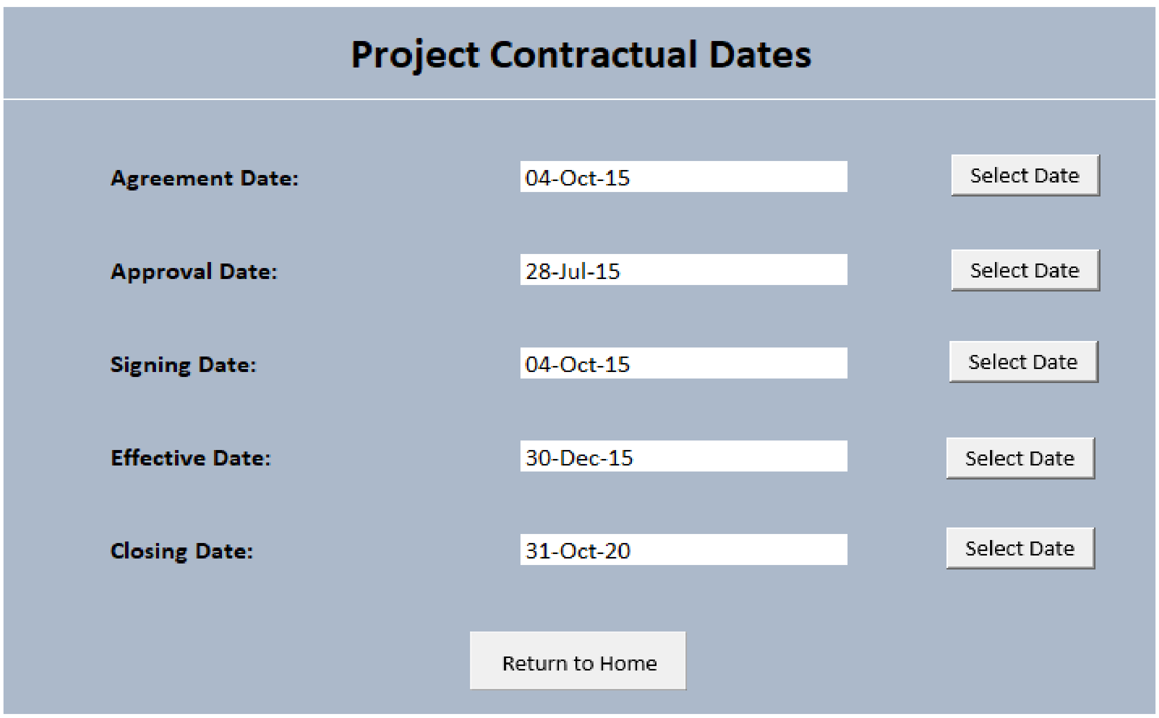


Figure 47: Project Contractual Dates

agreement date, the approval date, the signing date, the effective date, and the closing date. Each of the requested dates shall be used later in the model in different locations. In order to minimize any errors due to using the wrong format by the user, the VBA software shall be used to ensure that. The user shall select the dates via a built-in calendar micro where the macro shall be coded to fill the cells with a unique format.

After finalizing the dates entry, the user is to enter the loan financial information shown in Figure 48. The results-based finance funding approach is usually used in financing mega strategic projects. The total cost of the project usually comes from different contributors. The first contributor is the country institutions. The second option is to be financed by a lending institution. Finally, the last option is to receive grants and donations from international agencies. The objective of this phase of the data entry is to identify each portion of the project cost and its source. The screen requests the borrower’s amount, the

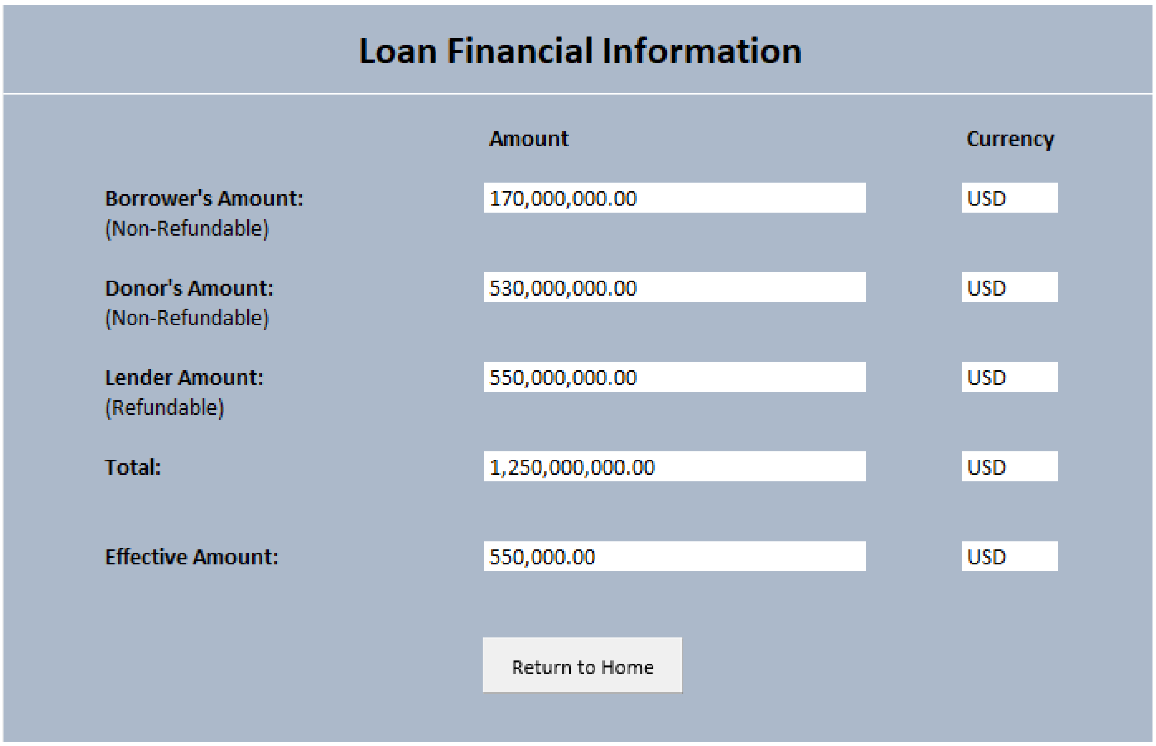


Figure 48: Loan Financial Information

donor’s amount, and the lender’s amount to calculate the total program cost. Also, the user shall select the currency from a dropdown menu again to minimize data entry errors due to misspelling or any other human error. The total cost of the program of the case study is 1.25 billion USD. The expected amount to be financed by the Egyptian government is 170 million USD, while the lender shall finance 550 million USD. Another 530 million USD shall be donated by other financial institutions.

The following screen aim is to input other financial information, Figure 49. The first input is the front-end fee, which is a single payment that is deducted from the loan amount at the beginning of the project. The following input is the commitment charge, which shall be paid frequently along the lifetime of the project against the unwithdrawn loan amount. The user shall define the annum percentage and the frequency of payment from another dropdown menu to ensure no errors. The user shall select a single currency to express the project cashflow in it. Unifying the currency along the model is an essential step. The total project cost and other financial expenses, such as the different financial fees and interest payments, shall be calculated in one currency to be able to obtain net cashflow. The same goes for the collected disbursements. Any advance payments that are stipulated in the contract conditions shall be expressed at the bottom of the screen. Moreover, the advance payment recovery method shall be selected from a menu. If not selected, the default value shall be "Upon DLI Achievement" as the recovery of the advance payments is usually done after the DLI value itself is collected. The front-end fee in the given case study is 0.25%. The commitment charge is also 0.25% pain semi-annually, while the first payment accrues 60 days after the signing date of the Loan Agreement. The currency of payment is selected to be the United States Dollars. The advance payment allowed in the Contract Conditions is 25% for each one of the DLIs and shall be fully recovered upon the DLI achievement.

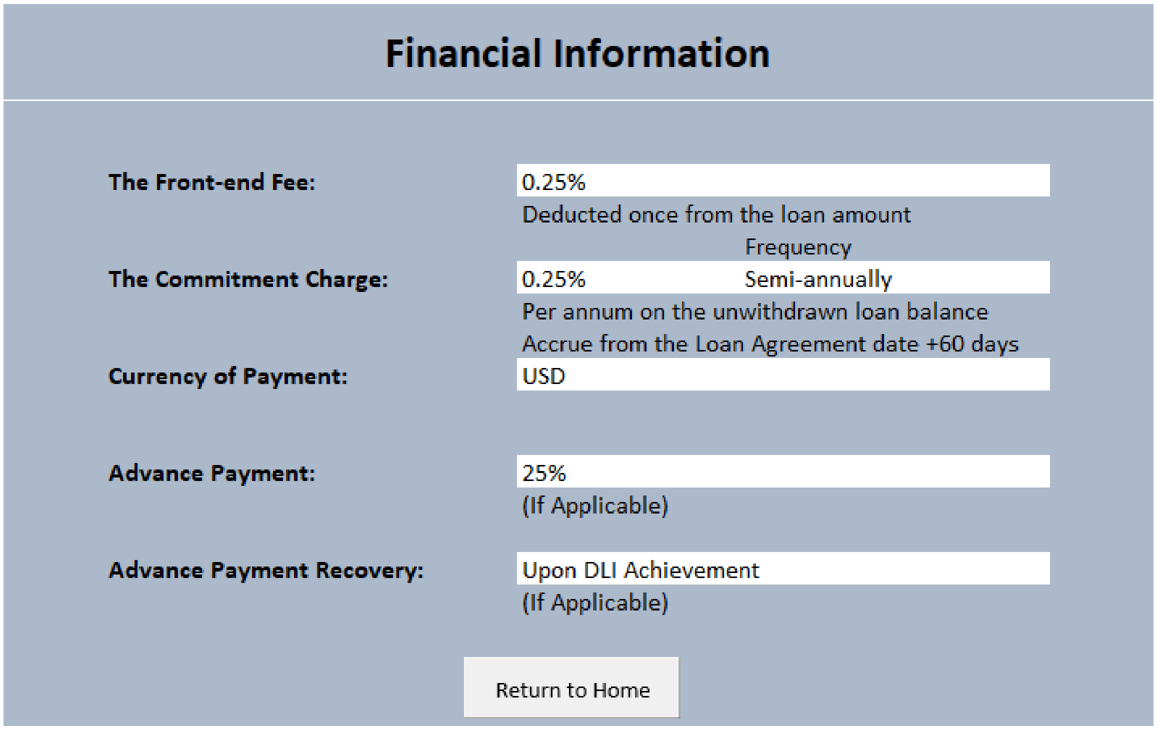


Figure 49: Other Financial Information

The user is then asked to input information with regard to the principal payment mechanism. In the rules of the engineering economy, the loan amortization schedule is generated from the monthly installments, where each installment is divided into two amounts allocated to the principal payment and the interest payment, respectively. Those amounts shall be different in each one of the installments. Yet, in some cases, the lender defines fixed percentages to be paid for the principal and the interest payments like the case in the presented case study. Hence, the model shall have two operation modes where the user shall select the method to calculate the loan amortization schedule. As shown in Figure 50, the two operation modes are "Regular Amortization Schedule" and "Fixed/Variable Spread". If the user selected the second mode of operation, he would be asked to input the installment share amount and the adjustment percentage for the last installment based on the number of installments. In the case study provided, there exist 50 payments, which shall consist of 49 payments of 1.67% and the 50th payment of 1.47% in order to obtain a total of 100% value of the loan.

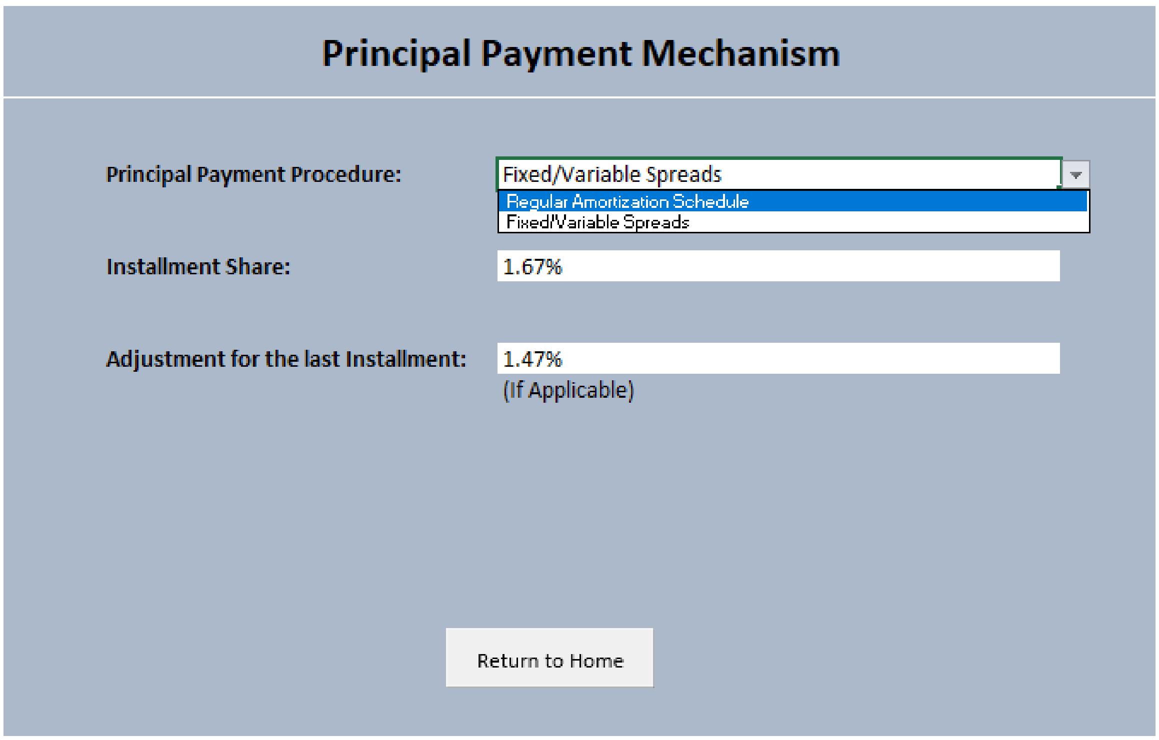


Figure 50: Principal Payment Mechanism

After defining the principal payment mechanism, the interest payment mechanism is detailed in the following screen, Figure 51. The user shall input an initial interest rate. For long-term loans, lenders usually tie the interest rate to a certain reference to avoid having an unrealistic figure. For instance, in the case study, the rate is tied against the London Inter-bank Offered Rate (LIBOR). In order to hedge the interest rate against high fluctuations, the contract parties may define an interest rate cap and an interest rate floor to protect the parties along with the project. In the case study, an interest rate cap of 3%

was selected while no floor is defined. The interest rate shall be semiannually paid along the periods defined.

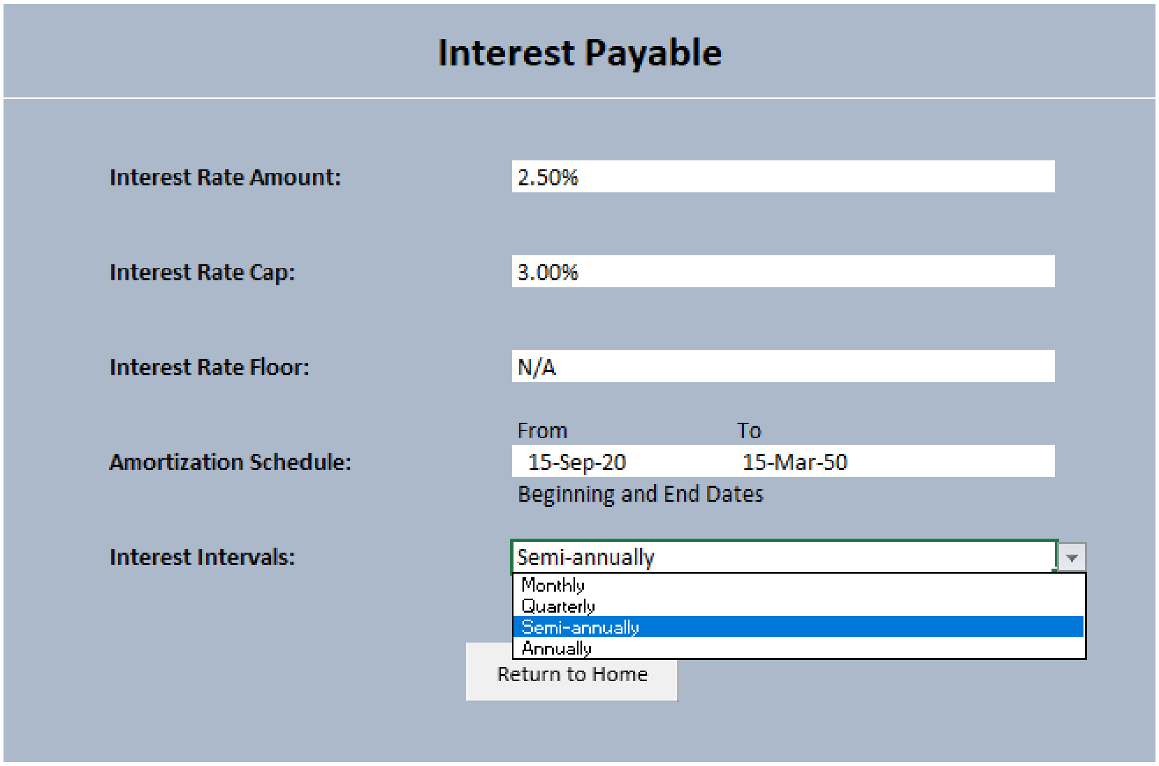


Figure 51: Interest Payment Information

The following group of inputs is the scope of the project and its time frame. The screen shown in Figure 52 reflects the different components of a typical scope of a mega sanitation project, which are the network, the pump station, and the treatment plants. The user shall first define the areas of execution; then, for each of the locations, different components of the projects are defined. Finally, the user shall define the scope execution dates, which are boundary dates. The dates are considered a contractual milestone and cannot be exceeded. They shall constitute one of the constraints in the model. The screen shall have different buttons that direct the user to other screens in order to fill in the required data.

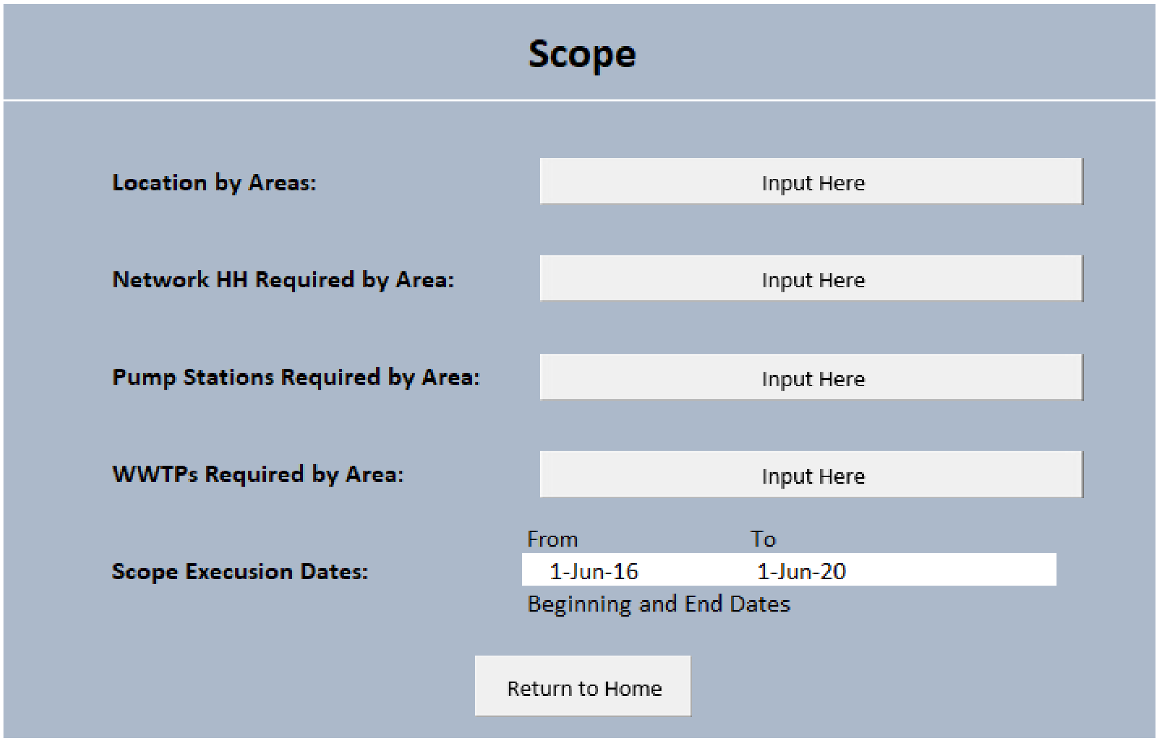


Figure 52: Scope Main Screen

The first set of data are the "Location by Areas", which shall direct the user to the screen shown in Figure 53. The project location shall be divided into certain areas and subareas. In the case study provided, the areas are given the governorate names while the subareas are given clusters names. The case study has three governorates: Dakahlia, Sharkia, and Beheira. A built-in macro code executed using the VBA language shall be responsible for the coding of the scope. For instance, for coding the locations, the first three letters of the areas are used as an acronym while the clusters are given a sequential numbering system. Figure 53 shows part of the coding system; the complete table shall be found in Appendix A. Another micro is designed in order to extend the formatted table as much as necessary to accommodate all the data entered with regards to the areas of scope. The information entered in the previous module shall be the basis for the later screens. The columns shall be automatically transferred to the next three groups of inputs. For each of the subareas, the user shall enter the scope required in terms of the required number of household connections, the pump stations, and the wastewater treatment plants that shall be executed. In order to navigate to the other screens, the user shall use the “back” button to get back to the screen in Figure 52.

Scope:

Kindly fill the below table:

Back

Ref	Area	Sub Area
Dak - 1	Dakahlia	Al Senblawin
Dak - 2	Dakahlia	Borg Nour Al Hommos
Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae
Dak - 4	Dakahlia	Al Robaa-C2 Villages
Dak - 5	Dakahlia	Shubrawish
Dak - 6	Dakahlia	Nawasa Al Ghayt
Dak - 7	Dakahlia	Demshlet Village
Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1
Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2
Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3
Dak - 11	Dakahlia	Meet Al Aamel 1
Dak - 12	Dakahlia	Meet Al Aamel 2
Dak - 13	Dakahlia	Meet Al Aamel 3
Dak - 14	Dakahlia	Barhamtoosh

Beh - 2	Beheira	Kom Hamada 2
Beh - 3	Beheira	Badr 1
Beh - 4	Beheira	Badr 2

Figure 53: Location by Areas

The user shall navigate the following three groups of inputs: “Network HH Required by Area”, “Pump Stations Required by Area” and “WWTPs Required by Area”. Figure 54 and Figure 55 show part of the screens dedicated to the data entry of the network scope and the wastewater treatment plant scope. The complete tables are shown in Appendix A. The areas and subareas information shall be ready for the user from the previous screen. In

Network HH Scope

Kindly fill the below table:

Back

Ref	Area	Sub Area	NT	
			Scope Yes/No	Target HH
NT - Dak - 1	Dakahlia	Al Senblawin	Yes	9,380
NT - Dak - 2	Dakahlia	Borg Nour Al Hommos	Yes	8,075
NT - Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae	Yes	2,125
NT - Dak - 4	Dakahlia	Al Robaa-C2 Villages	Yes	2,185
NT - Dak - 5	Dakahlia	Shubrawish	Yes	7,045
NT - Dak - 6	Dakahlia	Nawasa Al Ghayt	Yes	9,800
NT - Dak - 7	Dakahlia	Demshlet Village	Yes	3,980
NT - Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1	Yes	4,437
NT - Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2	Yes	4,437
NT - Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3	Yes	4,437
NT - Dak - 11	Dakahlia	Meet Al Aamel 1	Yes	3,447
NT - Dak - 12	Dakahlia	Meet Al Aamel 2	Yes	3,447
NT - Dak - 13	Dakahlia	Meet Al Aamel 3	Yes	3,446
NT - Dak - 14	Dakahlia	Barhamtoosh	Yes	4,245
NT - Dak - 24	Dakahlia	Dekerness	Yes	1,153
NT - Sha - 1	Sharkia	Gezeret Metawea	Yes	1,550
NT - Sha - 2	Sharkia	Zawar Abo Alil	Yes	1,320
NT - Sha - 3	Sharkia	Hamada	Yes	1,050

Figure 54: Required Number of Household Connections Defined by Area

WWTPs Scope

Kindly fill the below table:

Back

Ref	Area	Sub Area	TP		
			Scope Yes/No	Technology Used	Target m3/d
TP - Dak - 1	Dakahlia	Al Senblawin	Extension	Activated Sludge	33,000
TP - Dak - 2	Dakahlia	Borg Nour Al Hommos	Extension	Stabilization Ponds	5,000
TP - Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae	Yes	Stabilization Ponds	5,000
TP - Dak - 4	Dakahlia	Al Robaa-C2 Villages	Yes	NA	Ditto
TP - Dak - 5	Dakahlia	Shubrawish	Yes	Stabilization Ponds	7,500
TP - Dak - 6	Dakahlia	Nawasa Al Ghayt	Yes	Oxidation Ditches	10,000
TP - Dak - 7	Dakahlia	Demshlet Village	No	NA	-
TP - Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1	Extension	Stabilization Ponds	7,500
TP - Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2	Extension	NA	Ditto
TP - Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3	Extension	NA	Ditto
TP - Sha - 12	Sharkia	Hod Nageh	Yes	Stabilization Ponds	7,500
TP - Sha - 13	Sharkia	Kafr Dabous	Yes	Stabilization Ponds	5,000
TP - Sha - 14	Sharkia	Al Sids	Yes	Stabilization Ponds	9,000
TP - Beh - 1	Beheira	Kom Hamada 1	Yes	Stabilization Ponds	7,500
TP - Beh - 2	Beheira	Kom Hamada 2	Yes	NA	Ditto
TP - Beh - 3	Beheira	Badr 1	Yes	Oxidation Ditches	15,000
TP - Beh - 4	Beheira	Badr 2	Yes	NA	Ditto

Figure 55: The Wastewater Treatment Plants Required by Area

Figure 54, the user shall only state whether there exists a network scope in the area indicated by selecting “Yes” or “No” from a dropdown menu. Then, the user is required to enter the number of household connections required in each of the areas. The network scope shall automatically be assigned a distinctive reference through a built-in macro that uses the “NT” to indicate network scope followed by the Area code assigned earlier and a project number. In Figure 55, the user shall input similarly the nature of the scope required in the treatment plant. “Yes” indicates that a new treatment plant is required in the sub-area. “No” means no plants shall be required, and “Extension” means a renovation or an extension to an existing plant is required. The user shall select the technology used from a dropdown menu and shall indicate the required capacity of the plant. The previous information shall be used later in assessing the plant cost and scheduling data. Finally, a reference is assigned to each of the projects. “TP” at the beginning of the reference is an acronym for the treatment plant. The following three letters are the area code, and a distinctive serial is given to each of the projects.

After inputting the scope of work, the user shall return to the home screen in Figure 45 in order to add the disbursement schedule in Figure 56. The user shall enter some information in order to construct the disbursement schedule accordingly. First, the user shall enter the disbursement dates, which shall be the boundaries of the disbursement schedule. The disbursement frequency shall be selected, and the expected disbursement verification period is defined. This period shall be estimated according to the verification protocol explained earlier in the methodology. For the case study selected, the verification period is estimated to be 30 days from the submission of the Withdrawal Application to the actual money transfer from the lending institution to the borrower financial representative.

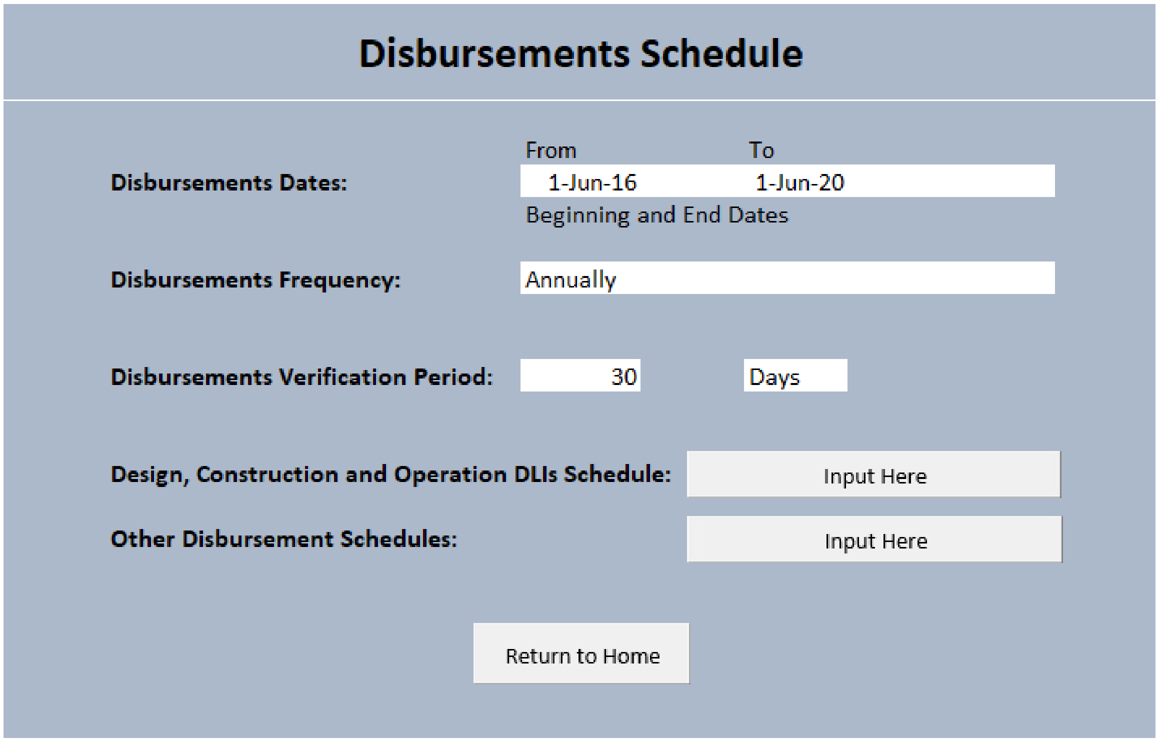
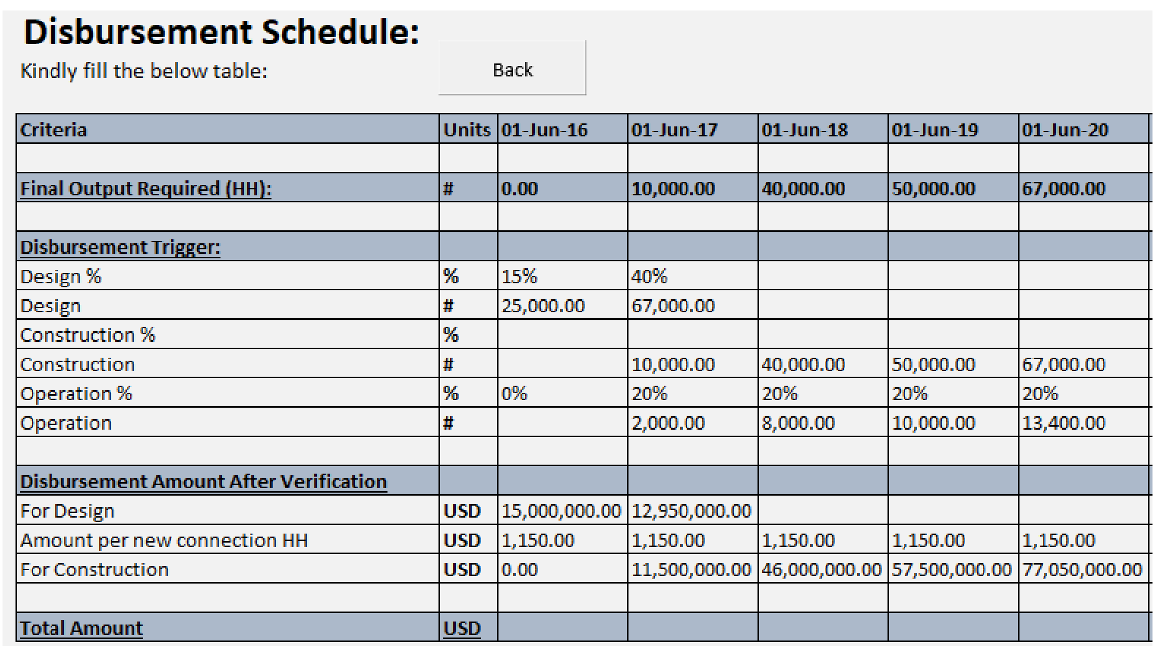


Figure 56: Disbursement Schedule

The user shall then enter the data for both the project execution DLIs and any other DLIs specified. Figure 57 shows the disbursement schedule with regards to the design,



Disbursement Schedule:

Kindly fill the below table: Back

Criteria	Units	01-Jun-16	01-Jun-17	01-Jun-18	01-Jun-19	01-Jun-20
Final Output Required (HH):	#	0.00	10,000.00	40,000.00	50,000.00	67,000.00
Disbursement Trigger:						
Design %	%	15%	40%			
Design	#	25,000.00	67,000.00			
Construction %	%					
Construction	#		10,000.00	40,000.00	50,000.00	67,000.00
Operation %	%	0%	20%	20%	20%	20%
Operation	#		2,000.00	8,000.00	10,000.00	13,400.00
Disbursement Amount After Verification						
For Design	USD	15,000,000.00	12,950,000.00			
Amount per new connection HH	USD	1,150.00	1,150.00	1,150.00	1,150.00	1,150.00
For Construction	USD	0.00	11,500,000.00	46,000,000.00	57,500,000.00	77,050,000.00
Total Amount	USD					

Figure 57: Detailed Disbursement Schedule

construction and operation DLIs. The disbursement schedule shall be pre-constructed using the information in the previous screen. The user shall input the disbursement linked indicators (DLIs) data in the allocated fields. The user shall be asked to enter the DLIs in order to ensure the alliance with its deadlines when deciding upon the timing of the packages. The output of the program is measured by the number of household connections (HH) to be designed and constructed in a certain area. The goal of the case study project is to construct 167,000 household connections functioning. This number is divided among the five years allocated to this program, as shown in the figure. The schedule is divided into two sections. The first section is the "disbursement triggers" which indicates the targets allocated to the required milestones. For example, by the first of June in 2017, it is required to finish the design of 67,000 household connections and to finish the construction of 10,000 household connections. The second section of the schedule illustrates the portions of the loan (disbursements) that shall be released upon the completion of the above-required results. In the above example, if the government were able to achieve the required target, the bank shall release an amount of USD 12,950,000 for the designed connections and an amount of USD11,500,000 for the constructed connections.

The user shall return back to Figure 56 in order to continue the input process of other DLIs. Figure 58 shows a pre-constructed table that the user shall fill in order to indicate the remaining DLIs required by the World Bank. Similar to the previous screen, the table consists of two parts. The top part shall include the description of the items and the measures required in order to verify the disbursement. While the bottom part shall include the amount to be disbursed.

Other DLIs Schedule:

Kindly fill the below table:

Back

Criteria (DLI Description)	Ref	Results Area	Unit	Total	01-Oct-15	01-Jun-16	01-Jun-17	01-Jun-18	01-Jun-19	01-Jun-20
Disbursement Trigger:										
DLI 2: Annual transfer of Performance Based Capital Grants (PBGC) by MHUCC to eligible WSCs	**DLI#2**	**1**				Yes	Yes	Yes	Yes	Yes
DLI 3: Design and implementation of the Annual Performance Assessment (APA) system for the WSCs, and WSCs achievement of the required APA threshold scores in accordance with the Program Operations Manual	**DLI#3**	**2**				3.1 PIAPs prepared for the three WSCs	3.2 A manual for carrying out the APA of the WSCs has been prepared and the first APA for each of the three WSCs has been carried out	3.3 Each WSC has achieved the minimum threshold APA scores in accordance with the manual and the Program Operations Manual	3.3 Each WSC has achieved the minimum threshold APA scores in accordance with the manual and the Program Operations Manual	3.3 Each WSC has achieved the minimum threshold APA scores in accordance with the manual and the Program Operations Manual
DLI 4: Preparation and approval of new national tariff structure for water and sanitation services by MHUUC to allow for sustainable cost recovery	**DLI#4**	**3**			4.1 New National Tariff Structure has been prepared by MHUUC		4.2 New National Tariff Structure has been approved by MHUUC and decree has been issued			
DLI 5: Establishment of PMU and approval of a National Rural Sanitation Strategy by MHUUC	**DLI#5**	**3**			5.1 PMU has been created with a mandate for theformulation and coordination of NRSP and the National Rural Sanitation Strategy		5.2 National Rural Sanitation Strategy has been approved by MHUUC	Key Action Plans for implementing the National Rural Sanitation Strategy have been designed (not time-bound; expectation/modelled for Year 3)	Key Action Plans for implementing the National Rural Sanitation Strategy have been designed (not time-bound; expectation/modelled for Year 3)	Key Action Plans for implementing the National Rural Sanitation Strategy have been designed (not time-bound; expectation/modelled for Year 3)
DLI6: Approval of Standard Operating Procedures for land acquisition under NRSP by MHUUC	**DLI#6**	**3**					Yes			
Disbursement Amount After Verification										
DLI 2: Annual transfer of Performance Based Capital Grants (PBGC) by MHUCC to eligible WSCs	**DLI#2**	**1**	**USD**	**40,000,000.00**		8,000,000.00	8,000,000.00	8,000,000.00	8,000,000.00	8,000,000.00
DLI 3: Design and implementation of the Annual Performance Assessment (APA) system for the WSCs, and WSCs achievement of the required APA threshold scores in accordance with the Program Operations Manual	**DLI#3**	**2**	**USD**	**170,000,000.00**		15,000,000.00	20,000,000.00	45,000,000.00	45,000,000.00	45,000,000.00
DLI 4: Preparation and approval of new national tariff structure for water and sanitation services by MHUUC to allow for sustainable cost recovery	**DLI#4**	**3**	**USD**	**50,000,000.00**	10,000,000.00		40,000,000.00			
DLI 5: Establishment of PMU and approval of a National Rural Sanitation Strategy by MHUUC	**DLI#5**	**3**	**USD**	**50,000,000.00**	10,000,000.00		30,000,000.00	3,333,333.33	3,333,333.33	3,333,333.33
DLI6: Approval of Standard Operating Procedures for land acquisition under NRSP by MHUUC	**DLI#6**	**3**	**USD**	**18,625,000.00**			18,625,000.00			
Total Amount			**USD**	**328,625,000.00**	**20,000,000.00**	**23,000,000.00**	**116,625,000.00**	**56,333,333.33**	**56,333,333.33**	**56,333,333.33**

Figure 58: Other DLIs Schedule

The user then returns to the home screen in order to enter the time schedules and the cost information. However, in the early stages of the project, some of the above information is not available yet. The user may select to assume some of the inputs, or he may resort to the built-in feature of the model. The built-in features provide default values for some of the inputs, such as the expected durations and costs of the projects and the different schools for calculating the loan amortization schedule. This feature is very important in case the user needs to forecast some values during the early stages of the project.

For example, the built-in feature in the model allows the user to select built-in schedules for networks project, pump station projects and wastewater treatment plants project, (Figure 59). This saves time and gives reasonable estimates to the project duration expected at early feasibility studies stages. Another example of the built-in feature is shown in Figure 59, which is part of the cost module. The user may enter predefined cost estimates for each of the projects, or the user may use default values. Parameters such as the length of the sewage network, the capacity of the pump stations, and the expected flows in treatment plants, are used in order to reach the cost estimate of concern. Another example of the built-in functions is used in preparing the loan amortization table, where the user has the choice of

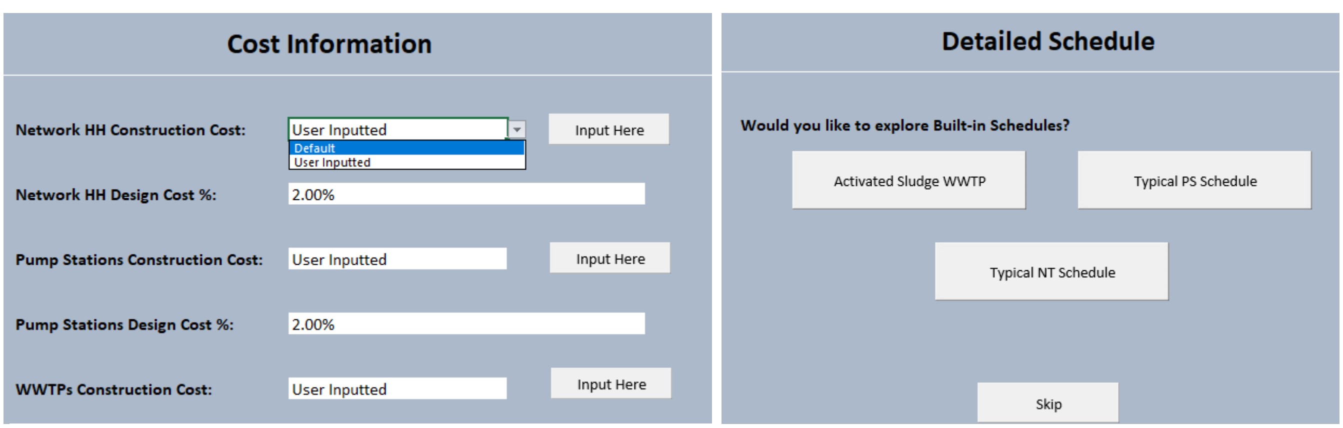


Figure 59: Examples of Built-In Features

automatically calculate the loan amortization table using engineering economy formulas or defining the principal portion like the case study that shall be discussed in the verification section.

5 . 3 Working Sheets

At this stage in the model, both the navigation sheets and the working sheets shall be working in parallel. The data inputted shall be processed in the background in the working sheets in order to develop schedules and cost information. The working sheets shall not be visible to the user; however, in the results section, the user may request to view the calculations sheets. The main reason for that is to avoid confusion for non-technical users of the model. The model shall disclose as many details as the user requests, as shall be shown in the results section.

The working sheets are coding sheets that shall define the different variables of the optimization process. Different schedules and cost information shall be processed to simulate the life cycle of the project in order to define the different scenarios of the packages. The sheets shall code the different components of the scope with their corresponding duration and cost in order to develop a master schedule for the work sequence. In addition, detailed schedules shall be developed for each component of the scope in order to develop a detailed cashflow for the project. The key execution companies shall also be defined in order to assess their market capacity and capabilities. The model shall determine the efficiency of each packaging scenario while ensuring that the disbursement linked indicators (DLIs) are respected and deadline dates are met. Moreover, a detailed comprehensive appropriation cashflow shall be developed in order to determine the portion of the project finances that shall be funded by the borrowing government. The objective function of the optimization process shall be to minimize the funds provided by the government in order to finance the project.

The following section of the model is concerned with time and cost information. The user shall be directed to the screen shown in Figure 60 to the Master Schedule Section. The purpose of this section is to define the relationships between the different parts of the scope. In other words, it shall define the dependencies (if they exist) between the different requirements of the scope. For instance, due to technical reasons, certain parts of the networks are required to be executed before other parts. Also, certain geographical areas are given priority due to an approved strategic plan, for example, or due to other political reasons or merely due to logistical plans. Hence, this part of the model shall highlight the previous requirements and ensure that the master schedule of the project respects the sequence inputted.

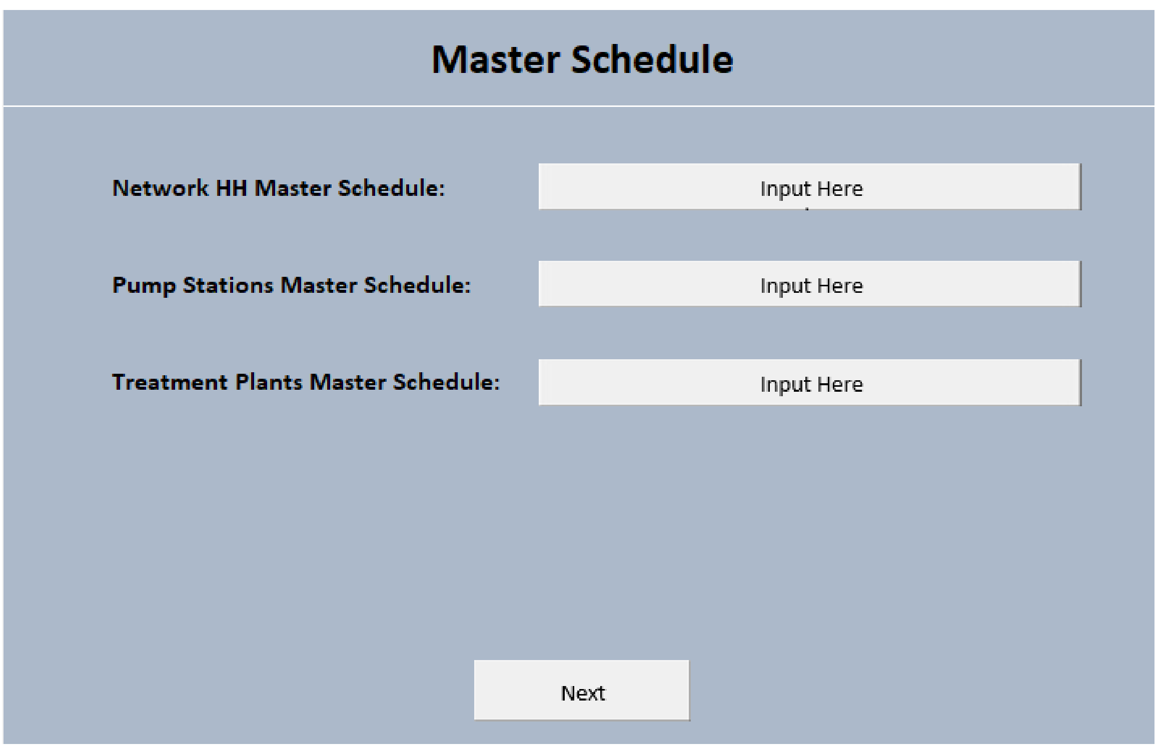


Figure 60: Master Schedule

After clicking the “Input Here” button in Figure 60, the user shall be directed to the corresponding sheet for the actual network, the pump stations, and the treatment plants. A sample of what the sheet shall look like is shown in Figure 61, which corresponds to the

Network HH Master Schedule

Kindly fill the below table:

Back

Ref	Area	Sub Area	NT Predecessor NT Activity	 Predecessor PS Activity	 Predecessor TP Activity
NT - Dak - 1	Dakahlia	Al Senblawin	NA	NA	TP - Dak - 1
NT - Dak - 2	Dakahlia	Borg Nour Al Hommos	NA	NA	TP - Dak - 2
NT - Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae	NA	NA	TP - Dak - 3
NT - Dak - 4	Dakahlia	Al Robaa-C2 Villages	NT - Dak - 3	NA	TP - Dak - 4
NT - Dak - 5	Dakahlia	Shubrawish	NA	NA	TP - Dak - 5
NT - Dak - 6	Dakahlia	Nawasa Al Ghayt	NA	NA	TP - Dak - 6
NT - Dak - 7	Dakahlia	Demshlet Village	NA	NA	NA
NT - Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1	NA	NA	TP - Dak - 8
NT - Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2	NT - Dak - 8	NA	TP - Dak - 9
NT - Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3	NT - Dak - 9	NA	TP - Dak - 10
NT - Dak - 11	Dakahlia	Meet Al Aamel 1	NA	NA	NA
NT - Dak - 12	Dakahlia	Meet Al Aamel 2	NT - Dak - 11	NA	NA
⋮					
NT - Sha - 14	Sharkia	Al Sids	NA	NA	TP - Sha - 14
NT - Beh - 1	Beheira	Kom Hamada 1	NA	NA	TP - Beh - 1
NT - Beh - 2	Beheira	Kom Hamada 2	NT - Beh - 1	NA	TP - Beh - 2
NT - Beh - 3	Beheira	Badr 1	NA	NA	TP - Beh - 3
NT - Beh - 4	Beheira	Badr 2	NA	NA	TP - Beh - 4

Figure 61: Network Master Schedule

networks part of the scope. The table shall generate automatically based on the scope entered before in Figure 54. As mentioned before, each area and subarea of the scope are given distinctive codes. These codes shall be used to define the relationship between the area and subareas by choosing the code of the predecessor project. The table has three columns representing the network projects, the pump station projects, and the wastewater treatment plants. Each cell of the three columns has a dropdown menu with the codes of all the projects in the program. The user shall select any restrictions in the sequence of the projects in order to be respected while generating the master schedule of the program.

After finishing the sheet corresponding to the networks, the pump stations, and the treatment plants, the user shall go back to Figure 60 to press “Next” in order to go to the following input group. Figure 62 shall include the following group of inputs. It shall be concerned with the detailed schedule of each of the projects. The user shall have two options, as shown in Figure 62. Either to select the built-in feature in the model or to input the schedule in detail. The model has three typical schedules for a network execution project, a pump station project, and an activated sludge wastewater treatment plant. The reason behind selecting the activated sludge technology is that the literature has shown that it is the most predominant technology that is used in the country where the case study is applied. The user shall use the built-in schedule to estimate the durations for each of the projects.

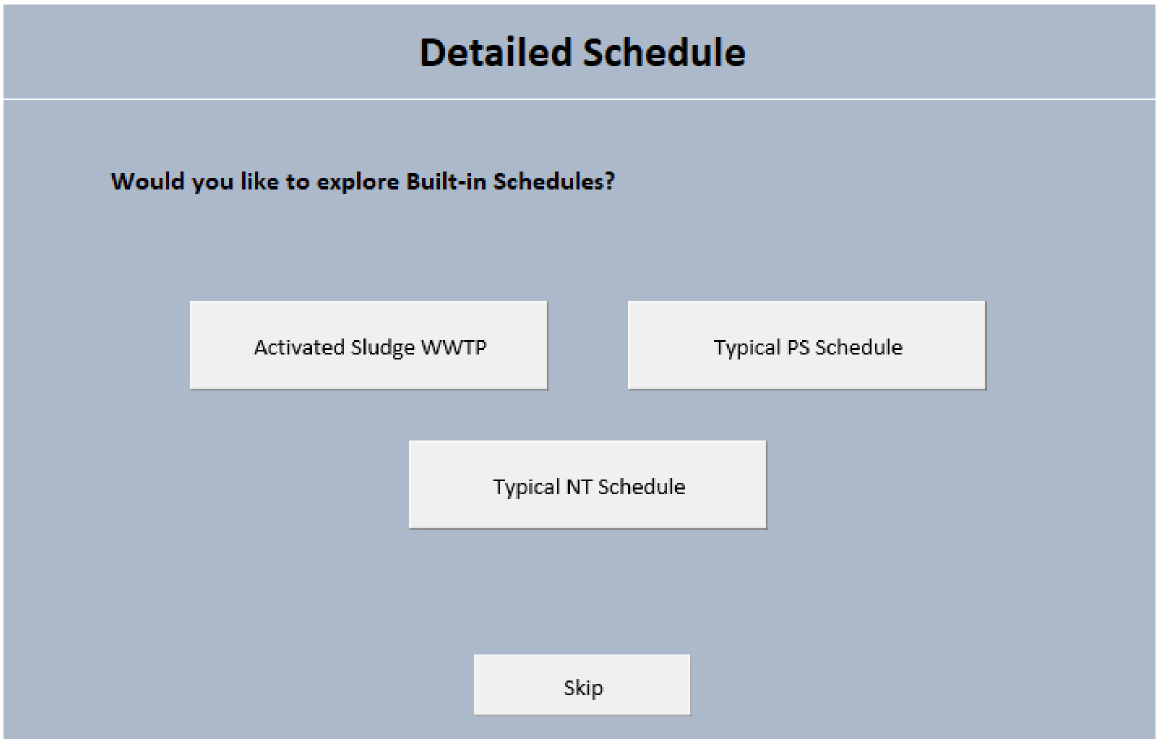


Figure 62: Detailed Schedule Navigation Sheet

Figure 63 shows part of a typical activated sludge wastewater treatment plant work breakdown structure (WBS) that shall be showed to the user to examine in case the user selected the built-in feature. The user may also examine the dependencies between the different activities and may also adjust any of the dependencies to his satisfaction, as shown

Wastewater Treatment Plant WBS							
Code	Level 1	Code	Level 2	Code	Level 3	Code	Activity Level
TP-A	Commencement & Site Handing Over	TP-A-10000	Site Handing Over	TP-A-10100	Site Handing Over	TP-A-10101	Site Handing Over
TP-B	Site Mobilization	TP-B-10000	Site Mobilization	TP-B-10100	Site Mobilization	TP-B-10101	Site Mobilization
TP-C	Surveying and Approvals	TP-C-10000	Site & Network Survey	TP-C-10100	Site & Network Survey	TP-C-10101	Site & Network Survey
		TP-C-20000	Permits and Environmental Approvals	TP-C-20100	Permits and Environmental Approvals	TP-C-20101	Permits and Environmental Approvals
TP-D	Geotechnical Test	TP-D-10000	Geotechnical Test	TP-D-10100	Geotechnical Test	TP-D-10101	Geotechnical Test
TP-E	Engineering	TP-E-10000	Engineering Drawings	TP-E-10100	Engineering Drawings	TP-E-10101	Hydraulic Profile Submittal & Approval
				TP-E-10200	P&ID Submittal & Approval	TP-E-10201	P&ID Submittal & Approval
				TP-E-10300	General Civil Outline Submittal & Approval	TP-E-10301	General Civil Outline Submittal & Approval
				TP-E-10400	General arrangement Layout Drawing Submittal & Approval	TP-E-10401	General arrangement Layout Drawing Submittal & Approval
				TP-E-10500	Geo Technical Report Submittal & Approval	TP-E-10501	Geo Technical Report Submittal & Approval
				TP-E-10600	Structural Drawing & Calculation Drawings & Approval	TP-E-10601	Structural Drawing & Calculation Drawings & Approval
		TP-E-20000	Electromechanical Equipment Submittal	TP-E-20100	Equipment Submittal	TP-E-20101	Equipment Submittal
				TP-E-20200	Equipment Submittal Review	TP-E-20201	Equipment Submittal Review
				TP-E-20300	Equipment Submittal Approval	TP-E-20301	Equipment Submittal Approval
TP-F	Electromechanical Procur	TP-F-10000	Overseas Equipment	TP-F-10100	Seepage Acceptance Station	TP-F-10101	PO Release

Figure 63: Part of WWTP WBS

in Figure 64, using the allocated code of the activity. The complete WBS and dependencies plans shall be included in Appendix A. Durations of the activities are also predefined, yet they can be modified by the user to reflect any amendment needed. The following screen, shown in Figure 65, shows the user a bar chart of the project of concern. The bar chart is a very useful tool to visualize the project progress along the project timeline. The user may also enter a commencement date to get an estimate of each of the activities start and finish date to assess the situation.

Wastewater Treatment Plant								
			Predecessor#1		Predecessor#2		Predecessor#3	
Code	Activity Description	Duration	Code	Activity Description	Code	Activity Description	Code	Activity Description
TP-A-10101	Site Handing Over	0						
TP-B-10101	Site Mobilization	10	TP-A-10101	Site Handing Over				
TP-C-10101	Site & Network Survey	1	TP-B-10101	Site Mobilization				
TP-C-20101	Permits and Environmental Approvals	32	TP-A-10101	Site Handing Over				
TP-D-10101	Geotechnical Test	10	TP-B-10101	Site Mobilization				
TP-E-10101	Hydraulic Profile Submittal & Approval	40	TP-C-10101	Site & Network Survey				
TP-E-10201	P&ID Submittal & Approval	40	TP-E-10101	Hydraulic Profile Submittal & Approval				
TP-E-10301	General Civil Outline Submittal & Approval	40	TP-C-20101	Permits and Environmental Approvals	TP-E-10101	Hydraulic Profile Submittal & Approval		
TP-E-10401	General arrangement Layout Drawing Submittal & Approval	15	TP-E-10201	P&ID Submittal & Approval				
TP-E-10501	Geo Technical Report Submittal & Approval	20	TP-D-10101	Geotechnical Test				
TP-E-10601	Structural Drawing & Calculation Drawings & Approval	10	TP-E-10301	General Civil Outline Submittal & Approval	TP-E-10501	Geo Technical Report Submittal & Approval		

Figure 64: Part of WWTP Dependencies

Wastewater Treatment Plant

Please Input the Commencement Date:	5-Feb-18	Back

Activity	Activity Description	Duration	ES	EF	Feb-18	Mar-18	Apr-18	May-18	Jun-18	Jul-18	Aug-18	Sep-18
TP-A-10101	Site Handing Over	0										
TP-B-10101	Site Mobilization	10	5-Feb-18	15-Feb-18	■							
TP-C-10101	Site & Network Survey	1	16-Feb-18	17-Feb-18								
TP-C-20101	Permits and Environmental Approvals	32	5-Feb-18	9-Mar-18	■	■						
TP-D-10101	Geotechnical Test	10	16-Feb-18	26-Feb-18								
TP-E-10101	Hydraulic Profile Submittal & Approval	40	18-Feb-18	30-Mar-18		■						
TP-E-10201	P&ID Submittal & Approval	40	31-Mar-18	10-May-18			■	■				
TP-E-10301	General Civil Outline Submittal & Approval	40	31-Mar-18	10-May-18			■	■				
TP-E-10401	General arrangement Layout Drawing Submittal & Approval	15	11-May-18	26-May-18								
TP-E-10501	Geo Technical Report Submittal & Approval	20	27-Feb-18	19-Mar-18		■						
TP-E-10601	Structural Drawing & Calculation Drawings & Approval	10	11-May-18	21-May-18								
TP-E-20101	Equipment Submittal	30	22-May-18	21-Jun-18					■			
TP-E-20201	Equipment Submittal Review	10	22-Jun-18	2-Jul-18								
TP-E-20301	Equipment Submittal Approval	1	3-Jul-18	4-Jul-18								
TP-F-10101	PO Release	15	5-Jul-18	20-Jul-18						■		

Figure 65: Part of a typical WWTP Bar Chart

However, if the user has already estimated figures of the durations of the projects during this stage of the study, in Figure 62, the skip button should direct him to Figure 66. In the

Figure 66: Detailed Schedules

figure, there are three buttons corresponding to each of the project's types. The user shall use the buttons to be directed to a more detailed sheet in order to enter the duration of each of the projects specified in the scope sheet.

For instance, if the user selected the button allocated to the network's projects, the model shall open a sheet similar to Figure 67. The first three columns of the table shall be filled automatically from the scope sheets filled before. The user shall be requested to fill in the design and construction durations columns. In most cases, the design is awarded to a different company than the construction except in the case of hiring design-build contractors. The model should put this into account when processing the sequence of the projects in the program. Also, the disbursement linked indicators (DLIs) usually contain terms and conditions for achieved results that have to do with the design separate from other DLIs for the execution and successfully operating the project. Moreover, during the

Network HH Durations

Kindly fill the below table:

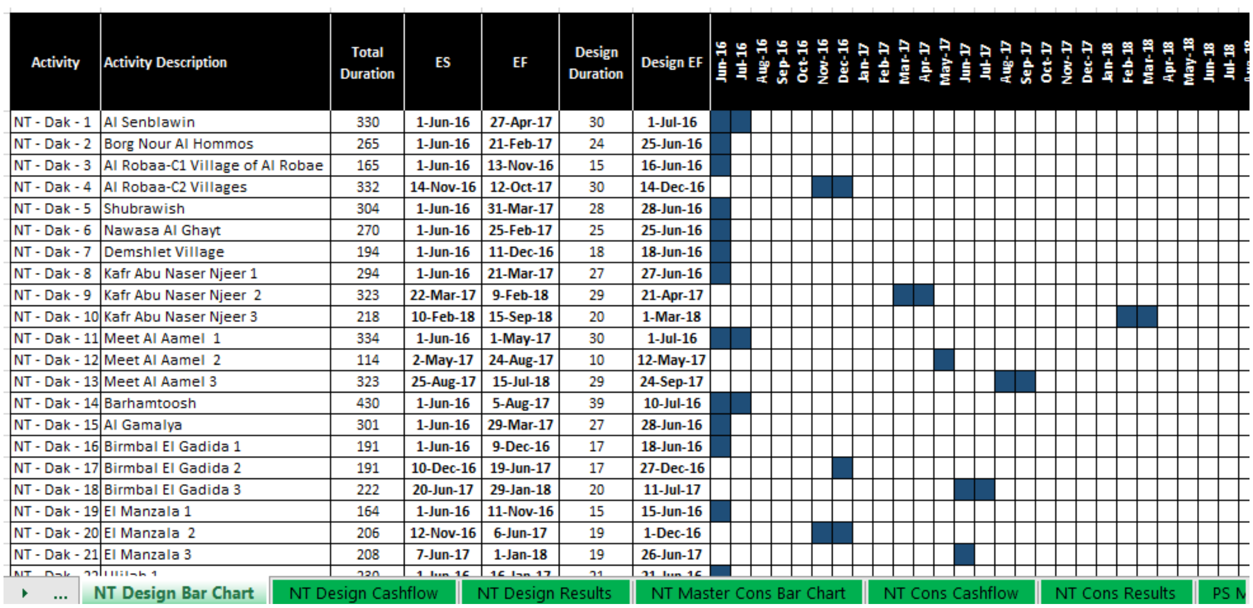
Back

Ref	Area	Sub Area	NT Duration	
			Design	Construction
			Days	Days
NT - Dak - 1	Dakahlia	Al Senblawin	30	300
NT - Dak - 2	Dakahlia	Borg Nour Al Hommos	24	241
NT - Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae	15	150
NT - Dak - 4	Dakahlia	Al Robaa-C2 Villages	30	302
NT - Dak - 5	Dakahlia	Shubrawish	28	276
NT - Dak - 6	Dakahlia	Nawasa Al Ghayt	25	245
NT - Dak - 7	Dakahlia	Demshlet Village	18	176
NT - Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1	27	267
NT - Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2	29	294
NT - Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3	20	198
NT - Dak - 11	Dakahlia	Meet Al Aamel 1	30	304
NT - Dak - 12	Dakahlia	Meet Al Aamel 2	10	104
NT - Dak - 13	Dakahlia	Meet Al Aamel 3	29	294
⋮				
NT - Sha - 13	Sharkia	Kafr Dabous	19	187
NT - Sha - 14	Sharkia	Al Sids	11	109
NT - Beh - 1	Beheira	Kom Hamada 1	19	187
NT - Beh - 2	Beheira	Kom Hamada 2	29	289
NT - Beh - 3	Beheira	Badr 1	30	301
NT - Beh - 4	Beheira	Badr 2	18	177

Figure 67: Networks Projects Durations

optimization process, durations shall be a variable that changes depending on the efficiency and production rate of the executing company. The timing of a negative cashflow shall vary accordingly; hence, it is very crucial to the minimization of the government funds. This inputted information shall be processed by the model in the background to prepare bar charts and cashflow diagrams as well later in the results section.

The model shall develop the design and execution schedules. Figure 68 shows part of the plot showing a preliminary sequence of the design process of sanitation network projects performed in "Dakahlia." The model shows the sequence in the form of a bar chart in order to be easy to follow by a non-engineering background government official. The user shall get a sense of the sequence of projects and their start and finish dates. This plot shall be adjusted via the model optimization tools in order to reach the optimum sequence of execution to fit the required disbursements linked indicators.



Activity	Activity Description	Total Duration	ES	EF	Design Duration	Design EF
NT - Dak - 1	Al Senblawin	330	1-Jun-16	27-Apr-17	30	1-Jul-16
NT - Dak - 2	Borg Nour Al Hommos	265	1-Jun-16	21-Feb-17	24	25-Jun-16
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	165	1-Jun-16	13-Nov-16	15	16-Jun-16
NT - Dak - 4	Al Robaa-C2 Villages	332	14-Nov-16	12-Oct-17	30	14-Dec-16
NT - Dak - 5	Shubrawish	304	1-Jun-16	31-Mar-17	28	28-Jun-16
NT - Dak - 6	Nawasa Al Ghayt	270	1-Jun-16	25-Feb-17	25	25-Jun-16
NT - Dak - 7	Demshlet Village	194	1-Jun-16	11-Dec-16	18	18-Jun-16
NT - Dak - 8	Kafr Abu Naser Njeer 1	294	1-Jun-16	21-Mar-17	27	27-Jun-16
NT - Dak - 9	Kafr Abu Naser Njeer 2	323	22-Mar-17	9-Feb-18	29	21-Apr-17
NT - Dak - 10	Kafr Abu Naser Njeer 3	218	10-Feb-18	15-Sep-18	20	1-Mar-18
NT - Dak - 11	Meet Al Aamel 1	334	1-Jun-16	1-May-17	30	1-Jul-16
NT - Dak - 12	Meet Al Aamel 2	114	2-May-17	24-Aug-17	10	12-May-17
NT - Dak - 13	Meet Al Aamel 3	323	25-Aug-17	15-Jul-18	29	24-Sep-17
NT - Dak - 14	Barhamtoosh	430	1-Jun-16	5-Aug-17	39	10-Jul-16
NT - Dak - 15	Al Gamalya	301	1-Jun-16	29-Mar-17	27	28-Jun-16
NT - Dak - 16	Birmbal El Gadida 1	191	1-Jun-16	9-Dec-16	17	18-Jun-16
NT - Dak - 17	Birmbal El Gadida 2	191	10-Dec-16	19-Jun-17	17	27-Dec-16
NT - Dak - 18	Birmbal El Gadida 3	222	20-Jun-17	29-Jan-18	20	11-Jul-17
NT - Dak - 19	El Manzala 1	164	1-Jun-16	11-Nov-16	15	15-Jun-16
NT - Dak - 20	El Manzala 2	206	12-Nov-16	6-Jun-17	19	1-Dec-16
NT - Dak - 21	El Manzala 3	208	7-Jun-17	1-Jan-18	19	26-Jun-17

Figure 68: Part of the Master Bar Chart for the Sanitation Network Projects

The following set of inputs on the home screen is the cost information. Figure 69 shows the cost information sheets navigation screen. The user shall be asked to input two types of cost information. The first type is costs related to the design, construction and operation DLIs, while the second type relates to other DLIs.

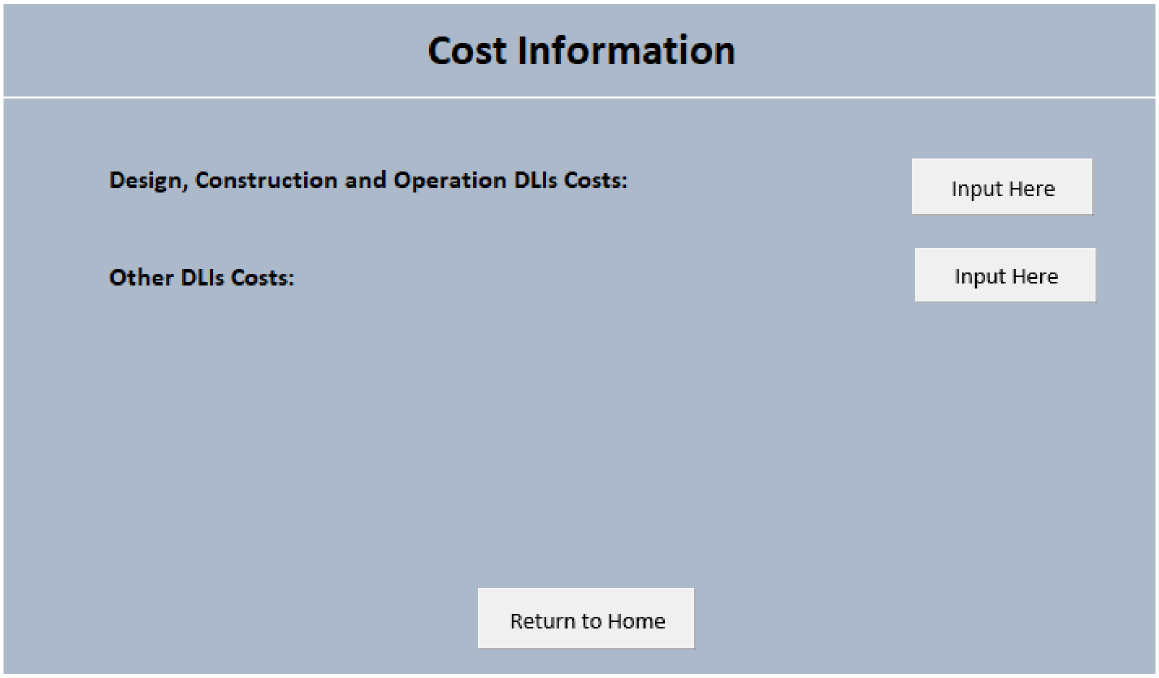


Figure 69: Cost Information

Figure 70 shows the cost information screen related to the design, construction and operation DLIs where, again, the user shall have to choose between selecting default values or input the costs in the model. The cost module shall guide the user to pre-inputted values for similar projects that can guide the cost estimation team through the early stages of the project plan, as shown in Figure 71. The model shall have two types of costs: the construction cost and the design cost. An assumption can be made to calculate the design cost as a fixed percentage of the construction cost, especially at the early stages of the project. The user shall have separate sheets for each type of project and shall be directed to them via the buttons on the right of the screen.

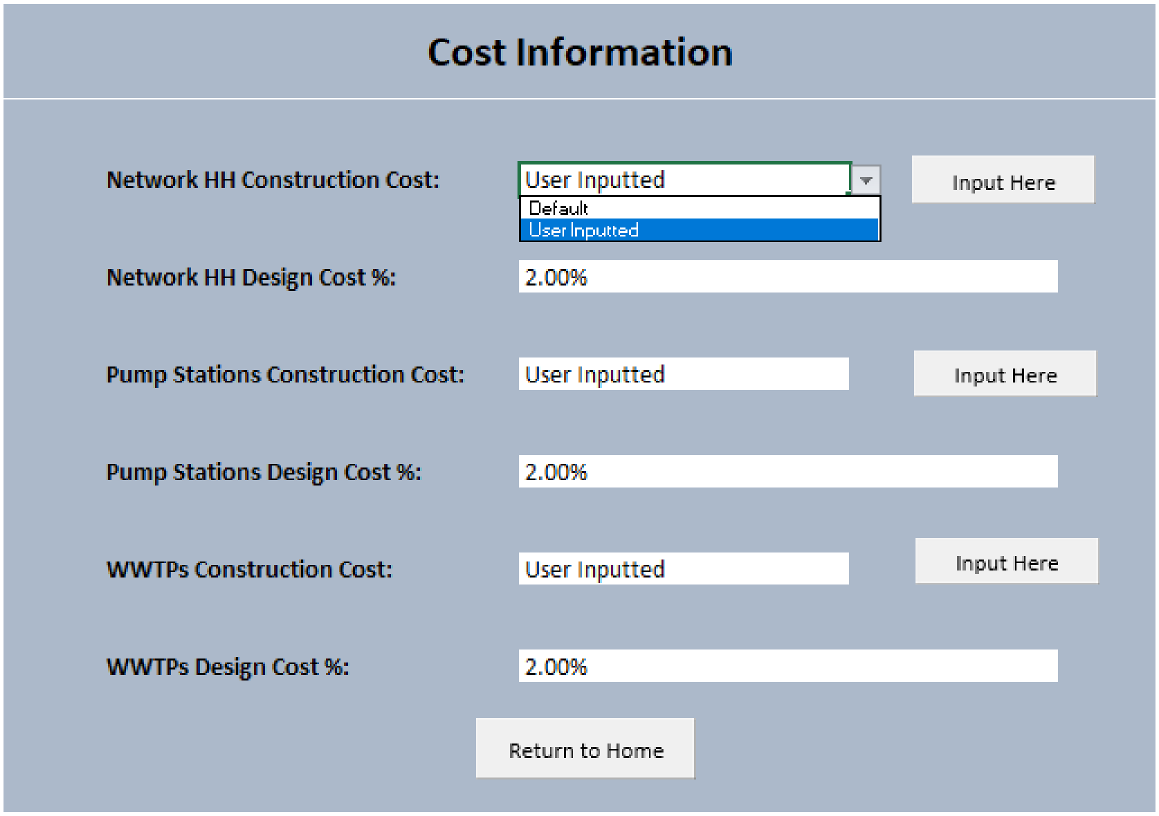


Figure 70: DCO Cost Information

Wastewater Treatment Plant

Code	Activity Description	Duration	Material	Overseas Cost in 2015	Local Cost in 2015
TP-F-10101	PO Release	15	Seepage Acceptance Station	201,331.00	
TP-F-10102	Ex- Work delivery	90			
TP-F-10103	Shipping	30			
TP-F-10104	Custom Clearance & Transportation to Site	15			
TP-F-10201	PO Release	15	Mechanical Fine Screens	253,078.00	
TP-F-10202	Ex- Work delivery	90			
TP-F-10203	Shipping	30			
TP-F-10204	Custom Clearance & Transportation to Site	15			
TP-F-10301	PO Release	15	Manual Coarse Bar Screen	253,078.00	
TP-F-10302	Ex- Work delivery	90			
TP-F-10303	Shipping	30			
TP-F-10304	Custom Clearance & Transportation to Site	15			
TP-F-10401	PO Release	15	Belt Conveyor	253,078.00	
TP-F-10402	Ex- Work delivery	90			
TP-F-10403	Shipping	30			
TP-F-10404	Custom Clearance & Transportation to Site	15			
TP-F-10501	PO Release	15	Grit Pumps	43,779.00	

Figure 71: Cost Module Pre-Inputted Values

When the user selects to input the costs, the model shall direct the user to a table of the project lists in order to input the corresponding costs. An example of the user inputted cost sheets is shown in Figure 72. The first three columns in the figure show a list of wastewater treatment plant projects that was extracted from the scope sheets. At the appropriation cost stage of the project, estimate figures should be prepared for each of the projects in the program. The user shall input the figures in the currency predefined in the financial information sheets at the beginning of the model. The currency used shall also be defined in the header of the fourth column of the table as a reminder. The design costs shall be calculated based on the percentage of the construction cost that is defined in the cost information sheet.

WWTPs Cost

Kindly fill the below table:

Back

Ref	Area	Sub Area	TP Construction Cost USD
TP - Dak - 1	Dakahlia	Al Senblawin	41,481,000
TP - Dak - 2	Dakahlia	Borg Nour Al Hommos	6,285,000
TP - Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae	3,142,500
TP - Dak - 4	Dakahlia	Al Robaa-C2 Villages	3,142,500
TP - Dak - 5	Dakahlia	Shubrawish	9,427,500
TP - Dak - 6	Dakahlia	Nawasa Al Ghayt	12,570,000
TP - Dak - 7	Dakahlia	Demshlet Village	NA
TP - Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1	3,142,500
TP - Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2	3,142,500
TP - Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3	3,142,500
TP - Dak - 11	Dakahlia	Meet Al Aamel 1	NA
TP - Dak - 12	Dakahlia	Meet Al Aamel 2	NA
TP - Dak - 13	Dakahlia	Meet Al Aamel 3	NA
TP - Dak - 14	Dakahlia	Barhamtoosh	NA
TP - Dak - 15	Dakahlia	Al Gamalya	12,570,000
⋮			
TP - Sha - 13	Sharkia	Kafr Dabous	6,285,000
TP - Sha - 14	Sharkia	Al Sids	11,313,000
TP - Beh - 1	Beheira	Kom Hamada 1	4,713,750
TP - Beh - 2	Beheira	Kom Hamada 2	4,713,750
TP - Beh - 3	Beheira	Badr 1	9,427,500
TP - Beh - 4	Beheira	Badr 2	9,427,500

Figure 72: Networks Projects Construction Costs

The user shall then return to the screen in Figure 69 in order to be directed to enter any other related costs to other DLIs. The user shall be directed to the screen in Figure 73, which shall be ready to enter the values of each of the DLIs. The dates and the DLIs descriptions are extracted from the data entered in the previous DLIs screens.

Other DLIs Costs

Kindly fill the below table:

Back

Ref	Result Area	Sub Area	DLI	01-Oct-15	01-Jun-16	01-Jun-17	01-Jun-18	01-Jun-19	01-Jun-20
			USD	USD	USD	USD	USD	USD	USD
DLI#2	1	DLI 2: Annual transfer of Performance Based Capital Grants (PBGC) by MHUCC to eligible WSCs	**4,000,000**	0	800,000	800,000	800,000	800,000	800,000
DLI#3	2	DLI 3: Design and implementation of the Annual Performance Assessment (APA) system for the WSCs, and WSCs achievement of the required APA threshold scores in accordance with the Program Operations Manual	**17,000,000**	0	1,500,000	2,000,000	4,500,000	4,500,000	4,500,000
DLI#4	3	DLI 4: Preparation and approval of new national tariff structure for water and sanitation services by MHUUC to allow for sustainable cost recovery	**5,000,000**	1,000,000	0	4,000,000	0	0	0
DLI#5	3	DLI 5: Establishment of PMU and approval of a National Rural Sanitation Strategy by MHUUC	**5,000,000**	1,000,000	0	3,000,000	333,333	333,333	333,333
DLI#6	3	DLI6: Approval of Standard Operating Procedures for land acquisition under NRSP by MHUUC	**1,862,500**	0	0	1,862,500	0	0	0

Figure 73: Other DLIs Costs

The user shall then return to the home page in order to enter the last set of inputs, which are the database of the executing companies of the projects. Figure 74 shows the executing companies' information sheet where the user shall enter three separate sets of inputs for the contracting companies, the consulting companies, and the design-build contracting companies. Figure 75 and Figure 76 show examples of the database sheets that represent the contracting and the consulting companies suggested to perform the scope of the project for the networks. The company's actual names are anonymized due to confidentiality reasons. Each company shall have two productivity measures against the number of household connections executed per day. Such information can be provided during the technical phase of the bidding document or simply through analyzing the company performance in previous projects. The productivity per day figure shall be used in preparing durations for the scheduling module. On the other hand, the maximum allowable productivity figure shall be the maximum number of household connections that the company can execute in parallel in all projects per month. This figure shall be used as one of the constraints in the optimization process, as shall be explained later on.

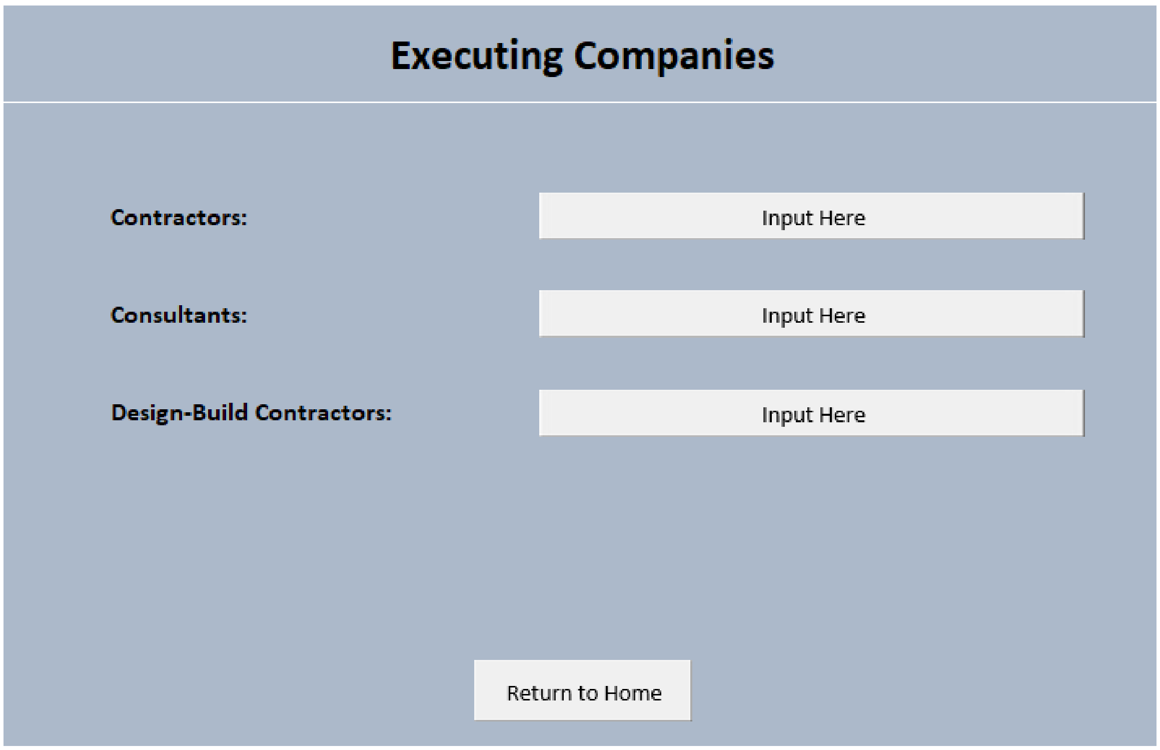


Figure 74: Executing Companies

After entering the executing companies, which is the last set of inputs, the user shall return back to the home page in Figure 45. The only two buttons left on the home page are "Click to Run Checks" and "Show Results". The checks section shall be explained in the validation part of this chapter as it shall be the section that guides the user to complete missing data in the model or mistakenly inputted data. The results section shall also be explained in the following section of the chapter. The following number of sheets shall not be visible to the user unless requested in the results section by an experienced user. In the previous part of this section, the working sheets have been working in parallel with the navigation sheets. From this point forward, the working sheets shall be working in the background without interacting with the navigation sheets. In order to ease the programming of the model, all relevant inputs shall be combined in a unified sheet, which is called the "working sheet", shown in Figure 77.

Contractors:

Kindly fill the below table:

Back

Ref	Name	Productivity	
		Per Day	Maximum Allowable
		HH	HH
C1	Contractors Limited	10	2,000
C2	Hold Co	20	4,000
C3	Team A Contractors	8	1,350
C4	YVC	15	2,200
C5	CCC	10	1,800
C6	LEW	20	3,200
C7	Total Contractors	8	1,440
C8	TUM	16	3,200
C9	BHA	9	1,530
C10	TYW	17	1,900
C11	JCA	10	1,800
C12	JKG	20	2,500

Figure 75: Contracting Companies

Consultants:

Kindly fill the below table:

Back

Ref	Name	Design Productivity	
		Per Day	Maximum Allowable
		HH	HH
S1	Sites Consultants	300	41,000
S2	AAB Consultants	150	60,000
S3	Trio Consultants	200	40,000
S4	TIR Consultants	100	39,000
S5	CCA Consulting	400	33,000
S6	LSA Consulting	200	66,000

Figure 76: Consultants Companies

Ref	Area	Sub Area	NT								
			Scope	Target	Design cost	Construction Cost	Design Duration	Construction Duration	Predecessor NT	Predecessor PS	Predecessor TP
			Yes/No	HH	USD	USD	Days	Days	Activity	Activity	Activity
Dak - 1	Dakahlia	Al Senblawin	Yes	9,380	168,465	8,423,240	30	300	NA	NA	TP - Dak - 1
Dak - 2	Dakahlia	Borg Nour Al Hommos	Yes	8,075	145,027	7,251,350	24	241	NA	NA	TP - Dak - 2
Dak - 3	Dakahlia	Al Robaa-C1 Village of Al Robae	Yes	2,125	38,165	1,908,250	15	150	NA	NA	TP - Dak - 3
Dak - 4	Dakahlia	Al Robaa-C2 Villages	Yes	2,185	39,243	1,962,130	30	302	NT - Dak - 3	NA	TP - Dak - 4
Dak - 5	Dakahlia	Shubrawish	Yes	7,045	126,528	6,326,410	28	276	NA	NA	TP - Dak - 5
Dak - 6	Dakahlia	Nawasa Al Ghayt	Yes	9,800	176,008	8,800,400	25	245	NA	NA	TP - Dak - 6
Dak - 7	Dakahlia	Demshlet Village	Yes	3,980	71,481	3,574,040	18	176	NA	NA	NA
Dak - 8	Dakahlia	Kafr Abu Naser Njeer 1	Yes	4,437	79,689	3,984,426	27	267	NA	NA	TP - Dak - 8
Dak - 9	Dakahlia	Kafr Abu Naser Njeer 2	Yes	4,437	79,689	3,984,426	29	294	NT - Dak - 8	NA	TP - Dak - 9
Dak - 10	Dakahlia	Kafr Abu Naser Njeer 3	Yes	4,437	79,689	3,984,426	20	198	NT - Dak - 9	NA	TP - Dak - 10
Dak - 11	Dakahlia	Meet Al Aamel 1	Yes	3,447	61,908	3,095,406	30	304	NA	NA	NA
Dak - 12	Dakahlia	Meet Al Aamel 2	Yes	3,447	61,908	3,095,406	10	104	NT - Dak - 11	NA	NA
Dak - 13	Dakahlia	Meet Al Aamel 3	Yes	3,446	61,890	3,094,508	29	294	NT - Dak - 12	NA	NA
Dak - 14	Dakahlia	Barhamtoosh	Yes	4,245	76,240	3,812,010	39	391	NA	NA	NA
Dak - 15	Dakahlia	Al Gamalya	Yes	2,580	46,337	2,316,840	27	274	NA	NA	TP - Dak - 15
Dak - 16	Dakahlia	Birmbal El Gadida 1	Yes	3,714	66,703	3,335,172	17	174	NA	NA	TP - Dak - 16
Dak - 17	Dakahlia	Birmbal El Gadida 2	Yes	3,713	66,685	3,334,274	17	174	NT - Dak - 16	NA	TP - Dak - 17
Dak - 18	Dakahlia	Birmbal El Gadida 3	Yes	3,713	66,685	3,334,274	20	202	NT - Dak - 17	NA	TP - Dak - 18
Dak - 19	Dakahlia	El Manzala 1	Yes	3,980	71,481	3,574,040	15	149	NA	NA	TP - Dak - 19
Dak - 20	Dakahlia	El Manzala 2	Yes	3,980	71,481	3,574,040	19	187	NT - Dak - 19	NA	TP - Dak - 20
Dak - 21	Dakahlia	El Manzala 3	Yes	3,980	71,481	3,574,040	19	189	NT - Dak - 20	NA	TP - Dak - 21
Dak - 22	Dakahlia	Ulilah 1	Yes	3,750	67,350	3,367,500	21	209	NA	NA	TP - Dak - 22
Dak - 23	Dakahlia	Ulilah 2	Yes	3,750	67,350	3,367,500	28	284	NT - Dak - 22	NA	TP - Dak - 23
Dak - 24	Dakahlia	Dekerness	Yes	1,153	20,708	1,035,394	27	274	NA	NA	TP - Dak - 24
Sha - 1	Sharkia	Gezeret Metawea	Yes	1,550	27,838	1,391,900	27	274	NA	NA	NA
Sha - 2	Sharkia	Zawar Abo Alil	Yes	1,320	23,707	1,185,360	18	184	NA	NA	NA
Sha - 3	Sharkia	Hamada	Yes	1,050	18,858	942,900	10	104	NA	NA	NA
Sha - 4	Sharkia	Dyarb Negm villages of Kafr Geined	Yes	4,310	77,408	3,870,380	18	184	NA	NA	TP - Sha - 4
Sha - 5	Sharkia	Dyarb Negm villages of Abu Ebeid,	Yes	2,840	51,006	2,550,320	18	176	NA	NA	TP - Sha - 5
Sha - 6	Sharkia	Snetet Al Refaa'yeen villages of El N	Yes	5,010	89,980	4,498,980	15	146	NA	NA	TP - Sha - 6
Sha - 7	Sharkia	Snetet Al Refaa'yeen villages of El N	Yes	4,600	82,616	4,130,800	20	198	NA	NA	TP - Sha - 7
Sha - 8	Sharkia	Abo Kbeer	Yes	6,270	112,609	5,630,460	39	387	NA	NA	TP - Sha - 8
Sha - 9	Sharkia	Al Ebrahemia	Yes	1,000	17,960	898,000	30	301	NA	NA	TP - Sha - 9
Sha - 10	Sharkia	Kasasen Al Azhar	Yes	6,618	118,859	5,942,964	30	298	NA	NA	TP - Sha - 10
Sha - 11	Sharkia	Kafr Alfarayha	Yes	2,819	50,629	2,531,462	27	265	NA	NA	TP - Sha - 11
Sha - 12	Sharkia	Hod Nageh	Yes	5,000	89,800	4,490,000	27	265	NA	NA	TP - Sha - 12
Sha - 13	Sharkia	Kafr Dabous	Yes	3,600	64,656	3,232,800	19	187	NA	NA	TP - Sha - 13
Sha - 14	Sharkia	Al Sids	Yes	5,300	95,188	4,759,400	11	109	NA	NA	TP - Sha - 14
Beh - 1	Beheira	Kom Hamada 1	Yes	2,050	71,912	3,595,592	19	187	NA	NA	TP - Beh - 1
Beh - 2	Beheira	Kom Hamada 2	Yes	4,004	83,694	4,184,680	29	289	NT - Beh - 1	NA	TP - Beh - 2
Beh - 3	Beheira	Badr 1	Yes	4,660	57,472	2,873,600	30	301	NA	NA	TP - Beh - 3
Beh - 4	Beheira	Badr 2	Yes	3,200	188,550	9,427,500	18	177	NA	NA	TP - Beh - 4

Figure 77: Part of the Working Sheet

The working sheet consists of three sections for each project type of sanitation projects: networks, pump stations, and wastewater treatment plants. Figure 77 shows only a part of the sheet, which is concerned with the network projects. The complete sheet is included in Appendix A. The first four columns are extracted from the scope module. The fourth column indicates the presence of this type of projects, in this case, a network project, in the scope. The fifth column, titled the target, indicates the number of household connections required in this area. The following two columns are extracted from the cost module section of the model, which indicates the design costs and construction costs of each area. The remaining columns are from the scheduling module, which indicates the design and construction durations and the dependencies relationships in the master schedule of the project inputted earlier.

The information combined in the working sheet shall be used to develop detailed monthly charts for the project schedule, the project cashflow, and the project achieved results. The following figures are an example of the developed charts in the case of a network project type. The developed charts consist of six charts divided into two groups. The first group of charts belongs to the design information, while the second group belongs to the construction information. The first two charts are shown in Figure 78 and Figure 79, which are part of the design and construction master schedule bar charts. The complete charts are shown in Appendix A. the bar chart schedule shows the sequence of the design and construction processes performed in all projects in parallel. The charts show the project's reference and description, followed by the estimated duration of both the construction and the design phase of the project. The chart also indicates the early start and early finish of each of the projects. Finally, the chart defines the design process duration and the early finish of the design process.

Network Design Master Schedule Bar Chart

Activity	Activity Description	Total Duration	ES	EF	Design Duration	Design EF
NT - Dak - 1	Al Senblawin	330	1-Jun-16	27-Apr-17	30	1-Jul-16
NT - Dak - 2	Borg Nour Al Hommos	265	1-Jun-16	21-Feb-17	24	25-Jun-16
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	165	1-Jun-16	13-Nov-16	15	16-Jun-16
NT - Dak - 4	Al Robaa-C2 Villages	332	14-Nov-16	12-Oct-17	30	14-Dec-16
NT - Dak - 5	Shubrawish	304	1-Jun-16	31-Mar-17	28	28-Jun-16
NT - Dak - 6	Nawasa Al Ghayt	270	1-Jun-16	25-Feb-17	25	25-Jun-16
NT - Dak - 7	Demshlet Village	194	1-Jun-16	11-Dec-16	18	18-Jun-16
NT - Dak - 8	Kafr Abu Naser Njeer 1	294	1-Jun-16	21-Mar-17	27	27-Jun-16
NT - Dak - 9	Kafr Abu Naser Njeer 2	323	22-Mar-17	9-Feb-18	29	21-Apr-17
NT - Dak - 10	Kafr Abu Naser Njeer 3	218	10-Feb-18	15-Sep-18	20	1-Mar-18
NT - Dak - 11	Meet Al Aamel 1	334	1-Jun-16	1-May-17	30	1-Jul-16
NT - Dak - 12	Meet Al Aamel 2	114	2-May-17	24-Aug-17	10	12-May-17
NT - Dak - 13	Meet Al Aamel 3	323	25-Aug-17	15-Jul-18	29	24-Sep-17
NT - Dak - 14	Barhamtoosh	430	1-Jun-16	5-Aug-17	39	10-Jul-16
NT - Dak - 15	Al Gamalya	301	1-Jun-16	29-Mar-17	27	28-Jun-16
NT - Dak - 16	Birmbal El Gadida 1	191	1-Jun-16	9-Dec-16	17	18-Jun-16
NT - Dak - 17	Birmbal El Gadida 2	191	10-Dec-16	19-Jun-17	17	27-Dec-16
NT - Dak - 18	Birmbal El Gadida 3	222	20-Jun-17	29-Jan-18	20	11-Jul-17

Figure 78: Network Design Master Schedule Bar Chart

Network Construction Master Schedule Bar Chart

Activity	Activity Description	Total Duration	ES	EF	Design Duration	Design EF
NT - Dak - 1	Al Senblawin	330	31-May-17	26-Apr-18	30	30-Jun-17
NT - Dak - 2	Borg Nour Al Hommos	265	20-Sep-16	12-Jun-17	24	14-Oct-16
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	165	20-Sep-16	4-Mar-17	15	5-Oct-16
NT - Dak - 4	Al Robaa-C2 Villages	332	5-Mar-17	31-Jan-18	30	4-Apr-17
NT - Dak - 5	Shubrawish	304	12-Oct-16	11-Aug-17	28	8-Nov-16
NT - Dak - 6	Nawasa Al Ghayt	270	20-Sep-16	16-Jun-17	25	14-Oct-16
NT - Dak - 7	Demshlet Village	194	1-Jun-16	11-Dec-16	18	18-Jun-16
NT - Dak - 8	Kafr Abu Naser Njeer 1	294	12-Oct-16	1-Aug-17	27	7-Nov-16
NT - Dak - 9	Kafr Abu Naser Njeer 2	323	2-Aug-17	22-Jun-18	29	1-Sep-17
NT - Dak - 10	Kafr Abu Naser Njeer 3	218	23-Jun-18	26-Jan-19	20	12-Jul-18
NT - Dak - 11	Meet Al Aamel 1	334	1-Jun-16	1-May-17	30	1-Jul-16
NT - Dak - 12	Meet Al Aamel 2	114	2-May-17	24-Aug-17	10	12-May-17
NT - Dak - 13	Meet Al Aamel 3	323	25-Aug-17	15-Jul-18	29	24-Sep-17
NT - Dak - 14	Barhamtoosh	430	1-Jun-16	5-Aug-17	39	10-Jul-16
NT - Dak - 15	Al Gamalya	301	20-Sep-16	18-Jul-17	27	17-Oct-16
NT - Dak - 16	Birmbal El Gadida 1	191	8-Jan-17	18-Jul-17	17	25-Jan-17
NT - Dak - 17	Birmbal El Gadida 2	191	19-Jul-17	26-Jan-18	17	5-Aug-17
NT - Dak - 18	Birmbal El Gadida 3	222	27-Jan-18	7-Sep-18	20	17-Feb-18
NT - Dak - 19	El Manzala 1	164	28-Apr-17	8-Oct-17	15	12-May-17

Figure 79: Network Construction Master Schedule Bar Chart

The following charts are the cashflow schedule for the design and the construction costs projected on the master schedule of the network projects. Figure 80 and Figure 81 show part of the cashflow schedules of the design and the construction processes projected on the master schedule. The complete charts shall be included in Appendix A.

Network Design Master Schedule Cashflow

Activity	Activity Description	Design Duration	Design Cost	Average Cost per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17
NT - Dak - 1	Al Senblawin	2	168,465	84,232	**84,232**	**84,232**									
NT - Dak - 2	Borg Nour Al Hommos	1	145,027	145,027	**145,027**										
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	1	38,165	38,165	**38,165**										
NT - Dak - 4	Al Robaa-C2 Villages	2	39,243	19,621						**19,621**	**19,621**				
NT - Dak - 5	Shubrawish	1	126,528	126,528	**126,528**										
NT - Dak - 6	Nawasa Al Ghayt	1	176,008	176,008	**176,008**										
NT - Dak - 7	Demshlet Village	1	71,481	71,481	**71,481**										
NT - Dak - 8	Kafr Abu Naser Njeer 1	1	79,689	79,689	**79,689**										
NT - Dak - 9	Kafr Abu Naser Njeer 2	2	79,689	39,844										**39,844**	**39,844**
NT - Dak - 10	Kafr Abu Naser Njeer 3	2	79,689	39,844											
NT - Dak - 11	Meet Al Aamel 1	2	61,908	30,954	**30,954**	**30,954**									
NT - Dak - 12	Meet Al Aamel 2	1	61,908	61,908											
NT - Dak - 13	Meet Al Aamel 3	2	61,890	30,945											
NT - Dak - 14	Barhamtoosh	2	76,240	38,120	**38,120**	**38,120**									
NT - Dak - 15	Al Gamalya	1	46,337	46,337	**46,337**										
NT - Dak - 16	Birmbal El Gadida 1	1	66,703	66,703	**66,703**										
NT - Dak - 17	Birmbal El Gadida 2	1	66,685	66,685							**66,685**				
NT - Dak - 18	Birmbal El Gadida 3	2	66,685	33,343											
NT - Dak - 19	El Manzala 1	1	71,481	71,481	**71,481**										

Figure 80: Network Design Cashflow

Network Construction Master Schedule Cashflow

Activity	Activity Description	Construction Duration	Construction Cost	Average Cost per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17
NT - Dak - 1	Al Senblawin	11	8,423,240	765,749													**765,749**	**765,749**	**765,749**
NT - Dak - 2	Borg Nour Al Hommos	9	7,251,350	805,706					**805,706**	**805,706**	**805,706**	**805,706**	**805,706**	**805,706**	**805,706**	**805,706**	**805,706**		
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	6	1,908,250	318,042					**318,042**	**318,042**	**318,042**	**318,042**	**318,042**	**318,042**					
NT - Dak - 4	Al Robaa-C2 Villages	10	1,962,130	196,213											**196,213**	**196,213**	**196,213**	**196,213**	**196,213**
NT - Dak - 5	Shubrawish	10	6,326,410	632,641						**632,641**	**632,641**	**632,641**	**632,641**	**632,641**	**632,641**	**632,641**	**632,641**	**632,641**	**632,641**
NT - Dak - 6	Nawasa Al Ghayt	9	8,800,400	977,822					**977,822**	**977,822**	**977,822**	**977,822**	**977,822**	**977,822**	**977,822**	**977,822**	**977,822**		
NT - Dak - 7	Demshlet Village	7	3,574,040	510,577	**510,577**	**510,577**	**510,577**	**510,577**	**510,577**	**510,577**	**510,577**								
NT - Dak - 8	Kafr Abu Naser Njeer 1	10	3,984,426	398,443						**398,443**	**398,443**	**398,443**	**398,443**	**398,443**	**398,443**	**398,443**	**398,443**	**398,443**	**398,443**
NT - Dak - 9	Kafr Abu Naser Njeer 2	10	3,984,426	398,443															
NT - Dak - 10	Kafr Abu Naser Njeer 3	7	3,984,426	569,204															
NT - Dak - 11	Meet Al Aamel 1	11	3,095,406	281,401		**281,401**	**281,401**	**281,401**	**281,401**	**281,401**	**281,401**	**281,401**	**281,401**	**281,401**	**281,401**	**281,401**			
NT - Dak - 12	Meet Al Aamel 2	4	3,095,406	773,852												**773,852**	**773,852**	**773,852**	**773,852**
NT - Dak - 13	Meet Al Aamel 3	11	3,094,508	281,319															
NT - Dak - 14	Barhamtoosh	14	3,812,010	272,286		**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**	**272,286**
NT - Dak - 15	Al Gamalya	10	2,316,840	231,684					**231,684**	**231,684**	**231,684**	**231,684**	**231,684**	**231,684**	**231,684**	**231,684**	**231,684**	**231,684**	
NT - Dak - 16	Birmbal El Gadida 1	7	3,335,172	476,453								**476,453**	**476,453**	**476,453**	**476,453**	**476,453**	**476,453**	**476,453**	
NT - Dak - 17	Birmbal El Gadida 2	6	3,334,274	555,712															**555,712**
NT - Dak - 18	Birmbal El Gadida 3	8	3,334,274	416,784															

Figure 81: Network Construction Cashflow

These charts shall be used to develop the comprehensive cashflow schedule of the whole program, which shall be used in the optimization process. In the first two columns, the charts show the project's description and reference. The following columns in the design cashflow schedule indicate the design costs and the durations in months. An average cost per month is calculated. In the cashflow schedule, the previous amount is allocated to the months specified in the execution bar chart schedule earlier. The construction cashflow schedule presents the construction costs and durations. An average is calculated for the monthly costs and projected on the execution months in the bar chart schedule. For simplicity, an assumption is made to use a uniform distribution of the costs along the project timeline. The assumption is valid since the projects are executed over a relatively short span of time, which makes the fluctuations in the rate of work is minimal.

The following two charts show a monthly distribution of the number of household connections designed and executed. Figure 82 shows the distribution of the designed household connections along the months of the design bar chart schedule. Figure 83 shows the same information for the constructed household connections. The figures show part of the charts, and the complete charts can be found in Appendix A. An assumption is made to uniformly distribute the number of achieved household connections on the months of execution. This is a valid assumption since the schedule of such repetitive projects usually uses the line of balance method. The importance of monthly distributing the results is to match the achieved results at a certain month with the required results in the disbursement linked indicators (DLI) schedule inputted earlier in Figure 57. The model shall check the results in order to determine the time the disbursement amount shall be included in the comprehensive cashflow schedule of the project.

The objective of this model is to be able to automatically generate work packages that optimize the project cashflow and minimize the amount funded by the government. In order to ensure that this condition is fully met, the amount funded by the government needs to be defined by allocating the funding gaps in the project cashflow schedule. Hence, the model shall prepare a comprehensive cashflow schedule, part of it shown in Figure 84. The complete schedule is included in Appendix A. The Table in the figure consists of several sections; each one of them represents either a cash inflow or a cash outflow. The cash outflow is indicated by two brackets instead of a negative sign. The first section of the table is a summary of the withdrawn loan balance versus the unwithdrawn loan balance. This section is used in calculating some of the figures, such as the interest payable and the commitment charge. The following section contains the financial loan fees, which are the front-end fee paid at the beginning of the contract and the commitment charge, which is paid periodically against the unwithdrawn loan amount. Then, the cashflow schedule includes the advance payment section and recovery. The project cashflow is then defined, followed by the disbursement amounts for the design and construction of the household connections as per the DLI disbursement schedule. Finally, the interest amount is included. At the bottom of the schedule, the cash-in and cash-out are calculated along with the net cashflow. The negative payments in the net cashflow are the amount of funds required by the government at a certain point in time.

Network Design Achieved Results (# of HH)

Activity	Activity Description	Design Duration	HH Connections	Average Achieved per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17
NT - Dak - 1	Al Senblawin	2	9,380	4,690	4,690	4,690														
NT - Dak - 2	Borg Nour Al Hommos	1	8,075	8,075	8,075															
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	1	2,125	2,125	2,125															
NT - Dak - 4	Al Robaa-C2 Villages	2	2,185	1,093						1,093	1,093									
NT - Dak - 5	Shubrawish	1	7,045	7,045	7,045															
NT - Dak - 6	Nawasa Al Ghayt	1	9,800	9,800	9,800															
NT - Dak - 7	Demshlet Village	1	3,980	3,980	3,980															
NT - Dak - 8	Kafr Abu Naser Njeer 1	1	4,437	4,437	4,437															
NT - Dak - 9	Kafr Abu Naser Njeer 2	2	4,437	2,219										2,219	2,219					
NT - Dak - 10	Kafr Abu Naser Njeer 3	2	4,437	2,219																
NT - Dak - 11	Meet Al Aamel 1	2	3,447	1,724	1,724	1,724														
NT - Dak - 12	Meet Al Aamel 2	1	3,447	3,447												3,447				
NT - Dak - 13	Meet Al Aamel 3	2	3,446	1,723															1,723	1,723
NT - Dak - 14	Barhamtoosh	2	4,245	2,123	2,123	2,123														
NT - Dak - 15	Al Gamalya	1	2,580	2,580	2,580															
NT - Dak - 16	Birmbal El Gadida 1	1	3,714	3,714	3,714															
NT - Dak - 17	Birmbal El Gadida 2	1	3,713	3,713							3,713									
NT - Dak - 18	Birmbal El Gadida 3	2	3,713	1,857													1,857	1,857		
NT - Dak - 19	El Manzala 1	1	3,980	3,980	3,980															
NT - Dak - 20	El Manzala 2	2	3,980	1,990						1,990	1,990									

Figure 82: Design Achieved Results (Household Connections)

Network Construction Achieved Results (# of HH)

Activity	Activity Description	Construction Duration	HH Connections	Average Achieved per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
NT - Dak - 1	Al Senblawin	11	9,380	853													853	853	853	853	853	853	853
NT - Dak - 2	Borg Nour Al Hommos	9	8,075	897					897	897	897	897	897	897	897	897	897						
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	6	2,125	354					354	354	354	354	354	354									
NT - Dak - 4	Al Robaa-C2 Villages	10	2,185	219											219	219	219	219	219	219	219	219	219
NT - Dak - 5	Shubrawish	10	7,045	705						705	705	705	705	705	705	705	705	705	705				
NT - Dak - 6	Nawasa Al Ghayt	9	9,800	1,089					1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089						
NT - Dak - 7	Demshlet Village	7	3,980	569	569	569	569	569	569	569	569												
NT - Dak - 8	Kafr Abu Naser Njeer 1	10	4,437	444						444	444	444	444	444	444	444	444	444	444				
NT - Dak - 9	Kafr Abu Naser Njeer 2	10	4,437	444																444	444	444	444
NT - Dak - 10	Kafr Abu Naser Njeer 3	7	4,437	634																			
NT - Dak - 11	Meet Al Aamel 1	11	3,447	313		313	313	313	313	313	313	313	313	313	313	313							
NT - Dak - 12	Meet Al Aamel 2	4	3,447	862												862	862	862	862				
NT - Dak - 13	Meet Al Aamel 3	11	3,446	313																313	313	313	313
NT - Dak - 14	Barhamtoosh	14	4,245	303		303	303	303	303	303	303	303	303	303	303	303	303	303	303				
NT - Dak - 15	Al Gamalya	10	2,580	258					258	258	258	258	258	258	258	258	258	258					
NT - Dak - 16	Birmbal El Gadida 1	7	3,714	531								531	531	531	531	531	531	531					
NT - Dak - 17	Birmbal El Gadida 2	6	3,713	619															619	619	619	619	619
NT - Dak - 18	Birmbal El Gadida 3	8	3,713	464																			
NT - Dak - 19	El Manzala 1	6	3,980	663												663	663	663	663	663	663		
NT - Dak - 20	El Manzala 2	8	3,980	498																	498	498	498

Figure 83: Construction Achieved Results (Household Connections)

Cashflow Schedule:

Loan Effective Amount	USD	548,625,000.00
Assumed Discount Rate	USD	2%
NPV for the Negative Cashflow Required	USD	(315,199,056.71)
Maximum Government Fund Required	USD	(195,611,107.46)

Item	Units	%	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16
Withdrawn Loan Balance	USD		20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	43,000,000
Unwithdrawn Loan Balance	USD		528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	505,625,000
Total Loan Amount	USD		548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000
Loan Financial Fees											
Front End Fee	USD	0.25%	(1,371,563)								
Commitement Charge	USD	0.25%	0	0	(660,781)	0	0	0	0	0	(632,031)
Subtotal	USD		(1,371,563)	0	(660,781)	0	0	0	0	0	(632,031)
Advance Payment											
Advance Payment	USD	25%	137,156,250								
Advance Payment Recovery	USD		(5,000,000)	0	0	0	0	0	0	0	(5,750,000)
Subtotal	USD		132,156,250	0	0	0	0	0	0	0	(5,750,000)
Project Cashflow											
Network Design	USD		0	0	0	0	0	0	0	0	(2,207,811)
Network Construction	USD		0	0	0	0	0	0	0	0	(1,054,829)
Pump Stations	USD		0	0	0	0	0	0	0	0	0
WWTPs	USD		0	0	0	0	0	0	0	0	(60,945,359)
Other DLIs Costs	USD		(2,000,000)	0	0	0	0	0	0	0	(2,300,000)
Subtotal	USD		(2,000,000)	0	0	0	0	0	0	0	(66,507,999)
Disbursements											
For Design	USD		0	0	0	0	0	0	0	0	0
For Construction	USD		0	0	0	0	0	0	0	0	0
Other DLIs	USD		20,000,000	0	0	0	0	0	0	0	23,000,000
Subtotal	USD		20,000,000	0	0	0	0	0	0	0	23,000,000
Interest Payable	USD	2.50%	(500,000)	0	0	0	0	0	0	0	(575,000)
Cash In	USD		157,156,250	0	0	0	0	0	0	0	23,000,000
Cum Cash In	USD		157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	180,156,250
Cash Out	USD		(8,871,563)	0	(660,781)	0	0	0	0	0	(73,465,031)
Cum Cash Out	USD		(8,871,563)	(8,871,563)	(9,532,344)	(9,532,344)	(9,532,344)	(9,532,344)	(9,532,344)	(9,532,344)	(82,997,374)
Net Cashflow	USD		148,284,688	0	(660,781)	0	0	0	0	0	(50,465,031)
Fund Required from Government	USD		0	0	(660,781)	0	0	0	0	0	(50,465,031)
Cum Net Cashflow	USD		148,284,688	148,284,688	147,623,906	147,623,906	147,623,906	147,623,906	147,623,906	147,623,906	97,158,876

Figure 84: Cashflow Schedule (Before Optimization)

The cashflow schedule summary is plotted in the cumulative cash-in and cumulative cash-out curve before optimization, as shown in Figure 85. The difference between the two curves shall be the fund required by the government at any certain point in time, which is the funding gap. The objective of the optimization process is to tighten the gap and to provide a near optimum allocation of the work packages in order to achieve the minimum amount possible to be funded by the borrower government.

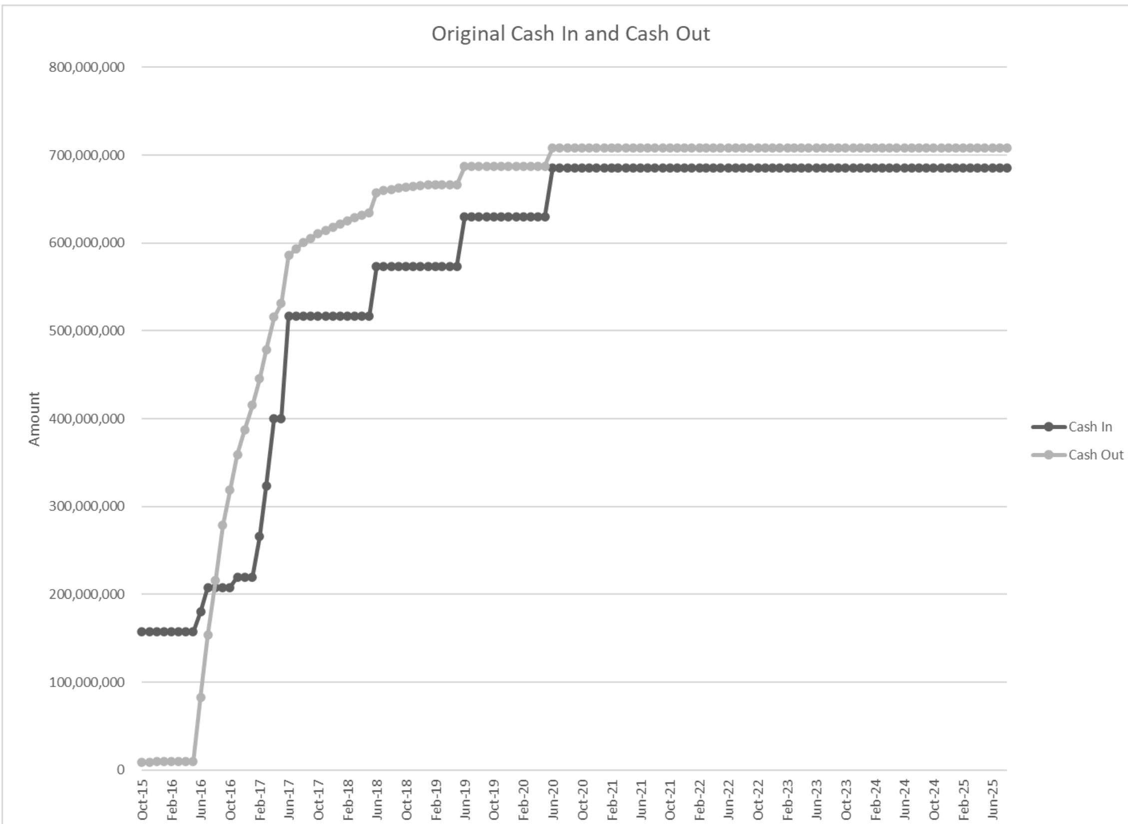


Figure 85: Cumulative Cash-in and Cumulative Cash-out Curves Before Optimization

The last type of working sheets is loan repayment schedules. As shown in Figure 50, the user should select a method for the loan repayment schedule, which is either using a fixed percentage for the repayment of the principal amount or by using the regular loan amortization schedules. Part of the loan repayment schedule using the fixed principal amount method is shown in Figure 86. The complete figure is included in Appendix A. the schedule is calculated upon fixing a certain percentage of the loan amount to be paid periodically as stated, and an adjustment is made at the last payment to ensure the loan

Loan Repayment (Fixed):

Loan Effective Amount	USD	550,000.00

Item	Units	%	Sep-20	Mar-21	Sep-21	Mar-22	Sep-22	Mar-23	Sep-23
Loan Repayment Schedule									
Pricipal Payment	USD	1.67%	9,185	9,185	9,185	9,185	9,185	9,185	9,185
Adjustment for Principal Last Payment	USD	1.47%	0	0	0	0	0	0	0
Subtotal	USD		9,185	9,185	9,185	9,185	9,185	9,185	9,185
Cum Total	USD		9,185	18,370	27,555	36,740	45,925	55,110	64,295
Loan Balance	USD		540,815	531,630	522,445	513,260	504,075	494,890	485,705
Loan Interest Amount	USD	2.50%	13,520	13,291	13,061	12,832	12,602	12,372	12,143
Loan Amortization Amount	USD		22,705	22,476	22,246	22,017	21,787	21,557	21,328

Figure 86: Loan Repayment (Fixed Principal Amount Method)

amount is not exceeded. Then, the interest amount is calculated from the remaining balance after deducting the principal amount paid. Figure 87 shows the loan repayment schedule in case of using the default method of the loan amortization schedule.

Loan Repayment (Default):

Loan Effective Amount	USD	550,000.00
Amortization Rate	USD	2.50%
Effective Rate	USD	1.25%
Uniform Payment	USD	13,084.46

Item	Units	%	Sep-20	Mar-21	Sep-21	Mar-22	Sep-22	Mar-23	Sep-23
Loan Repayment Schedule									
Uniform Payment	USD		13,084	13,084	13,084	13,084	13,084	13,084	13,084
Beginning Balance	USD		550,000	543,791	537,503	531,138	524,693	518,167	511,559
Interest Payment	USD		6,875	6,797	6,719	6,639	6,559	6,477	6,394
Pricipal Payment	USD		6,209	6,287	6,366	6,445	6,526	6,607	6,690
Ending Balance	USD		543,791	537,503	531,138	524,693	518,167	511,559	504,869
Net Cashflow	USD		13,084	13,084	13,084	13,084	13,084	13,084	13,084

Figure 87: Loan Repayment (Default Method)

5 . 4 Optimization Sheets (Packages Assignment Module)

The packaging assignment module shall run in order to develop the near-optimum combination of the packages performed by a certain executing company from the database entered earlier in the model. There exist an endless number of combinations when allocating the different projects to the executing companies in the database. The model shall use different combinations of the above variables in order to ensure practicality and efficiency in allocating the available resources. The model shall use the genetic algorithms (GA) method, which is one of the meta-heuristic methods used in order to reach a near-optimal solution for such complicated optimization problems. The method depends on the "survival of the fittest" concept. The parents (the original population) shall produce new generations. The best individuals or solutions shall survive by becoming the fittest. Individuals can also be mutated or combined in order to obtain a better solution. The selection is made by having a fitness equation, which is the objective function.

The genetic algorithms (GA) method continues to evolve in several iterations wherein each iteration, a selection is made to choose the best/fittest individuals. The model shall use a software called Palisade's Decision Tools Suite, which is a popular tool for performing optimization processes using the Genetic Algorithms solving technique. The software helps tremendously in minimizing the time needed to perform iterations. Thirsty thousand iterations were performed.

In the model, the constraints shall be the maximum number of deliverables that can be performed by a single company. For example, in the case of a consultancy company, the maximum number of drawings to be produced per month shall be the constraint that has to be respected when determining the allocated projects. A loop shall be created in order to test the different combinations of the required scope based on these constraints. The model shall simulate the whole process of creating a management plan, including preparing detailed schedules and cost estimates for the different combinations. Through each of the iterations, the working sheets shall keep developing options, schedules and cashflows.

The importance of the cashflow sheet is the calculation of the objective function to ensure that the funding required by the government is minimized. The optimization process shall have three options to optimize. The first option is the “NPV for the Negative Cashflow Required”. The net present value is selected to reflect the fund amount in the present time using a discount rate that accounts for the nominal interest rate with the expected inflation amount as shown in Equation 4 where r is the discount rate used, i is the nominal interest rate, and g is the expected inflation rate.

$$r = \frac{(i - g)}{(1 + g)}$$

Equation 4: Real Interest Rate

The second option is the “Maximum Government Fund Required” which is the highest negative cumulative cashflow value, which denotes the peak of the curve. By selecting the most optimum combination of the project packages, the above value shall be minimized. The model shall ensure that the DLIs are collected in the timing that minimizes the peak of the negative cashflow curve. The third option is to minimize the above two figures, which shall minimize the amount of fund required by the government and at the same time, normalize the negative cashflow curve as much as possible. Equation 5 shows the combined objective function of the mathematical model, which needs to be minimized in order to reduce this amount of funds needed from the government. The function represents the combined option three and it is divided into two sections denoting option one and option two.

$$NPV\ of\ Funds\ Required\ by\ the\ Government =$$

$$Min\ f(x) = \left\| \sum_{j=1,Z=1}^{n} \frac{\left((AP+D)-(F+CC+AR+C+IP)\right)_Z}{(1+r)^j} \right\| + \max \left\| \{S_1, S_2, S_3, \ldots, S_y\} \right\|$$

Where

$(AP + D) - (F + CC + AR + C + IP) < 0$

AP: Advance Payment Released

D: Loan Disbursements

F: Front End Fees

CC: Commitment Charge

AR: Advance Payment Recovery

C: Design and Execution Costs

IP: Interest Payable

Z: the period number of an individual cashflow

j: the number of periods required to discount a cashflow

S: Individual Net Cashflows at time y

y: the period index of an individual cashflow

Equation 5: The Combined Objective Function

The key variables are the different costs incurred along the lifecycle of the project and the loan disbursements collected upon the achievement of the DLIs shown in Equation 5. The first group of variables is the loan financial fees variables, which are the front-end fee and the commitment charges. Other variables include: the advance payment released, the advance payment recovery, the loan disbursements, the design and execution costs and the interest payable.

As shown in Figure 75, the contracting companies shall be given a reference code that shall be used in the selection process. The same coding process shall be assigned to different consultants and design-build contractors. Part of the packages assignment module is shown in Figure 88 that belongs to the network projects in the Dakahliya region. The complete module shall be included in Appendix A. The codes of the assigned executing companies are going to be the different variables that shall change in the third and the seventh columns. The figure also demonstrates the design and construction productivity expected from the

Packages Assignment Module

Back

Activity	Activity Description	Assigned Consultant	Design Productivity HH per Day	HH Required HH	Design Duration Days	Assigned Contractor	Construction Productivity HH per Day	HH Required HH	Construction Duration Days
NT - Dak - 1	Al Senblawin	2	150	9,380	63	3	8	9,380	1,251
NT - Dak - 2	Borg Nour Al Hommos	4	100	8,075	81	3	8	8,075	1,077
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	3	200	2,125	11	4	15	2,125	142
NT - Dak - 4	Al Robaa-C2 Villages	1	300	2,185	7	2	20	2,185	109
NT - Dak - 5	Shubrawish	4	100	7,045	70	1	10	7,045	705
NT - Dak - 6	Nawasa Al Ghayt	4	100	9,800	98	7	8	9,800	1,225
NT - Dak - 7	Demshlet Village	1	300	3,980	13	8	16	3,980	249
NT - Dak - 8	Kafr Abu Naser Njeer 1	2	150	4,437	30	7	8	4,437	555
NT - Dak - 9	Kafr Abu Naser Njeer 2	2	150	4,437	30	7	8	4,437	555
NT - Dak - 10	Kafr Abu Naser Njeer 3	4	100	4,437	44	8	16	4,437	277
NT - Dak - 11	Meet Al Aamel 1	4	100	3,447	34	7	8	3,447	431
NT - Dak - 12	Meet Al Aamel 2	4	100	3,447	34	3	8	3,447	460
NT - Dak - 13	Meet Al Aamel 3	6	200	3,446	17	7	8	3,446	431
NT - Dak - 14	Barhamtoosh	2	150	4,245	28	2	20	4,245	212
NT - Dak - 15	Al Gamalya	6	200	2,580	13	1	10	2,580	258
NT - Dak - 16	Birmbal El Gadida 1	6	200	3,714	19	7	8	3,714	464
NT - Dak - 17	Birmbal El Gadida 2	6	200	3,713	19	3	8	3,713	495
NT - Dak - 18	Birmbal El Gadida 3	4	100	3,713	37	3	8	3,713	495
NT - Dak - 19	El Manzala 1	4	100	3,980	40	3	8	3,980	531
NT - Dak - 20	El Manzala 2	4	100	3,980	40	5	10	3,980	398
NT - Dak - 21	El Manzala 3	6	200	3,980	20	3	8	3,980	531
NT - Dak - 22	Ulilah 1	1	300	3,750	13	4	15	3,750	250
NT - Dak - 23	Ulilah 2	4	100	3,750	38	7	8	3,750	469
NT - Dak - 24	Dekerness	1	300	1,153	4	5	10	1,153	115

Figure 88: Packages Assignment Module

technical review of the executing company and the required number of household connections to be performed in the designated area.

Figure 89 shows a typical model definition window by Palisade's Decision Tools Suite: Evolver. The objective of the model is to minimize the funds required by the government in order to cover the gap between the cost of household connections execution and the collection of the loan disbursements. The variables are the different consultants, contractors, and design-build contractors allocated to each of the projects. Each executing company is given a certain index number in the form of an array. In the “adjustable cell ranges” section in Figure 89, the evolver tool shall allocate each package to a certain value in the above arrays based on the delivery method selected. The crossover rate and the

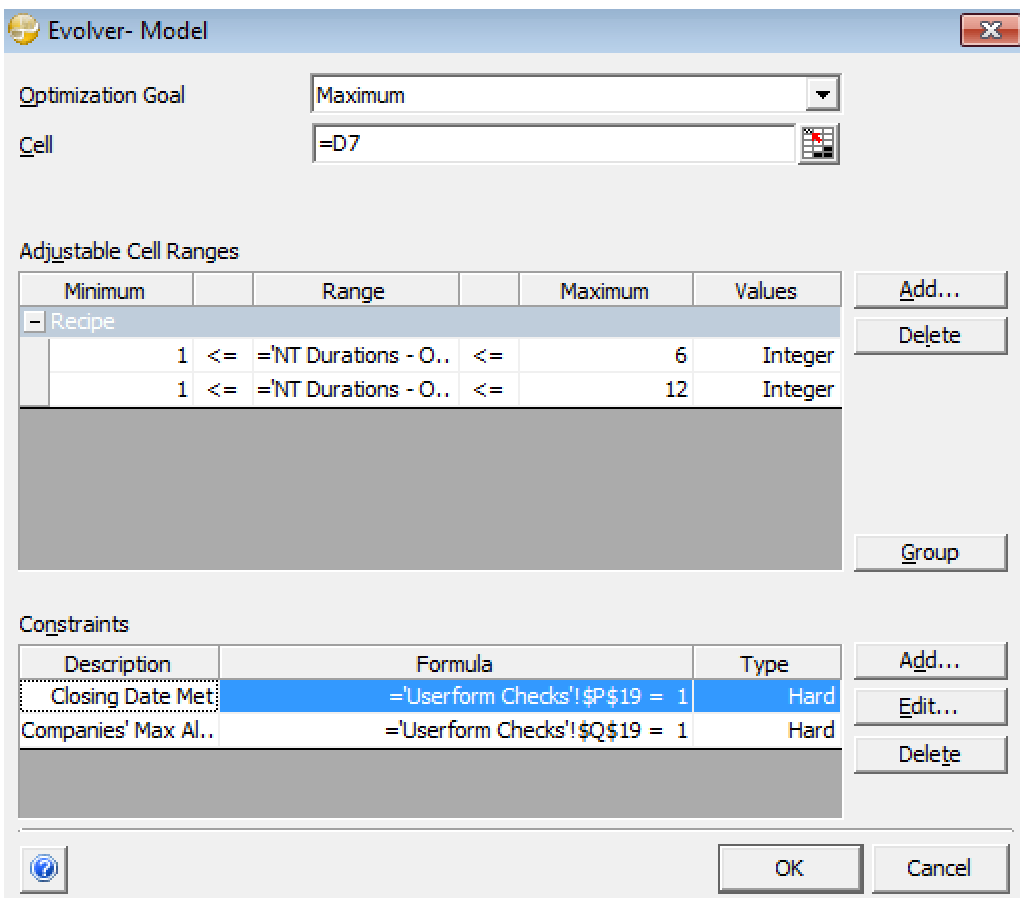


Figure 89: Evolver Model Definition Screen

mutation rate are selected automatically. One of the advantages of the Evolver software is that it changes the mutation rate dynamically to obtain the most suitable rate for the optimization process. The model shall create thousands of scenarios for the different combinations of the executing companies allocated to each part of the scope. For each one of the scenarios, the model shall create full schedule plans in order to calculate the productivity and the cashflow corresponding to this scenario. The constraints shall be to ensure that the monthly expected productivity based on the package size allocated to a certain company will not exceed the maximum allowable capacity of the awarded companies. The model shall ensure that at any point in time, the project is working in a way to collect the disbursements at the exact time needed to reduce the funds required by the public treasury.

5 . 5 Results and Discussions

In order to show the results of the optimization process, the user shall return to the home screen in Figure 45 after entering the last set of inputs. The home screen has a button at the bottom titled "Show Results", which shall direct the user to the screen in Figure 90.

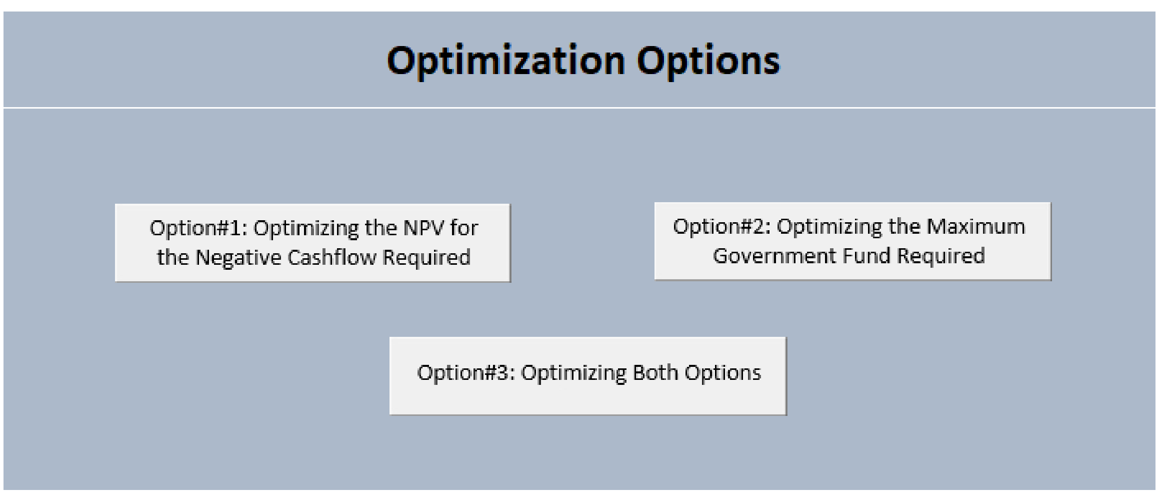


Figure 90: Optimization Options

The first option of the optimization process is optimizing the net present worth of all the negative cashflows only. The second option is to optimize the maximum of the peak negative values that shall be required from the borrowing government. Finally, the third option is to optimize both values as per the combined objective function. After selecting a suitable option, the user shall be directed to a screen similar to Figure 91.

Figure 91 shows the results sheet, where all the outputs of the model are categorized into ten separate sets of data. The reason behind this separation is to ensure that the user is provided with the exact level of detail required by his position. For example, upper management officials are usually concerned with the final output, which is the percentage reduction in government expenditures at the end of the program. On the other hand, a planning engineer shall be concerned with looking at the final bar chart schedules and

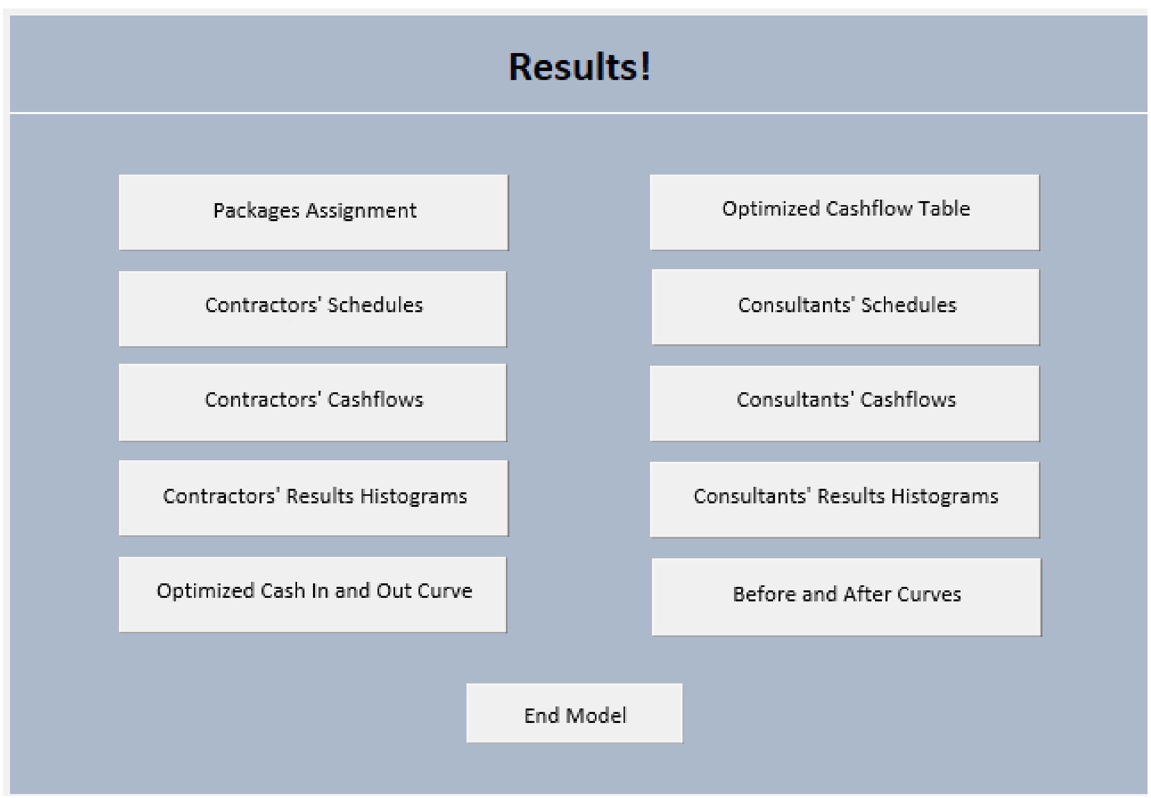


Figure 91: Results Navigation Sheet

durations. The project financial officer is probably concerned with the project cashflow and the cash-in and cash-out amounts.

The first set of data is the packages assignment, which is shown in Figure 88. The figure shows part of the chart where each of the executing companies is allocated to a certain project. The projects belonging to a certain company constitute the package assigned. The following output is the optimized cashflow table. Figure 92 shows part of the optimized cashflow schedule belonging to option three. The complete schedule shall be included in Appendix A. the figure has the same row distribution as Figure 84, including the financial information of the loan agreement, the advance payment information, the project's cashflow, the loan disbursements, and the interest payable. The optimization process helped in rescheduling the project packaging sequence in order to ensure that the amounts corresponding to the funds required by the borrower government are minimized.

The results navigation sheets also provide a number of charts that aids in the project management plan preparations. The charts include bar chart schedules for both the design and the construction phase of the projects. The results section also provides detailed monthly cashflows for each of the projects in the program that are combined to form the project cashflows section in the optimized cashflow schedule. This section also provides a monthly breakdown for the achieved results in terms of the number of achieved household connections for each project. Moreover, this section has detailed monthly achieved results for each of the executing companies. Histograms are also provided to be able to visualize the monthly workload of each of the executing companies.

Cashflow Schedule (Optimized):

Loan Effective Amount	USD	548,625,000.00
Discount Rate	USD	2%
NPV for the Negative Cashflow Required	USD	(303,147,922.54)
Maximum Government Fund Required	USD	(162,214,478.70)

Back

Item	Units	%	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16
Withdrawn Loan Balance	USD		20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	43,000,000
Unwithdrawn Loan Balance	USD		528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	528,625,000	505,625,000
Total Loan Amount	USD		548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000	548,625,000
Loan Financial Fees											
Front End Fee	USD	0.25%	(1,371,563)								
Commitement Charge	USD	0.25%	0	0	(660,781)	0	0	0	0	0	(632,031)
Subtotal	USD		(1,371,563)	0	(660,781)	0	0	0	0	0	(632,031)
Advance Payment											
Advance Payment	USD	25%	137,156,250								
Advance Payment Recovery	USD		(5,000,000)	0	0	0	0	0	0	0	(5,750,000)
Subtotal	USD		132,156,250	0	0	0	0	0	0	0	(5,750,000)
Project Cashflow											
Network Design	USD		0	0	0	0	0	0	0	0	(2,043,821)
Network Construction	USD		0	0	0	0	0	0	0	0	(5,537,713)
Pump Stations	USD		0	0	0	0	0	0	0	0	0
WWTPs	USD		0	0	0	0	0	0	0	0	(60,945,359)
Other DLIs Costs	USD		(2,000,000)	0	0	0	0	0	0	0	(2,300,000)
Subtotal	USD		(2,000,000)	0	0	0	0	0	0	0	(70,826,893)
Disbursements											
For Design	USD		0	0	0	0	0	0	0	0	0
For Construction	USD		0	0	0	0	0	0	0	0	0
Other DLIs	USD		20,000,000	0	0	0	0	0	0	0	23,000,000
Subtotal	USD		20,000,000	0	0	0	0	0	0	0	23,000,000
Interest Payable	USD	2.50%	(500,000)	0	0	0	0	0	0	0	(575,000)
Cash In	USD		157,156,250	0	0	0	0	0	0	0	23,000,000
Cum Cash In	USD		157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	157,156,250	180,156,250
Cash Out	USD		(8,871,563)	0	(660,781)	0	0	0	0	0	(77,783,924)
Cum Cash Out	USD		(8,871,563)	(8,871,563)	(9,532,344)	(9,532,344)	(9,532,344)	(9,532,344)	(9,532,344)	(9,532,344)	(87,316,268)
Net Cashflow	USD		148,284,688	0	(660,781)	0	0	0	0	0	(54,783,924)
Fund Required from Government	USD		0	0	(660,781)	0	0	0	0	0	(54,783,924)
Cum Net Cashflow	USD		148,284,688	148,284,688	147,623,906	147,623,906	147,623,906	147,623,906	147,623,906	147,623,906	92,839,982

Figure 92: Optimized Cashflow Schedule

Figure 93 shows part of the optimized network design bar chart. The complete schedule is included in Appendix A. The model has updated the sequence of the projects to generate the work packages to be allocated to each consultant company. The projects' start and finish dates have been altered using the float with respecting the dependencies inputted in the master schedule screen. The new sequence shall minimize the amount of funds and provide better results. The same concept is applied in Figure 94, which shows part of the construction bar chart schedule for the network's projects

Network Design Master Schedule Bar Chart - Optimized

Activity	Activity Description	ES	Design Duration	Design EF
NT - Dak - 1	Al Senblawin	1-Jun-16	63	3-Aug-16
NT - Dak - 2	Borg Nour Al Hommos	1-Jun-16	81	21-Aug-16
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	1-Jun-16	11	12-Jun-16
NT - Dak - 4	Al Robaa-C2 Villages	2-Nov-16	7	9-Nov-16
NT - Dak - 5	Shubrawish	1-Jun-16	70	10-Aug-16
NT - Dak - 6	Nawasa Al Ghayt	1-Jun-16	98	7-Sep-16
NT - Dak - 7	Demshlet Village	1-Jun-16	13	14-Jun-16
NT - Dak - 8	Kafr Abu Naser Njeer 1	1-Jun-16	30	1-Jul-16
NT - Dak - 9	Kafr Abu Naser Njeer 2	8-Jan-18	30	7-Feb-18
NT - Dak - 10	Kafr Abu Naser Njeer 3	17-Aug-19	44	30-Sep-19
NT - Dak - 11	Meet Al Aamel 1	1-Jun-16	34	5-Jul-16
NT - Dak - 12	Meet Al Aamel 2	10-Sep-17	34	14-Oct-17
NT - Dak - 13	Meet Al Aamel 3	18-Jan-19	17	4-Feb-19
NT - Dak - 14	Barhamtoosh	1-Jun-16	28	29-Jun-16
NT - Dak - 15	Al Gamalya	1-Jun-16	13	14-Jun-16
NT - Dak - 16	Birmbal El Gadida 1	1-Jun-16	19	20-Jun-16
NT - Dak - 17	Birmbal El Gadida 2	28-Sep-17	19	17-Oct-17
NT - Dak - 18	Birmbal El Gadida 3	25-Feb-19	37	3-Apr-19
NT - Dak - 19	El Manzala 1	1-Jun-16	40	11-Jul-16
NT - Dak - 20	El Manzala 2	25-Dec-17	40	3-Feb-18
NT - Dak - 21	El Manzala 3	9-Mar-19	20	29-Mar-19
NT - Dak - 22	Ulilah 1	1-Jun-16	13	14-Jun-16
NT - Dak - 23	Ulilah 2	20-Feb-17	38	30-Mar-17
NT - Dak - 24	Dekerness	1-Jun-16	4	5-Jun-16

Figure 93: Network Design Bar Schedule (Optimized)

The sequence of the projects has been altered with respecting the dependencies in the master schedule to obtain a better distribution of cash-out and achieve the results earlier in the project. Part of the corresponding cashflow schedules to the above bar charts is shown in Figure 95 and Figure 96. The complete figures are included in Appendix A. The charts show a monthly distribution of expected expenditure for design fees and the construction expenses for each project. The summary at the bottom of those schedules shall represent the project cashflow section in the compiled cashflow schedule of the program. On the

Network Construction Master Schedule Bar Chart - Optimized

Activity	Activity Description	Total Duration	ES	EF
NT - Dak - 1	Al Senblawin	1,314	1-Jun-16	6-Jan-20
NT - Dak - 2	Borg Nour Al Hommos	1,158	1-Jun-16	3-Aug-19
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	153	1-Jun-16	1-Nov-16
NT - Dak - 4	Al Robaa-C2 Villages	116	2-Nov-16	26-Feb-17
NT - Dak - 5	Shubrawish	775	1-Jun-16	16-Jul-18
NT - Dak - 6	Nawasa Al Ghayt	1,323	1-Jun-16	15-Jan-20
NT - Dak - 7	Demshlet Village	262	1-Jun-16	18-Feb-17
NT - Dak - 8	Kafr Abu Naser Njeer 1	585	1-Jun-16	7-Jan-18
NT - Dak - 9	Kafr Abu Naser Njeer 2	585	8-Jan-18	16-Aug-19
NT - Dak - 10	Kafr Abu Naser Njeer 3	321	17-Aug-19	3-Jul-20
NT - Dak - 11	Meet Al Aamel 1	465	1-Jun-16	9-Sep-17
NT - Dak - 12	Meet Al Aamel 2	494	10-Sep-17	17-Jan-19
NT - Dak - 13	Meet Al Aamel 3	448	18-Jan-19	10-Apr-20
NT - Dak - 14	Barhamtoosh	240	1-Jun-16	27-Jan-17
NT - Dak - 15	Al Gamalya	271	1-Jun-16	27-Feb-17
NT - Dak - 16	Birmbal El Gadida 1	483	1-Jun-16	27-Sep-17
NT - Dak - 17	Birmbal El Gadida 2	514	28-Sep-17	24-Feb-19
NT - Dak - 18	Birmbal El Gadida 3	532	25-Feb-19	10-Aug-20
NT - Dak - 19	El Manzala 1	571	1-Jun-16	24-Dec-17
NT - Dak - 20	El Manzala 2	438	25-Dec-17	8-Mar-19
NT - Dak - 21	El Manzala 3	551	9-Mar-19	10-Sep-20
NT - Dak - 22	Ulilah 1	263	1-Jun-16	19-Feb-17
NT - Dak - 23	Ulilah 2	507	20-Feb-17	12-Jul-18
NT - Dak - 24	Dekerness	119	1-Jun-16	28-Sep-16

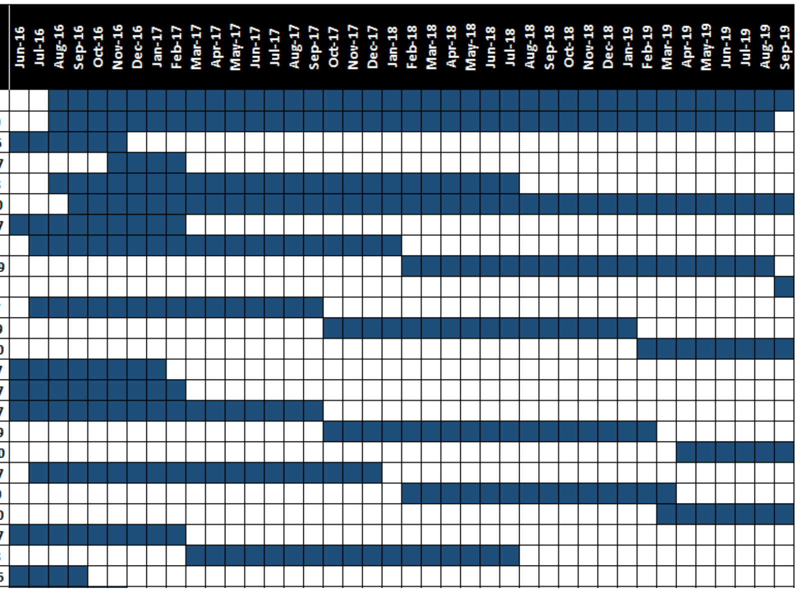


Figure 94: Network Construction Bar Schedule (Optimized)

other hand, in order to be able to calculate the DLI disbursement time in the cashflow schedule, a detailed figure is needed to calculate the achieved results and their execution time. The objective of the model is to be able to reduce the funding gap by optimizing the time of the expenditures and trying to collect the loan disbursements as early as possible. Figure 97 and Figure 98 shall provide a detailed calculation of the achieved results per month represented by the number of designed and constructed household connections. The model shall check at the end of each month whether the cumulative number of household connections designed or constructed has met the DLIs requirements for this month in order to release the corresponding disbursement. The optimized cashflow schedule shall reflect the disbursed amount and start applying for the interest payments accordingly.

The model also provides detailed schedules for the packages in Figure 99 and Figure 100. For example, Figure 99 shows the design package allocated to a consultant company coded S4.

Network Design Master Schedule Cashflow - Optimized

Activity	Activity Description	Design Duration (Months)	Design Cost (USD)	Average Cost per Month (USD)	Jun-16 (1)	Jul-16 (2)	Aug-16 (3)	Sep-16 (4)	Oct-16 (5)	Nov-16 (6)	Dec-16 (7)	Jan-17 (8)	Feb-17 (9)	Mar-17 (10)
NT - Dak - 1	Al Senblawin	3	168,465	56,155	56,154.93	56,154.93	56,154.93							
NT - Dak - 2	Borg Nour Al Hommos	3	145,027	48,342	48,342.33	48,342.33	48,342.33							
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	1	38,165	38,165	38,165.00									
NT - Dak - 4	Al Robaa-C2 Villages	1	39,243	39,243						39,242.60				
NT - Dak - 5	Shubrawish	3	126,528	42,176	42,176.07	42,176.07	42,176.07							
NT - Dak - 6	Nawasa Al Ghayt	4	176,008	44,002	44,002.00	44,002.00	44,002.00	44,002.00						
NT - Dak - 7	Demshlet Village	1	71,481	71,481	71,480.80									
NT - Dak - 8	Kafr Abu Naser Njeer 1	2	79,689	39,844	39,844.26	39,844.26								
NT - Dak - 9	Kafr Abu Naser Njeer 2	2	79,689	39,844										
NT - Dak - 10	Kafr Abu Naser Njeer 3	2	79,689	39,844										
NT - Dak - 11	Meet Al Aamel 1	2	61,908	30,954	30,954.06	30,954.06								
NT - Dak - 12	Meet Al Aamel 2	2	61,908	30,954										
NT - Dak - 13	Meet Al Aamel 3	2	61,890	30,945										
NT - Dak - 14	Barhamtoosh	1	76,240	76,240	76,240.20									
NT - Dak - 15	Al Gamalya	1	46,337	46,337	46,336.80									
NT - Dak - 16	Birmbal El Gadida 1	1	66,703	66,703	66,703.44									
NT - Dak - 17	Birmbal El Gadida 2	2	66,685	33,343										
NT - Dak - 18	Birmbal El Gadida 3	3	66,685	22,228										
NT - Dak - 19	El Manzala 1	2	71,481	35,740	35,740.40	35,740.40								
NT - Dak - 20	El Manzala 2	3	71,481	23,827										

Figure 95: Network Design Cashflow Schedule (Optimized)

Network Construction Master Schedule Cashflow - Optimized

Activity	Activity Description	Construction Duration (Months)	Construction Cost (USD)	Average Cost per Month (USD)	Jun-16 (1)	Jul-16 (2)	Aug-16 (3)	Sep-16 (4)	Oct-16 (5)	Nov-16 (6)	Dec-16 (7)	Jan-17 (8)	Feb-17 (9)	Mar-17 (10)	Apr-17 (11)	May-17 (12)
NT - Dak - 1	Al Senblawin	42	8,423,240	200,553			200,553	200,553	200,553	200,553	200,553	200,553	200,553	200,553	200,553	200,553
NT - Dak - 2	Borg Nour Al Hommos	37	7,251,350	195,982			195,982	195,982	195,982	195,982	195,982	195,982	195,982	195,982	195,982	195,982
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	6	1,908,250	318,042	318,042	318,042	318,042	318,042	318,042	318,042						
NT - Dak - 4	Al Robaa-C2 Villages	4	1,962,130	490,533						490,533	490,533	490,533	490,533			
NT - Dak - 5	Shubrawish	24	6,326,410	263,600			263,600	263,600	263,600	263,600	263,600	263,600	263,600	263,600	263,600	263,600
NT - Dak - 6	Nawasa Al Ghayt	41	8,800,400	214,644				214,644	214,644	214,644	214,644	214,644	214,644	214,644	214,644	214,644
NT - Dak - 7	Demshlet Village	9	3,574,040	397,116	397,116	397,116	397,116	397,116	397,116	397,116	397,116	397,116	397,116			
NT - Dak - 8	Kafr Abu Naser Njeer 1	19	3,984,426	209,707		209,707	209,707	209,707	209,707	209,707	209,707	209,707	209,707	209,707	209,707	209,707
NT - Dak - 9	Kafr Abu Naser Njeer 2	19	3,984,426	209,707												
NT - Dak - 10	Kafr Abu Naser Njeer 3	11	3,984,426	362,221												
NT - Dak - 11	Meet Al Aamel 1	15	3,095,406	206,360		206,360	206,360	206,360	206,360	206,360	206,360	206,360	206,360	206,360	206,360	206,360
NT - Dak - 12	Meet Al Aamel 2	16	3,095,406	193,463												
NT - Dak - 13	Meet Al Aamel 3	15	3,094,508	206,301												
NT - Dak - 14	Barhamtoosh	8	3,812,010	476,501	476,501	476,501	476,501	476,501	476,501	476,501	476,501	476,501				
NT - Dak - 15	Al Gamalya	9	2,316,840	257,427	257,427	257,427	257,427	257,427	257,427	257,427	257,427	257,427	257,427			
NT - Dak - 16	Birmbal El Gadida 1	16	3,335,172	208,448	208,448	208,448	208,448	208,448	208,448	208,448	208,448	208,448	208,448	208,448	208,448	208,448
NT - Dak - 17	Birmbal El Gadida 2	17	3,334,274	196,134												
NT - Dak - 18	Birmbal El Gadida 3	17	3,334,274	196,134												
NT - Dak - 19	El Manzala 1	18	3,574,040	198,558		198,558	198,558	198,558	198,558	198,558	198,558	198,558	198,558	198,558	198,558	198,558
NT - Dak - 20	El Manzala 2	14	3,574,040	255,289												

Figure 96: Network Construction Cashflow Schedule (Optimized)

Network Design Achieved Results (#of HH) - Optimized

Activity	Activity Description	Design Duration	HH Connections	Average Achieved per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17
		Months	#	#	1	2	3	4	5	6	7	8	9	10
NT - Dak - 1	Al Senblawin	3	9,380	3,127	3,127	3,127	3,127							
NT - Dak - 2	Borg Nour Al Hommos	3	8,075	2,692	2,692	2,692	2,692							
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	1	2,125	2,125	2,125									
NT - Dak - 4	Al Robaa-C2 Villages	1	2,185	2,185						2,185				
NT - Dak - 5	Shubrawish	3	7,045	2,348	2,348	2,348	2,348							
NT - Dak - 6	Nawasa Al Ghayt	4	9,800	2,450	2,450	2,450	2,450	2,450						
NT - Dak - 7	Demshlet Village	1	3,980	3,980	3,980									
NT - Dak - 8	Kafr Abu Naser Njeer 1	2	4,437	2,219	2,219	2,219								
NT - Dak - 9	Kafr Abu Naser Njeer 2	2	4,437	2,219										
NT - Dak - 10	Kafr Abu Naser Njeer 3	2	4,437	2,219										
NT - Dak - 11	Meet Al Aamel 1	2	3,447	1,724	1,724	1,724								
NT - Dak - 12	Meet Al Aamel 2	2	3,447	1,724										
NT - Dak - 13	Meet Al Aamel 3	2	3,446	1,723										
NT - Dak - 14	Barhamtoosh	1	4,245	4,245	4,245									
NT - Dak - 15	Al Gamalya	1	2,580	2,580	2,580									
NT - Dak - 16	Birmbal El Gadida 1	1	3,714	3,714	3,714									
NT - Dak - 17	Birmbal El Gadida 2	2	3,713	1,857										
NT - Dak - 18	Birmbal El Gadida 3	3	3,713	1,238										
NT - Dak - 19	El Manzala 1	2	3,980	1,990	1,990	1,990								
NT - Dak - 20	El Manzala 2	3	3,980	1,327										

Figure 97: Network Design Achieved Results (Optimized)

Network Construction Achieved Results (#of HH) - Optimized

Activity	Activity Description	Construction Duration	HH Connections	Average Achieved per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17
		Months	#	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14
NT - Dak - 1	Al Senblawin	42	9,380	223			223	223	223	223	223	223	223	223	223	223	223	223
NT - Dak - 2	Borg Nour Al Hommos	37	8,075	218			218	218	218	218	218	218	218	218	218	218	218	218
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	6	2,125	354	354	354	354	354	354	354								
NT - Dak - 4	Al Robaa-C2 Villages	4	2,185	546						546	546	546	546					
NT - Dak - 5	Shubrawish	24	7,045	294			294	294	294	294	294	294	294	294	294	294	294	294
NT - Dak - 6	Nawasa Al Ghayt	41	9,800	239				239	239	239	239	239	239	239	239	239	239	239
NT - Dak - 7	Demshlet Village	9	3,980	442	442	442	442	442	442	442	442	442	442					
NT - Dak - 8	Kafr Abu Naser Njeer 1	19	4,437	234		234	234	234	234	234	234	234	234	234	234	234	234	234
NT - Dak - 9	Kafr Abu Naser Njeer 2	19	4,437	234														
NT - Dak - 10	Kafr Abu Naser Njeer 3	11	4,437	403														
NT - Dak - 11	Meet Al Aamel 1	15	3,447	230		230	230	230	230	230	230	230	230	230	230	230	230	230
NT - Dak - 12	Meet Al Aamel 2	16	3,447	215														
NT - Dak - 13	Meet Al Aamel 3	15	3,446	230														
NT - Dak - 14	Barhamtoosh	8	4,245	531	531	531	531	531	531	531	531	531						
NT - Dak - 15	Al Gamalya	9	2,580	287	287	287	287	287	287	287	287	287	287					
NT - Dak - 16	Birmbal El Gadida 1	16	3,714	232	232	232	232	232	232	232	232	232	232	232	232	232	232	232
NT - Dak - 17	Birmbal El Gadida 2	17	3,713	218														
NT - Dak - 18	Birmbal El Gadida 3	17	3,713	218														
NT - Dak - 19	El Manzala 1	18	3,980	221		221	221	221	221	221	221	221	221	221	221	221	221	221
NT - Dak - 20	El Manzala 2	14	3,980	284														

Figure 98: Network Construction Achieved Results (Optimized)

S4

Activity	Activity Description	Design Duration	HH Connections	Average Achieved per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17
NT - Dak - 1	Al Senblawin	3	9,380	3,127										
NT - Dak - 2	Borg Nour Al Hommos	3	8,075	2,692	**2,692**	**2,692**	**2,692**							
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	1	2,125	2,125										
NT - Dak - 4	Al Robaa-C2 Villages	1	2,185	2,185										
NT - Dak - 5	Shubrawish	3	7,045	2,348	**2,348**	**2,348**	**2,348**							
NT - Dak - 6	Nawasa Al Ghayt	4	9,800	2,450	**2,450**	**2,450**	**2,450**	**2,450**						
NT - Dak - 7	Demshlet Village	1	3,980	3,980										
NT - Dak - 8	Kafr Abu Naser Njeer 1	2	4,437	2,219										
NT - Dak - 9	Kafr Abu Naser Njeer 2	2	4,437	2,219										
NT - Dak - 10	Kafr Abu Naser Njeer 3	2	4,437	2,219										
NT - Dak - 11	Meet Al Aamel 1	2	3,447	1,724	**1,724**	**1,724**								
NT - Dak - 12	Meet Al Aamel 2	2	3,447	1,724										
NT - Dak - 13	Meet Al Aamel 3	2	3,446	1,723										
NT - Dak - 14	Barhamtoosh	1	4,245	4,245										
NT - Dak - 15	Al Gamalya	1	2,580	2,580										
NT - Dak - 16	Birmbal El Gadida 1	1	3,714	3,714										
NT - Dak - 17	Birmbal El Gadida 2	2	3,713	1,857										
NT - Dak - 18	Birmbal El Gadida 3	3	3,713	1,238										
NT - Dak - 19	El Manzala 1	2	3,980	1,990	**1,990**	**1,990**								
NT - Dak - 20	El Manzala 2	3	3,980	1,327										

Figure 99: Example of Achieved Results for Consultant Company (S4)

C7

Activity	Activity Description	Construction Duration	HH Connections	Average Achieved per Month	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Jul-17	Aug-17	Sep-17	Oct-17	Nov-17	Dec-17
		Months	#	#	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
NT - Dak - 1	Al Senblawin	42	9,380	223																			
NT - Dak - 2	Borg Nour Al Hommos	37	8,075	218																			
NT - Dak - 3	Al Robaa-C1 Village of Al Robae	6	2,125	354																			
NT - Dak - 4	Al Robaa-C2 Villages	4	2,185	546																			
NT - Dak - 5	Shubrawish	24	7,045	294																			
NT - Dak - 6	Nawasa Al Ghayt	41	9,800	239				**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**	**239**
NT - Dak - 7	Demshlet Village	9	3,980	442																			
NT - Dak - 8	Kafr Abu Naser Njeer 1	19	4,437	234		**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**	**234**
NT - Dak - 9	Kafr Abu Naser Njeer 2	19	4,437	234																			
NT - Dak - 10	Kafr Abu Naser Njeer 3	11	4,437	403																			
NT - Dak - 11	Meet Al Aamel 1	15	3,447	230		**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**	**230**			
NT - Dak - 12	Meet Al Aamel 2	16	3,447	215																			
NT - Dak - 13	Meet Al Aamel 3	15	3,446	230																			
NT - Dak - 14	Barhamtoosh	8	4,245	531																			
NT - Dak - 15	Al Gamalya	9	2,580	287																			
NT - Dak - 16	Birmbal El Gadida 1	16	3,714	232	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**	**232**			
NT - Dak - 17	Birmbal El Gadida 2	17	3,713	218																			
NT - Dak - 18	Birmbal El Gadida 3	17	3,713	218																			
NT - Dak - 19	El Manzala 1	18	3,980	221																			
NT - Dak - 20	El Manzala 2	14	3,980	284																			

Figure 100: Example of Achieved Results for a Contracting Company (C7)

The figure demonstrates part of the achieved results, which are in terms of the number of designed household connections. Figure 100 also shows the construction package allocated to a contracting company coded C7, where the figure demonstrated the number of constructed household connections per month.

Histograms are also provided for each of the packages in order to be able to visually inspect the monthly workload as well. Two examples of work packages histograms are shown in Figure 101 for the consulting company S4 and the contracting company C7. The histograms are a very suitable means to present information for non-technical users. It is suitable for presentations for the upper management and high-rank government officials to convey an idea about the workload of each of the executing companies.

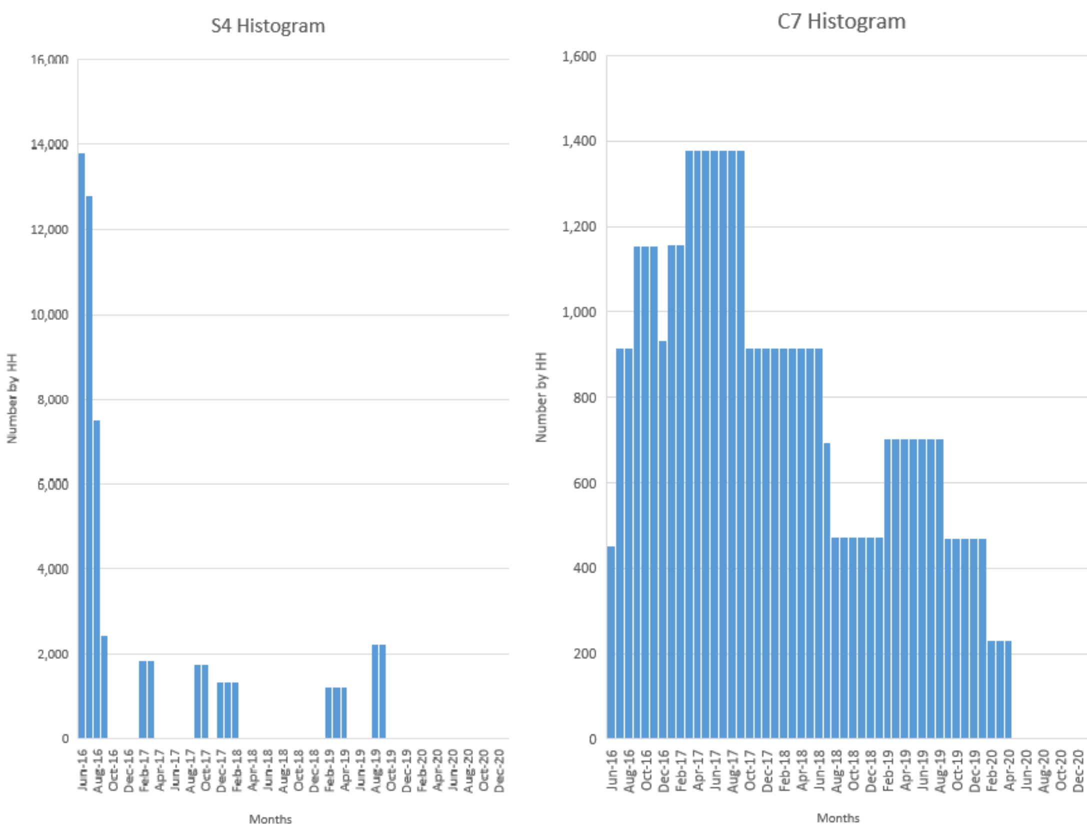


Figure 101: Company S4 and Company C7 Work Packages Histogram

The final set of outputs presented in the results navigation sheets is the cashflow diagrams. Figure 102 shows the optimized cash-in and cash-out diagrams. In order to visually inspect the effect of the optimization process, the model has a section for before and after curves. The curves in this section shall be discussed in detail in the verification section.

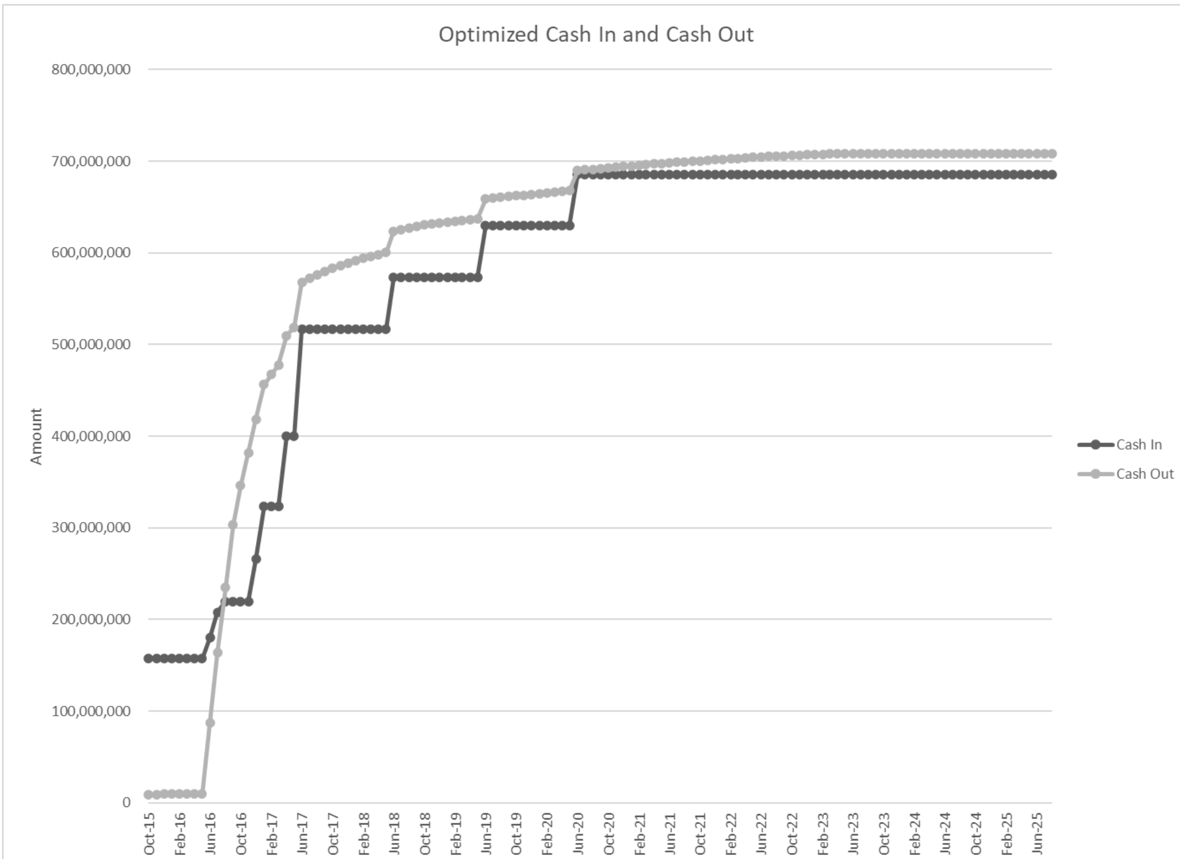


Figure 102: Optimized Cash-in and Cash-out Diagram

The previous section has presented a comprehensive preview of the model variety of outputs, including master schedules, detailed schedules, cashflows, histograms, and cash-in and cash-out diagrams. The following section shall summarize the results of the three optimization options for the provided case study.

Figure 84 shows the calculations for the project cashflow before optimization, where the net present value of the funds that are required by the government is calculated to be circa USD 315,199,056 and the maximum funds required from the government is circa USD195,611,107.

The optimization option one is to optimize the net present value of the funds that are required by the government. The values before and after optimization are shown in Table 15. The net present worth before optimization was circa USD 315,199,056; the same value has been reduced to be circa USD 298,156,270 after optimization. The net present value of the negative cashflows has been reduced by 5.4 percent after the optimization process.

Table 15: Option#1 - Government Funds Required Before and After Optimization

NPV for the Negative Cahflow Required		
Before Optimization	$	(315,199,056.71)
After Optimization	$	(298,156,270.57)
Difference	**$**	**(17,042,786.14)**
% Optimized		**5.41%**

Moreover, when optimization option two is selected, the model shall optimize the maximum negative value that denotes the peak of the negative net cashflow curve. The summary of the results of option two is shown in Table 16. The maximum funds required from the government before optimization was circa USD195,611,107, the same value after optimization is calculated to be circa USD159,126,074. The model has reduced the peak value of the negative cashflows by 18.7 percent.

Table 16: Option#2 - Government Funds Required Before and After Optimization

Maximum Government Fund Required		
Before Optimization	$	(195,611,107.46)
After Optimization	$	(159,126,074.13)
Difference	**$**	**(36,485,033.33)**
% Optimized		**18.65%**

The third option is to optimize both values using the combined objective function as summarized in Table 17. The net present value of the funds that are required by the government is optimized to be circa USD 303,147,922 and the maximum funds required from the government is circa USD162,214,478.

Table 17: Option#3 - Government Funds Required Before and After Optimization

NPV for the Negative Cahflow Required		
Before Optimization	$	(315,199,056.71)
After Optimization	$	(303,147,922.54)
Difference	**$**	**(12,051,134.17)**
% Optimized		**3.82%**

Maximum Government Fund Required		
Before Optimization	$	(195,611,107.46)
After Optimization	$	(162,214,478.70)
Difference	**$**	**(33,396,628.76)**
% Optimized		**17.07%**

Combined		
Before Optimization	$	(510,810,164.17)
After Optimization	$	(465,362,401.24)
Difference	**$**	**(45,447,762.93)**
% Optimized		**8.90%**

The model has achieved to minimize the objective function by 8.9 percent reduction, which is a combination of 3.82 percent reduction in the NPV of negative cashflows and 17.07 percent reduction in the maximum amount of funds needed by the borrowing country at a certain point in time.

The model provides the user with many user-friendly charts that can be used for reporting purposes by government officials, as illustrated in the previous section and summarized in the results navigation sheet shown in Figure 91. The before and after charts provide another method for validating the model by visually illustrating changes due to the optimization process. The first chart is the cash-in before and after optimization shown in Figure 103. As shown in the figure, the cash-in curve is shifted to the left after optimization, which indicates that the disbursements have been received earlier due to the packaging process becoming more effective. The packaging process optimization has resulted in achieving the DLIs faster and consequently receive disbursement earlier in the schedule.

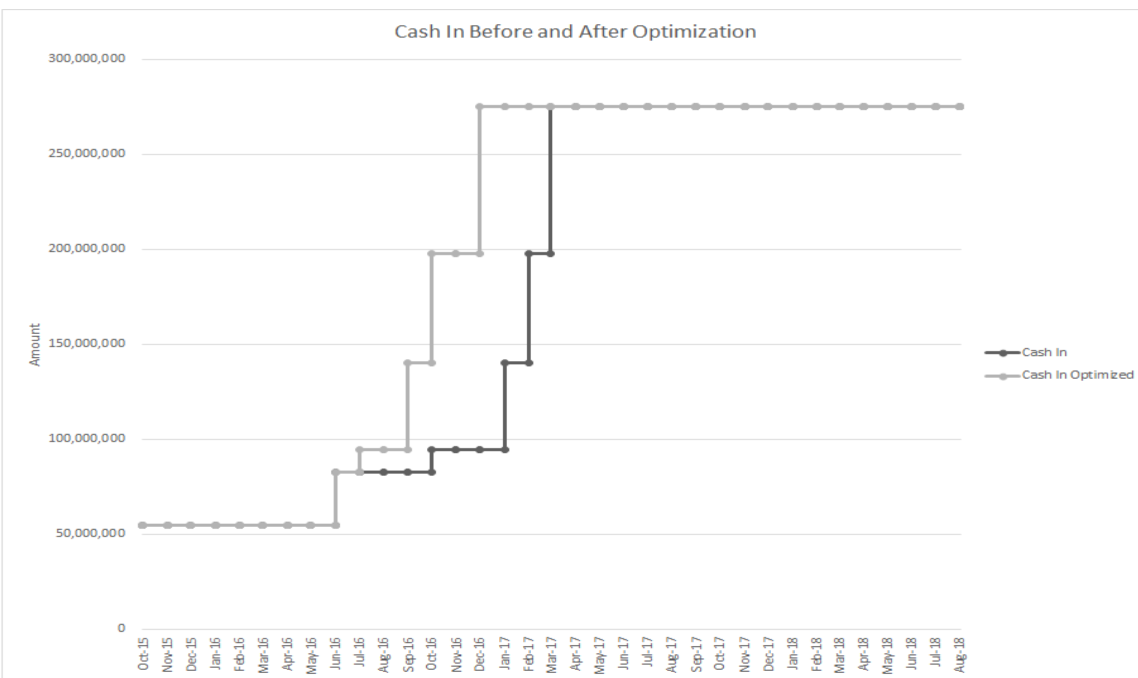


Figure 103: Cash-In Before and After Optimization

Figure 104 shows the cash-out before and after the optimization process. Although, in the early quarters of 2019, the expenses seem to be expedited and collected earlier, yet as shown in Figure 105, the net cashflow after optimization of the same period is actually smaller due to the early collection of disbursements, which neutralized the curve at this area. Moreover, in the following period, the cash-out curve is flattened because the expenditures have been better allocated due to packaging optimization. The optimization process has distributed the packages efficiently by providing better use of the schedule float and the constraints provided. During the same period, the negative values in the net cashflow have also been reduced due to the optimization process.

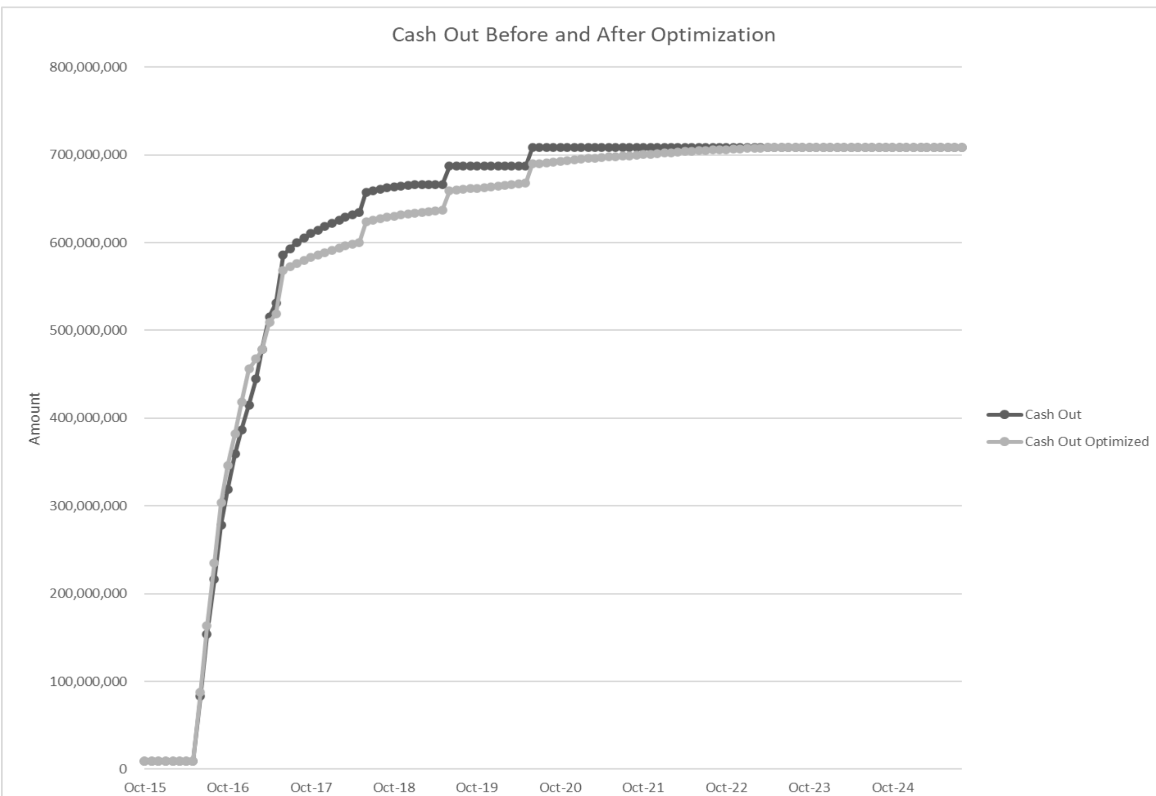


Figure 104: Cash-Out Before and After Optimization

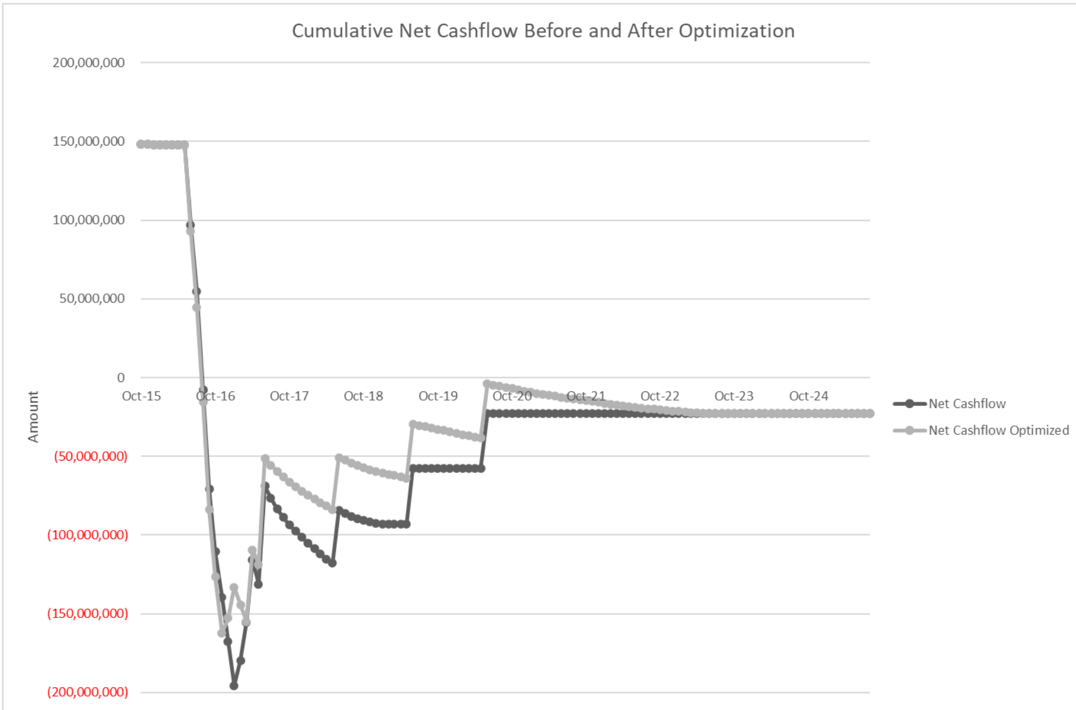


Figure 105: Net Cashflow Before and After Optimization

CHAPTER 6 : CONCLUSION

6 . 1 Contributions and Conclusions

This research optimizes the packaging process of sanitation mega infrastructure projects using the “Results-Based-Finance” funding mechanism. The research is concerned with sanitation infrastructure projects as wastewater treatment has become a priority for many countries and, more specifically, for developing countries. Untreated wastewater constitutes massive environmental hazards, which are the reason for the spread of many diseases. In addition, the “Results-Based-Finance” mechanism is a unique funding method that is developed by the World Bank in the nineties. The unique mechanism way of making the loan disbursements subject to the achievement of the results detailed in the scope of work. This mechanism is recommended for developing countries. Not only, the country benefits from the execution of the required infrastructure project but also it aids in providing support and complete reform to the targeted sector. Dealing with a complex funding tool with a tedious schedule makes no room for errors. The sector officials have many lessons learned in the management process.

The model provided in this research offers a tool to optimize the packaging process of mega infrastructure sanitation projects funded through the “Results-Based-Finance” mechanism. When executing the packages, the government is responsible for the funding until the collection of the loan disbursements after achieving the required results. The packages are selected in a way that ensures that the public treasury is credited with the lowest amount of money possible to execute the project. The optimization process provides three optimization options. The first option is to normalize the negative cashflow curve by minimizing the peak, the second option is to provide a better distribution of the cash inflows and outflows by reducing the present worth amount of the negative cashflows. The third option is a combination of the above two objectives.

The model provides a tool that presents a complete simulation of a results-based-financed project. The model provides data concerned with the loan agreements, the financial loan terms, the execution plan, the project cashflows, and the key companies. It decomposes the scope of the given case study into packages that are easier to manage and control. The model outputs are not only the content of the packages but also a complete management plan which shows the executing parties, the expected output results, the entire execution plan, the cashflow to be funded by the government, and finally, the timing and amounts of the disbursements expected to be received from the lending institution.

The model methodology has been illustrated using the Unified Modelling Language (UML), which is understood by most programmers for ease of communication. The implemented model is constructed by using a number of computer-aided programs, including Microsoft Excel, Visual Basic for Applications (VBA) programming language, and the Palisade's Decision Tools Suite. The model is designed in a user-friendly way in order to enable non-engineer officials to track and use the model easily. The outputs of the model can be easily exported for reporting purposes by the government.

The model suggested simulates the project starting from the agreement signing phase up until the delivery of all the results and the receiving of the loan disbursements. The Unified Modelling Language (UML) is used in this research to illustrate the different modules of the suggested model. Object-oriented processes and operations are modeled using different diagrams of the language. The Use Case Diagram has been used to model the agreement process, while the Class Diagram has simulated the packaging optimization process. Finally, the Sequence Diagram has been plotted to model the verification process of the achievement of the results.

The model develops an algorithm that enables the user to reach the optimum combination of the project deliverables in order to minimize the funding gap. The optimum packages ensure achieving the results as early as possible to minimize the time needed to collect the loan disbursements. This extremely reduces the amount of funds required to be secured by the government. This is a vital output of the model since, in the case of developing countries, funds are very limited and should be allocated carefully. Moreover, the optimum package allocation ensures better management in terms of better planning and better cost control.

The model has been verified using different techniques such as system checks that have to do with the different types of programming errors. The model has also been tested statistically using a sensitivity analysis module to ensure its flexibility and capabilities.

Finally, the model has been validated using a case study of a sanitation results-based financed project located in Egypt. The combined objective function incorporated two components that need to be minimized. The first component is the net present value of the negative net cashflows where the objective is to normalize the curve by reducing the negative cashflows amount as much as possible. By selecting the optimization option one, this value has been reduced by 5.4 percent as shown in Table 15. The second component of the objective function that needs to be minimized is the maximum negative cashflow value, which is the peak of the curve. This value has been reduced by 18.7 percent as shown in Table 16. Table 17 summarizes the results of the model. The optimization process has succeeded in achieving the combined objective function and minimizing its value by 8.9 percent. A 3.82 percent reduction has been achieved in the net present value of all negative cashflows. On the other hand, the maximum amount of funds needed by the borrowing country has been reduced by 17.07 percent.

6 . 2 Limitations and Future Works

There exist some potential limitations to the study. The first limitation is due to the lack of previous studies in the same area. Since RBF is a relatively new funding mechanism, the literature was somehow limited. Very few prior researches were conducted on RBF project management, and almost none of them has to do with the packaging of the project. The following limitation is the speed of the implementation software used. Microsoft Excel processing speed is low compared to other software used in simulation such as Python, Ruby, R-Language, and Lisp, (Miller, Hersberger, & Jone, 2013). In future research, it is recommended to apply the UML charts using different software with a more considerable processing speed. The model has been applied to a sanitation project, yet with some minor alterations, the model can be modified to fit other types of infrastructure projects. In addition, the model has been applied to data collected from a case study located in Egypt. Future works shall be to use the model for data from other countries to avoid the sample bias limitation.

Finally, it is recommended to add the effect of environmental issues on both the cost estimation and the schedule formation modules that might arise during the project, such as high groundwater table, pollution, and spread of diseases. Also, the effect of expected disputes resulting from land acquisition is to be studied. Finally, it is suggested to add a hybrid financing mechanism that shall include two or more funding mechanisms other than the RBF mechanism.

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APPENDIX A –WORK PACKAGES OPTIMIZATION OF RBF MEGA SANITATION PROJECTS MODEL