ABSTRACT

Title of Dissertation: MODEL DEVELOPMENT FOR REAL-TIME CONSTRUCTION SCHEDULING

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This research is focused on a model development of a segmented construction schedule that would be accessible at any time in any place in the world. Although a construction schedule directs the flow of construction by means of closely monitoring predicted activity, there is a knowledge gap to date as to how individual segments of scheduling information can be provided in an Construction Schedule Executive Summary through web-based technology and model development to any interested party. An Owner/Contractor would be concerned about the status of their project(s) at any point and at any time. The work herein addresses this gap through model development that can go inside of a web-based cost/resource loaded construction schedule and extract components (segments) that will be for the use of the Owner/Contractor. This is contingent upon the Project Superintendent and/or the Project Manager updating the progress at the end of the work day. The model will provide summary tasks to include; the activity, the cost of the activity, the resource, cost to a point of an activity, float, and whether an activity is on time, behind or ahead of schedule for the benefit of the Owner. A case study is presented

to validate the model development that will be used to advance the current state-of-the-practice in construction scheduling and management.

MODEL DEVELOPMENT FOR REAL-TIME CONSTRUCTION SCHEDULING

By

Parris J. McGhee-Bey

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I am indebted to my dissertation advisors, Dr. Kofi Nyarko and Dr. Monique Head. Since the first time I met Dr. Nyarko he believed in my idea and gave endless support. It all started in the fall of 2016. I initially thought I was headed in the right direction with my idea of a substantial industry and societal contribution, but it was going nowhere. I met Dr. Nyarko through a colleague and he made me aware of a different approach to what and how I should present my idea. I defined my research and explained its developmental processes through a modern technique. I would like to give Dr. Nyarko the credit for the success I have achieved during this intense level of advanced study. Besides my advisor, I would like to thank all of my committee members (Dr. Jiang Li, Dr. Cecelia Wright Brown, Dr. Jiang Li, Dr. Mehdi Shokouhian and Dr. Hellon Ogallo.

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Glossary

Use Case Model. This model describes the proposed functionality of the new system. A Use Case represents a discrete unit of interaction between a user (human or machine) and the system. It is a single unit of meaningful work; i.e., login to system, register with the system and create order are all Use Cases.

`Use Case Diagram. Used for describing the behavior of the target system from an external point of view.

Conceptual model. This is a representation of a system, made of the composition of concepts which are used to help people know, understand, or simulate a subject the model represents.

Object-oriented modeling is an approach to modeling an application that is used at the beginning of the software life cycle when using an object-oriented approach to software development.

Analysis model. This analysis method uses modeling to perform the analysis to capture and communicate the results.

Iteration of Analysis. The process for arriving at a decision or a desired result by repeating rounds of analysis or a cycle of operations. The objective is to bring the desired decision closer to discovery with each repetition (iteration).

Iteration of Evaluation. This is a type of design of methodology that is based on a cyclic process. The type of processing can be prototyping, testing, analyzing, and refining a product.

Artifact Diagram. This type of diagram is a classifier that represents some physical entity, a piece of information that is used or is produced by a software development process, or by the deployment and operation of a system.

Preface

The basis of this research is generated from my knowledge of one of the primary entices of the development of a construction project, the construction schedule. For the company Owner/Prime Contractor the schedule is the pulse of the construction effort. The schedule is used to determine the direction the project and/or individual tasks/activities are moving. In addition, an Owner/Prime Contractor would love to be able to look at various states their project(s) were in at any point in time and from anywhere in the world. These phenomena are what drive my research. Even for an Owner, a construction schedule could appear somewhat convoluted and confusing. If an Owner/Prime Contractor, with the touch of a button on their phone have a birds-eye view at any and from anywhere of a construction project's simple and direct criteria it would make life them much easier. The purpose of this paper is to make idea happen via modeling the idea using Enterprise Architecture.

Chapter 1: INTRODUCTION

Envision: A construction company Owner/Contractor has several on-going projects occurring at the same time. Without making a phone call, the owner does not have the ability to look at specific segments of a project's construction schedule at any time from any location. To solve this, a model would be created that would allow the Owner to use any mobile devise to view a company projects' web-based construction schedules. The Owner would be able to review segments of the construction schedule and have real-time progress status remotely.

Many types of construction scheduling software currently exist in the construction industry. They are very detailed with a lot of features that may not be of interest to an Owner that is purely interested in specifics on any of a number of projects while on the move or simply in a relaxed mode. But there are none that has the ability to provide only certain specifics such as the segmentation of certain information that is specifically pertinent to the Owner/Prime Contractor and is considered in short, the executive summary.

Understanding the daily progress of a construction project is very important to a construction company Owner. To be able to monitor the previously mentioned specifics at any time and from anywhere would be ideal. Such scheduling specifics, like; 1) project activities (tasks), 2) cost of activities, 3) percent of completion, 4) resource(s) of an activity, 5) float (free/total), 6) whether an activity is ahead of schedule, 7) if an activity is on schedule, or 8) if an activity is behind schedule, would be highly necessary and important to an Owner. To accomplish this task, a particularly coded mobile application

is needed to advance the current state-of-the-practice for construction scheduling for real-time assessment.

Chapter 2: AIMS AND OBJECTIVES

The research aim is to develop a model of an application that shows how through directed implementation an ability to read a web-based construction schedule and produce a view of what is considered segmented executive summary from any place at any time. The following objectives will be addressed:

1) To develop a model that will satisfy the research aim.
2) To create a case study to validate workability. This will be established by producing a sample project.
3) The model will show the execution functions that are critical to retrieving the executive summary.

The objective is to satisfy the need of the user, the model development would need to;

- Be mobile
- View all on-going projects
- List all projects and all associated activities
- Have secure access
- All the Superintendent and/or Project Manager input data that would update the status and values of assigned projects
- Allow the Owner/Contractor to have a review of all ongoing projects with updated progress, values and status

The model will have the following features:

- Be able to operate on a computer, laptop, tablet or mobile phone
- Present “Summary View” to the owner and “Update View” to the Project Managers & Superintendents of projects.

- List view of all projects with navigation to content details
- Each project activity would cover the following details of an executive summary;
    1. Activity
    2. Cost of activity
    3. Percent of completion
    4. Resources
    5. Behind schedule
    6. On schedule
    7. Ahead of schedule
- The Owner/Prime Contractor could be able to email “summary views”
- Navigation to each construction location may be provided
- Contact Superintendent or Project Manager options in application for direct connection
- Notes section for Owner to leave memos for Superintendents or Project Managers

Chapter 3: PROPOSED METHODOLOGY

3.1 Overview: Intellectual Merit

What makes this research unique is that of all the scheduling software and mobile application that is attributed to construction scheduling, there is none that has been developed that will segment components i.e. provide an activity, the cost of an activity, the resource of an activity, the float of an activity or activities, whether the activity is on schedule, behind schedule or ahead of schedule. It was learned that there are two distinct parts that need to be considered: First, a legitimate construction schedule must be developed. To define what is meant by legitimate, a true construction schedule that is built through a Work Breakdown Structure (WBS) [see Appendix], WBS dictionary [see Appendix], and a Network Diagram. This should be done before developing the schedule.

3.1.1 Work Breakdown Structure (WBS)**:** The WBS is a view into the project which shows what work the project encompasses. It is a tool which helps to easily communicate the work and processes involved to execute the project. It is a key project deliverable that organizes a team's work into manageable sections. And visually defines the scope into manageable chunks that a project team can understand. Each level of the work breaks down structure provides further definition and detail.

There are several different views that the WBS can be developed in: The Outline View, Hierarchical Structure View, Tabular View, and the Tree Structure View. During this research the "Outline View" will be used in developing the WBS.

The Outline View presents an easy view to and understand layout for the WBS. It is also a good layout to use when developing the WBS because you can easily make changes, especially since the Microsoft Word auto numbering feature updates the numbering.

3.1.2 WBS Dictionary: The WBS dictionary contains all the details of the WBS which are necessary to successfully complete the project. Most importantly it contains a definition of each work package which can be thought of as a mini scope statement. A supporting document that provides detailed information about each element contained in the WBS, including work packages and account controls.

3.1.3 Network Diagram**:** This is a visual representation of a project's schedule. Complements to the network diagram includes PERT (Program Evaluation & Review Technique), utilized as a method to break-down and chart various steps needed to complete and predict the earliest possible completion date) and Gantt Chart (a graphical representation used in project management that will show the length of time tasks in the project should take, as measured against real time).

3.2 Terminology:

Activity (Task): Construction task of which a Subcontractor is responsible.

Activity Cost: The contracted dollar amount of each individual task.

Percent of Completion**:** The percentage of an individual task that has been completed within a certain percentage of the task duration and contract duration.

Float (Total)**:** The amount of time that a task in a project network can be delayed without causing a delay to the project completion date.

Float (Free)**:** The amount of time that a task in a construction project network can be delayed without causing a delay to subsequent tasks.

Resource**:** Provide (a person or organization) with materials, money, staff, and other necessary for an effective operation.

3.3 System Documentation: A Step by Step Approach

- Background: A company Owner did not have the ability to look at specifics of a construction schedule at any time from any where
- Problem Definition: Develop a framework that will summarize a segmented construction schedule. A construction Owner needs to have the ability to review segments of the construction schedule remotely.
- Problem Description/Statement: A construction company Owner/Contractor does not have the ability to look at segmented specifics of a construction schedule. He needs to review this schedule at any time and from any place in the world. The Owner/Contractor needs to perform this through a web-based construction schedule. It has been determined that a construction Owner, on a day to day basis is very business (traveling, etc.). Because he/she may have multiple projects the idea has come about that it would be great to have a mechanism that will allow a construction Owner to review the status of ongoing projects in an instant. To achieve this function a framework can be implemented through a web-based portal. To evaluate this framework a mock construction

schedule will have to be developed. With the standard parameters of live construction project.

Chapter 4: PROCESSES: RESEARCH TASKS

4.1 Literature Reviews:

For the literature review, several topics were examined to understand the workflow for which the model development was based as well as show that to date no one has addressed being able to produce an executive summary schedule using a mobile app based on a free/source framework. As such, more than 20 authors are cited who have published on relevant work related to construction scheduling, and are presented as a summary herein for sections:

4.1a) Construction *Scheduling Using the Constraint Satisfaction Problem Method* **(**Lorterapong and Ussavadilokrit 2013)

The authors of this writing focused on noting the difference between the traditional CPM and the proposed CSP-based scheduling method. A case example was used as a point of comparison. Construction projects are subject to numerous constraints of different types. The CSP-based scheduling method concentrates on satisfying project constraints. The CPM-based methods concentrate on scheduling activities as per predefined and fixed logic. At the outset of the scheduling process, CPM in a general sense will require planners to understand all the project constraints. Once these constraints are understood they're used to formulate a project network for forward and backward CPM calculations. If conditional constraints are considered like "Road 1 can begin as soon as Road 2 or Road 3 is finished," cannot be incorporated into one network logic. Multiple logics will have to be separately modeled. This process could be time consuming for large projects. Constraints can be

imposed in a more expressive and flexible manner in the CSP-based scheduling method. The project-monitoring task can be performed by the CSP method. Remaining duration of in-progress activities, percent of completion and actual start/finish times are treated as new constraints. Consistency and propagation as they relate to scheduling variables apply to the checking of the constraints. Planners can use backtrack searching algorithms to search for a valid schedule (if one exists). Project updating is performed in CPM-based methods and is based on the same network logic that is used to generate a baseline. The planner will have to manually alter the sequence if the project is experiencing delays. The planner can also perform a time-cost trade-off. There are a lot of different constraints on construction projects. Of which are most difficult during the construction scheduling process. The way in which the constraints are satisfied ensures the practicality of a schedule. In review of this research it was clear that there was an obvious need that created a foundation to incorporate CSP into construction scheduling. The concept of Constraint Satisfaction Problem-method is a brilliant idea as relates to pre- & newly discovered constraints.

This writing does not discuss the segmentation of a construction schedule for the benefit of the Owner as described in the present research.

4.1b) 4*D Scheduling: A Case Study*, (Basu 2007)

This review is about a 3D CAD model that is attached to the 4th dimension of time in a construction schedule. It was very challenging developing 3D models from 2D CAD drawings while relating the CAD

elements to real schedules. The norm now is 3D CAD elements. Schedule outputs can be linked to the CAD elements from Primavera or Microsoft Project to produce effective 4D schedules.

The study of a 4D scheduling effort for a large construction program was initiated. This exercise was developed to help non-technical stakeholders visualize the design, construction and phasing of the total building program that's to be funded. The dimensions to be conveyed through this effort were:

- programming phasing and sequencing of work
- the length of time it would take; and,
- performance of major construction elements

A 3D CAD model of the entire program was linked to a schedule. The objective was to visualize the phasing and sequencing of the construction and the communication of the scope. The scope was communicated to the lay stakeholder. This was achieved by constructing a 3D CAD model, a 3D model of the entire program. After this was done linking the model was satisfied. This was conveyed to the lay stakeholder by way of constructing a 3D CAD model of the entire program and linking the model to a schedule. The project team began to discover other uses for this model due to the 3D CAD model being dimensionally accurate. Other uses like logistic planning, site line studies, walk-through, etc.

- Context of 4d Scheduling

Some of the concepts and acronyms:

BIM – Building Information Modeling or Model – Digital format of a digital representation of the building process that can facilitate exchange and produce interoperability in digital format.

VDC (Virtual Design and Construction), a concept developed by CIFE at Stanford University.

Three-dimensional representation of an object is 3D CAD. They could be models, that are made up of components and have properties. Time is the fourth dimension (i.e. 4D). It is linked to the 3D Model. The linking of estimates and schedule to a 3D model is considered 5D.

- Assembling A 4D Schedule

A Primavera schedule was linked to a 3D CAD model by way of 4D scheduling package. In preparing a 4D schedule a 3D CAD drawing or rendering is not sufficient. In preparing a 4D schedule, a 3D model is required. The 3D model is made up of components that have meaning in construction constituents (i.e. column, beams, floors, walls, etc.). The 3D model takes a lot effort to prepare, especially where the norm is 2D drawings.

- Benefits of 4D Scheduling

4D scheduling and 3D modeling are both clear and unclear in any comprehensive division. For example, the savings in cost and schedule, risk reduction, improved quality, reduction and claims are clear, using the models to communicate project parameters to non-technical stakeholders and get their buy-in.

- How 4D Scheduling Differs from Conventional Scheduling

4D scheduling forces the scheduler to think in a different kind of way. A way that causes the scheduler to adjust the way of scheduling development e.g.,
A 4D schedule gives the scheduler the ability to look inside, outside and under the building or site. This ability affords the scheduler the opportunity to verify the planned sequence. The scheduler plans at a greater depth and refines logic due to constant visual feedback forces.

- What 4D scheduling Does Not Do

4D scheduling does not support a lot of the facets of current scheduling practices. Offsite activities like submittal approval, fabrication or coordination, procurement cycles, etc. are not supported by 4D models. Conventional scheduling would need to carry these critical activities without the benefit of displaying them visually.

- Critical Path, Late Dates and Float

At present, there are no features built into the 4D that will show the critical path, total float and late dates. Showing the critical path in a different color does make visual sense, there will remain the question; of what value is it in showing total float or late dates visually?

- Cost, Resources and Earned Value

Cost and resource loading, cash flow analysis and earned value analysis are not supported by 4D. It is not understood if they need to be supported in the 4D model or just stay a part of an existing scheduling practice.
4D scheduling is becoming a reality. There has been confirmation of their value in cost and time with field data. This can provide an opportunity for

scheduler to enhance their value to the project team. BIM and 4D scheduling proactively offers new challenges shaping tools and improving productivity and usability and establishing standards of practice. Schedulers must seek out opportunities and promote its use in influencing the technology, the tools and the practice standards.

There are opportunities to use the research of my mobile application. Only because BIM and 4D will have a scheduling component. If the 3D model and the time dimension (4D) is internet based it can be utilized. And any owner can review their executive summary at any time from any place.

4.1c) *A dynamic scheduling model for construction enterprises,* (Amer 2014)

This writing is about what most researchers focused on when it came to optimal or near-optimal predictive schedules that happen to have schedule problem characteristics that were different. Dynamic environments are what construction projects operate in. they are subject to real-time events. Taking this into consideration, the development of a dynamic scheduling model that can enhance real-time events would be ideal for successful implementation of construction systems. There are literature reviews for scheduling, dynamic scheduling and optimization. Despite a number of researches that have been presented and applications performed, dynamic scheduling in manufacturing and other industries, dynamic scheduling literature in the construction industry was scarce. From what's known there are two primary paths of research. A path that gives rise to development of the practical solution and the other related to the development of the core model. Path one, this path involved the

development of computer-based dynamic scheduling frame work. This concept could be used within the construction industry. The second path, based on the schedule models in literature, develop a mathematical model with extensions according to practical considerations that are related to the construction.

This review is about a questionnaire survey given to a number of construction project managers and construction project management practitioners from different countries about the problem under study for the proposed solution. The basis for the functionality of specifications ia a dynamic framework, etc.

This research does not touch on the direction or mode of my research. This is about the development of a new type of framework hat is in the of a software tool. This software as fully integrated with current planning/scheduling practices. If this dynamic can result in a success completion it is possible that segmental extraction is possible.

4.1d) *Automation in construction scheduling: a review of the literature* (Vahid et al. 2014).

This review is about the automating the process of generating construction schedules. Researchers Newell and Simon tried to find better ways to use web-based algorithms and applications to simplify the scheduling process. Automatically generating and optimizing construction schedule research has been around for about four decades, starting in the early 1960's. Newell and Simon tried to find ways to use different applications and

computer-based algorithms make the process of scheduling simpler and smoother. Past accumulative construction was used as a database and new projects were scheduled accordingly. Case-based reasoning (CBR) and knowledge-based approaches. CBR is a different major artificial intelligence tool. It can take the specific knowledge of formally practiced situations and exploit them. E.g.., a new problem is explained from a CBR method remembers a situation that occurred earlier that is compatible to a present problem. The CBR method has the ability to adapt and use an older case(s) to explain, critique or develop new situations. CBR's main features are:

- It doesn't need a specific domain model
- Its application is reduced to identifying important features that describe a case
- It handles a huge amount of information using data bases.
- It receives new knowledge in the form of new cases to learn.

In reviewing this article, it was simple to see that the applicable personal research could not be incorporated in this idea. Case-based reasoning does not fit the concept of a web-based construction schedule in the sense that its theory is very abstract.

4.1e) How *the Critical Chain Scheduling Method is working for Construction*, **(**Yang 2007).

This review is focuses on the delays that occur in traditional scheduling techniques such as the critical path method (CPM) and program evaluation & review technique (PERT). The concept of the theory of constraints (TOC)

gave rise to critical chain scheduling (CCS). CCS may can schedule control and planning more effective than traditional scheduling techniques. This type of scheduling in no way infringes on the topic of this research. It does possess possibilities the ability to incorporate the research ideas.

4.1f) *Engineering project construction schedule control method research,* (Zhou 2011)

In review of this writing it is understood that this research focuses on control methods of the construction process and attempts to help to improve the management process of the construction schedule. Schedule control of construction projects is an ongoing effort in management control. This particular is that of dynamic processes in addition to being a process cycle. From the period of when the construction begins there is schedule movement. At this time there is a construction plan execution dynamic process. At the point of when the actual progress is not consistent with the schedule a behind or ahead of construction deviation is generated. In the construction schedule control process, the causes need to be analyzed and that that is responsible for the production of any deviation. This effort should take various methods and measures that correspond to adjusting a new starting point. And then proceed according to the construction plan and construction activities. Once new disruption factor appears, the progress control process should kick in and create a new deviation. Theoretically, this concept, construction project schedule control, could strengthen project schedule management. It does not compare with the research at hand. However, if a company owner can view

his ongoing projects in an instant, any adjustment to the construction project can be made immediately. There is the possibility to use my research with the is idea of construction schedule control.

4.1g) *Factors Affecting Implementation of Resource Scheduling in Indian Construction Projects* (Venkatesh, Malathi, and Umarani 2012)

The focus of this writing is resource scheduling. This writing sites the traditional methods of critical path method (CPM) and program evaluation review technique (PERT) are based on time and that the actual work during a construction project is not completed on time. The authors conclude that a resource based scheduled should be followed because the completion of a construction schedule on time is dependent on the availability of the resources needed to meet a project deadline.

4.1h) *Decision making and uncertainty analysis in success of construction projects* (Kermanshachi and Sharareh 2016).

This writing focuses on schedule performance and construction costs that has determinants that relate to the general characteristics of a project, the best practices for heavy industrial projects and features that are specific. This study takes a look at how corresponding factors relate between each phase of a project., the way a model that is considered qualitative will help an Owner and the Project Manager get success in their projects at the early stage of the project. CII-RT305 data set is methodology that was used to perform the design research. Using mean value substitution, missing data points were generated. They were transformed to their corresponding z-values. Sample

statistical tests were performed to include at least two t-tests, The Kruskal-Wallis test (a non-parametric method for testing whether samples originate from the same distribution) and the chi-squared test (is any statistical hypothesis test where the sampling distribution of the test statistic is a chi-squared distribution when the null hypothesis is true). The purpose of these two tests were to identify critical cost and schedule performance indicators. This research does not in any way infringe on the research at hand. Studying cost and schedule performance does not promote segmentation of a construction schedule.

4.1i) *Project Scheduling and Monitoring: Current Research Status* **(**Ahuja and Thiruvengadam 2004).

This writing discusses the variations in project scheduling and monitoring. In 2001 (Chevallier and Russell 2001) showed that one way to generate draft schedules based on limited user's input is to create an editable rule base by way of an expert system combining templates that are standard with modifiable knowledge that is predefined with knowledge in a project management system. This paper also cited a new concept that will increase the reliability of a project schedule that may be accurate because of the activity's durations [Ben-Haim and Laufer 1998]. In an effort to provide a method of transformation of a verbal statement to numerical system, using fuzzy set theory is used as a considerable approach. A fuzzy set model is used to determine the parameter of statistical distribution their ongoing level of diversity on schedule durations, Mishra (1989). This writing talks about the

Limitations of CPM/PERT scheduling tools and development of new tools, *scheduling fast- track construction projects*, *time cost optimization*, *Resource allocation for repetitive construction activities/projects*, *Management Issues*, *Construction planning and Project monitoring and controlling*. Although these concepts are valuable in the project scheduling and monitoring real, they do not cross over into the research at hand. They do not speak on segmentation of construction scheduling for the benefit of the Owner and the ability for him to monitor any project in an instant.

4.1j) Planning *and Scheduling Department: Functional Aspects* **(**Ahcom, and Shash 2005).

This writing is about providing Contractors having benchmarks that will allow them to evaluate their subsystems. In short, the idea here is the development of a model that describes the Planning and Scheduling subsystem aspects. It involved the qualitative evaluation of various outputs that gives rise to a subsystem potentially. Planning and Scheduling aspects were defined with respect to key functions, location within an organization, key personnel, the duties of chief planning and scheduling engineering, planning and scheduling tools, planning and scheduling techniques, links with other departments and departments with the most effective practices. According to the authors, these aforementioned aspects explained in depth the Contractors with the effective subsystem that will better project effectiveness in a largely cost oriented industry. This research exposed and suggests various aspects and practices for the scheduling subsystem as well as planning, which

in turn will assist in organizing an ideal Contractor system. Considering a construction Contractor, a system that consists of subsystems (Subcontractors) that could be organized in a certain way for delivering building services. As mentioned, the purpose of the research in this writing is to develop a model that will present the functional aspects of a Contractors planning and scheduling department. This writing in no way infringes on the research at hand. It does not speak on segmentation of a construction schedule and provide it to the Owner by way of mobile application. However, this concept can be introduced in terms of a "functional aspect."

4.1k) *Construction schedule early warning from the perspective of probability and visualization,* **(**Yuan et al. 2017).

This writing enumerates to the undertenancies that could lead to various descriptions between the actual and the planes construction schedules. It cites the Monte Carlo method (MCM) and Building Information Modeling (BIM) used to develop a construction schedule early warning model (MCM-BIM-CSEWM). A system prototype of MCM-BIM-CEWSM prototype is developed in this paper. There are specific processes of work are explained through a large construction project. This process showed that MCM-BIM-CSEWM will not only address the logical relationship between but will visually show, according to construction-duration probably, early warning. This will occur other than construction duration in comparison with early warning models or systems traditionally. The research methodology it is based on certain research methods; i.e. CPM, MCM and BIM. MCM-BIM-

CSEWM's different functions are fulfilled with these methods. Then MCM-BIM-CSEWM has to be established (MCM-based schedule pre-warning principle). Once the actual schedule is greater than the planned schedule, it will carry out early warning. This does not take into account how volatile subsequent construction activities are. Afterwards, MCM-BIM-CSEWM application is demonstrated. This writing does not deploy any concepts that infringe on the research at hand. In addition, there doesn't seem to be an available to incorporate my research.

4.1l) *Construction scheduling using multi-constraint and genetic algorithms approach* (Nashwan and Eknarin 2005)

At the construction work face, reliable construction schedules are important. Construction schedules are needed for effective co-ordination across the supply chain and various trades. This writing is about the reliability of construction schedules enhancement and they being improved through the satisfaction of all potential constraints prior to execution on the site. Regarded as potential constraints are physical dependency of construction products, availability of resources, execution space, client instruction, execution logic and others. A limited set of construction constraints are dealt with using current scheduling tools and techniques that are designed for that purpose. Multi-constraint scheduling, of which is four major groups of construction constraints that was introduced to deal the potential constraints. Resource, contract, physical and information constraints was used to give a demonstration of the approach. There was a genetic algorithm (GA-*a method*

for solving both constrained and unconstrained optimization problems that is based on natural selection) that was developed and used for a multi-constraint optimization problem. The GA altered activities' priorities and construction methods in order arrive at a near or optimum set of project smooth resource, cost and duration profile. This occurs given multiple constraints like limited working area resource information and activity dependency. In conclusion, it was determined that GA can be made available for use for near optimum and constraint-free schedules within time. This method would be absolutely necessary to improve predictability and the productivity of construction sites.

This study doesn't infringe on the ongoing research. It does not give rise to the ability to segment a construction schedule.

4.1m) *Simplified Spreadsheet Solutions: II Overall Schedule Optimization* (Hegazy and Ersahin 2001)

This writing addresses the overall complexity of schedule optimization when considering certain constraints, i.e. cost, time and resources. This task could be daunting because of inherent difficulties of constructions projects. Modeling all aspects has associated difficulties and not having the ability to use traditional tools/methods to solve a large problem. This writing explains an approach that is practical for modeling and optimization of overall construction schedules. A spreadsheet-based model was developed and made relatively simple to the user. Cash-flow management, resource leveling, resource allocation and time-cost trade-off analysis are components of critical-path network scheduling. These components are integrated with the

spreadsheet model. Genetic algorithms, and an optimization technique that is non-traditional was used to handle large-size optimization and locate a globally optimal solution, taking into account all the aspects simultaneously. Within this writing a detailed description of the model is presented along with a hypothetical case study that was being used with it. As it stands, to automate the development of optimizing construction schedules, integration of the model with a simple information system will be described. The optimization of a construction schedule in itself is essential for the construction industry as a whole. But this research does not overlap the current research at hand. The research that will be presented is about the segmentation of a construction schedule and providing the Owner with pertinent executive information. But, during the optimization process of a schedule it is possible to provide an Owner with some exact executive information.

4.1n) Graphical-*based multistage scheduling method for RC buildings* **(***Huang 2006)*

This writing is about a new method that is considered practical for scheduling Reinforced Concrete (RC) building superstructures. The back-drop for this new specialized scheduling is Taiwan. Taiwan Contractors are becoming specialized in certain of types of construction. These types of construction specialization need schedule models that provide better scheduling results for every type of construction. Graphical-Based Multistage Scheduling Method (GMSM) is the new practical method. This new method is specifically for RC building superstructures. The purpose of this research is to

provide quantitative information as a guide for the scheduling of RC building superstructures. It is understood that GMSM is easily implemented in any worksheet software. Mostly high-rise RC structures are in the urban areas in Taiwan. There can only be an increase in profits and a means to reduce the impact on urban traffic when using a scheduling model for this type of construction. A two-category system was developed and proposed by O'Brien (1975), 1) non-repetitive work, i.e. foundations, earthwork. A graphical-based scheduling method that's developed in this study is applicable to repetitive RC building structures in Taiwan. These schedule approaches are theoretical in nature. They are for repetitive projects based on the 'Assembly Line Balance' principle. There are a couple premises that needs to be adhered to, 1) work continuity and 2) lower bound limits of construction appropriateness. Linear Scheduling Method (LSM) and Line of Balance LOB ae the principle methods. Units having activities that are identical and assumed variable LSM method and constant for the LOB method [Moselhi and Khaled, 1993]. The difference between the two methods is the duration. There are assumptions and formulations in detail in GMSM. This study explains that assumptions that are considered common in various studies is the work continuity for each and every from one unit to the next; Or in partial units work continuity.

4.1o) *Evaluation and comparison of project scheduling methods and software used in the construction industry* (Parlak 2016).

This writing is about evaluating scheduling methods. It is also about common construction project management software (CPMS). The

Construction Project Management Software that is referred to are Primavera and Microsoft Project. The objective is to use a survey to determine the most widely used project scheduling techniques. Because, project scheduling is very deterministic, this is the reason for the effort for project success. Gantt Chart Method and PDM are useful according to evaluation results, for small to medium projects, LOB technique is used for repetitive projects, PERT is for uncertain projects and the method used for complex projects is CPM. The comparison of CPMS show that MS project is cheaper and Primavera is detailed, more robust and professional. Twenty-two participants completed the survey. The participants were US and Turkey construction companies. The results demonstrated that the CPM and Gantt Chart Method are the most common methods. In considering CPMS, MS Project is most widely used. Running a close second there was Primavera.

The information in this writing is good to know but it does not delve into the segmentation of a construction schedule. But, because MS Project is being used in this survey it is possible for the concept to be incorporated.

4.1p) *Scheduling system for high rise building construction*, (Arditi, Sikangwan, and Tokdemir 2002).

This writing is about the development of a computerized system that will be used to schedule high-rise building construction. It has been developed using line-of-balance (LOB, as in previous study) technology assisted by an expert system. According to recent literature on the techniques available for scheduling and controlling construction projects of a repetitive nature shows

that Gantt charts are inadequate. There are supposedly serious problems with using network methods in certain circumstances. There is evidence that the construction of high-rise buildings has a repetitive nature but differs in some respects from other repetitive projects such as pipelines or pavement construction. There were two new concepts that have been introduced into line-of-balance methodology to accommodate the special conditions encountered in high rise building construction. ‘Flexible’ unit networks and ‘multi-level’ are the two concepts. LOB diagrams have been coded into a scheduling module called ‘Lob plans’. The authors of this writing speak of a series of databases having been compiled regarding the productivity of resources. They also speak about an expert system module (Lobex) having been developed to facilitate decision-making at network generation level. The scheduling module, the databases, and the expert system have been organized into an integrated system called, Chriss by means of communication and command routines that interface between the modules and the user input. A 16-storey building project has been used in testing Chriss' performance. The integrated system proved to be user friendly and reliable. However this writing does not speak on the ability to segment a construction schedule for the benefit of the Owner.

4.1q) *Task-Staffing-Technology fit In Construction Scheduling* (Yang 2015)

This writing is regarding a proposed study of technology fit model about combing task/staffing. It goes into the advantages and disadvantages of the critical path method (CPM) and the linear-scheduling method (LSM). And the

reasons as to why they are not used as one might expect in construction scheduling. The author of this writing developed a task-technology model fit that's purpose is to measure the extent to which how a functional construction schedule can match tasks that are expected to be performed by the scheduling staff. Also, there was a staffing-technology fit model that's purpose would be to measure to the extent of which a constructing method will match the staff's experience, their capabilities and their know-how. The developers of this phenomenon proposed these models that were supposed answer to the lack of so-called proper instruments that could evaluate the extent the extent to which scheduling methods are used in the construction industry. This development is because it has been an ongoing challenge in the construction industry to link construction scheduling methods and tasks that are expected to primarily be performed by construction schedulers. The critical path method has a lot of advantages but according to the author of this writing there are limits. The linear schedule method isn't used as much as the CPM. It is generally thought of, for projects composed of activities of a repetitive nature as being very effective. Bear in mind, LSMs are purely based on a continuous flow of resources. In addition, they effective for projects that show characteristics that are repetitive. A survey was executed by the use of a questionnaire that was given to professionals who have a lot of years of construction scheduling. To understand the statistical significance between task-technology fit and staffing -technology fit for LSM and CPM applications, a measure of statistical analyses were performed. According to the results, there are significant

differences between judgments LSM and CPM users. All this shows is that task-technology fit is very different in LSM and CPM applications. Comparably, staffing-technology fit is just as different in LSM and CPM.

In reviewing this writing, it was determined that there is nothing about this writing that resembles the standing research and does not touch on the idea of construction schedule segmentation.

4.1r) *Assessing Decision Making Strategies in Construction Management By using A Schedule-Based Simulation Framework* (Tang 2013).

This writing addresses contingencies that managers, as a whole, during a construction project may have to deal with. The fact that they are faced with challenging decision-making tasks, that are supposedly, effectively keep a construction project on track. This task is very challenging because construction projects are not typical and they possesses irreversible processes. This being understood the author of this writing believes that there is a serious need to apply a methodological approach to developing a few alternative strategies for management to make certain decisions during the planning phase. These management strategies can be deployed to manage alternative scenarios that may result from expected and unexpected disruptions in the as-planned schedule.

The objective of this writing is the development of a schedule-based simulation framework to design, assess and enhance sequences of the decision for the execution stage. Incorporating of a research by the introduction of the application of decision strategies to manage a project and to establish an

iterative methodology to continuously assess and improve decision strategies and schedules.

This writing is great in the sense of the introduction of decision-making strategies to manage construction projects. However, it does not touch on the ability to segment a construction for the benefit of the company Owner.

4.1s) *CPM Scheduling: How Industry Views Its Use* (Galloway 2006)

This writing is about how a well-developed, consistently updated critical path method (CPM) schedule will increase the probability of a project finishing on time, within budget and/or assisting in party-agreed extensions of time. When a CPM schedule is consistent and accurate it will allow the demonstration of the history by either party. This history will be to show how the project was executed. If there are delays that have occurred to the project, this history will show when, where and what activities that were specifically impacted by these delays. A good tight CPM schedule can be very crucial when there is a need to demonstrate the execution of a project and what was critical at that time. This can be especially useful when there is a need to resolve disputes that could come up as the project progresses. Even including to completion. Tracking critical activities with a CPM schedule allows a Contractor to know when the critical path is changing. Tracking delayed activities are also important as well as providing the flexibility to being able to re-sequencing and/or work around plans for various project activities to avoid a delay. CPM methodologies in delay analysis are also widely carried among experts testifying on delays after the fact. In consideration of differences, a

need has developed for standards for CPM scheduling and delay analysis; in which is common ground from which terms, applications and definitions are universally understood.

This writing is a demonstration of the power of CPM scheduling. Delays can be acknowledged through segmentation of mobile application. But this is a general approach. It still does not speak in terms as a facet of mobile application segmentation. Of which is the crux of the research at hand.

4.1t) *Development of a BIM-based structural framework optimization an simulation system for building construction,* (Sung et al. 2012)

Regarded as a needed tool for managing the process of building construction from the beginning to the end, Building Information modeling (BIM) is a technology allows for consistent management information. As it stands, the information that is provided by BIM is rarely applied to on-site construction planning and scheduling. This writing describes a BIM-based structural framework optimization and simulation system for managing construction planning and scheduling. A dynamic visualization of the construction process was conducted according to the optimized schedules. This was done by applying a predefined calculation formula and logic coupled with 3D geometry data and process data to determine the amount of work required for major construction processes. Also, if more than two different construction schedules are fed into the system, it can compare construction schedules using its comparison simulation function. The authors of this initially created a 3D geometry for the building based on a work breakdown

structure (WBS). At that point, geometry data that was extracted from 3D geometry was put together with process data into the system. Resource data that was termed as human resources, equipment and materials was linked to process data and quantity data. Construction method data, i.e. rebar, forming and concrete work were highlighted. From that point on, construction method data was used to create detailed items for process data. At the end, a construction schedule was created by inputting calculation logic and calculation formula into the system. This process was done determined the workload that would be required for each crucial process. Dynamic visualization was performed depending on the schedule optimization acquires from a 4D simulation function. Bear in mind that, if the structure of the process data, the properties of the resource data, etc. changes, the construction schedule automatically changes, and a new simulation result can be gotten. The system can compare more than two different constructions schedules through a comparison simulation to help a user predict results easily and accurately.

This study has strong overtones of construction scheduling by using comparison simulation to predict results. But, it does not give rise to the segmentation of a construction schedule for the immediate view of the Owner.

State of Practice: Primavera/MS Project vs. Mode Development

Features	Primavera	MS Project	Model Development
Percent of completion	cumbersome to retrieve	cumbersome to retrieve	Simple to retrieve, touch of a button
Float	cumbersome to retrieve	cumbersome to retrieve	Simple to retrieve, touch of a button
Resource	cumbersome to retrieve	cumbersome to retrieve	Simple to retrieve, touch of a button

Table 1

4.2 CASE STUDY:

A mock project schedule will be developed to demonstrate the functionality of the mobile application model. While the schedule for the mock project is being developed the mobile app model development will be concurrent. The study involved the development of an actual construction project. Microsoft Project Professional was used to develop the construction project for this research. Microsoft Project Professional can be used as a web-based schedule.

4.3 MODEL DEVELOPMENT:

The process begins with establishing the System Development Life Cycle (SDLC)

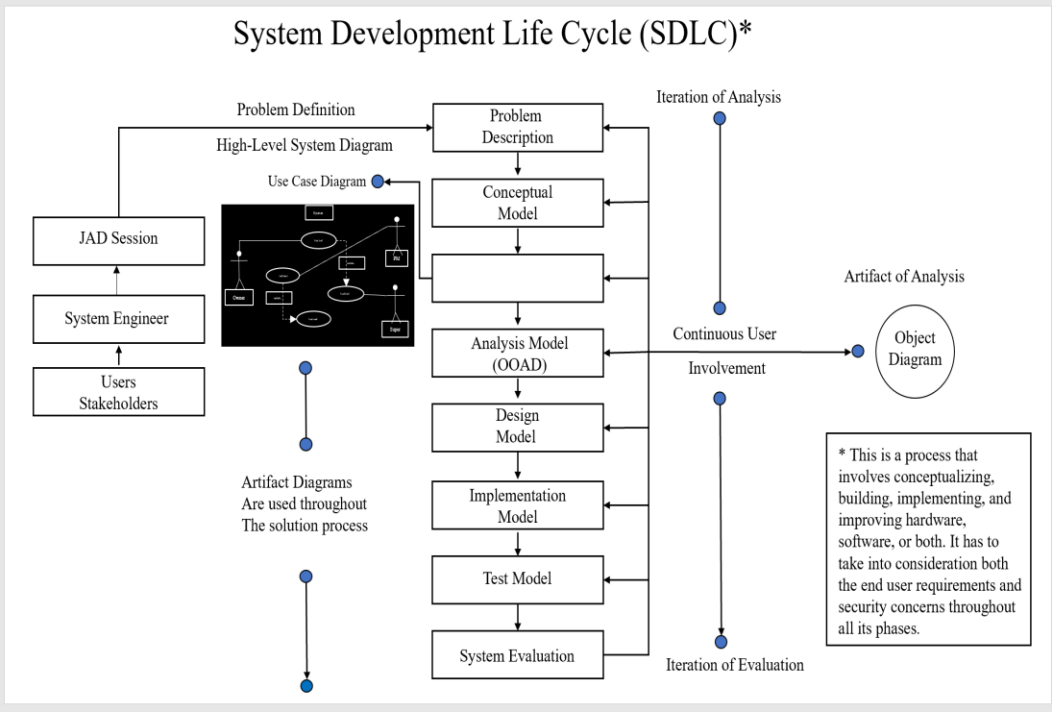

Figure 1. System Development Life Cycle

Figure 1, Initially, the Users/Stakeholders are identified, followed by the involvement of a System Engineer and engaging in a Joint Application Development (JAD) Session; of which works to define the problem and create a High-Level System Diagram.

Joint Application Development Session: is a methodology that involves the client or end user in the design and development of an application, through a succession of collaborative workshops.

Problem Definition: Develop a framework that will summarize a segmented construction schedule executive summary. A construction Owner needs to have the ability to review predetermined segments of the construction schedule remotely.

High-Level System Diagram, First Pass at Diagramming the Problem

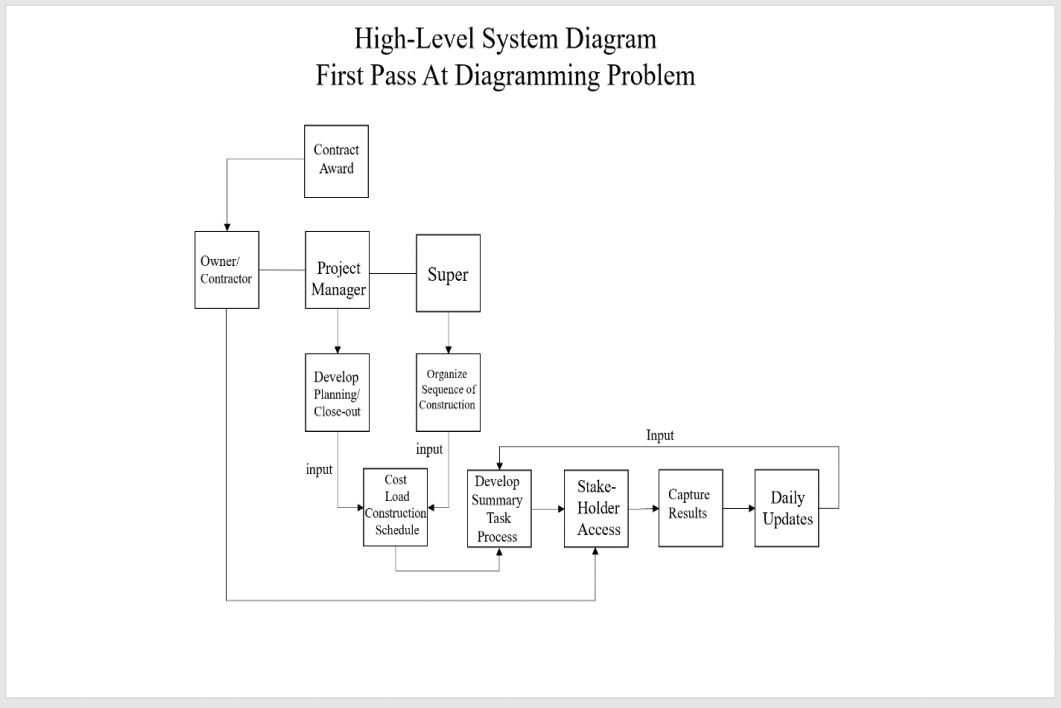

Figure 2. High-Level System Diagram

Figure 2 is a that diagram explains the architecture that would be used for developing a software product. The architecture diagram provides an overview of an

entire system, identifying the main components that would be developed for the product and their interfaces.

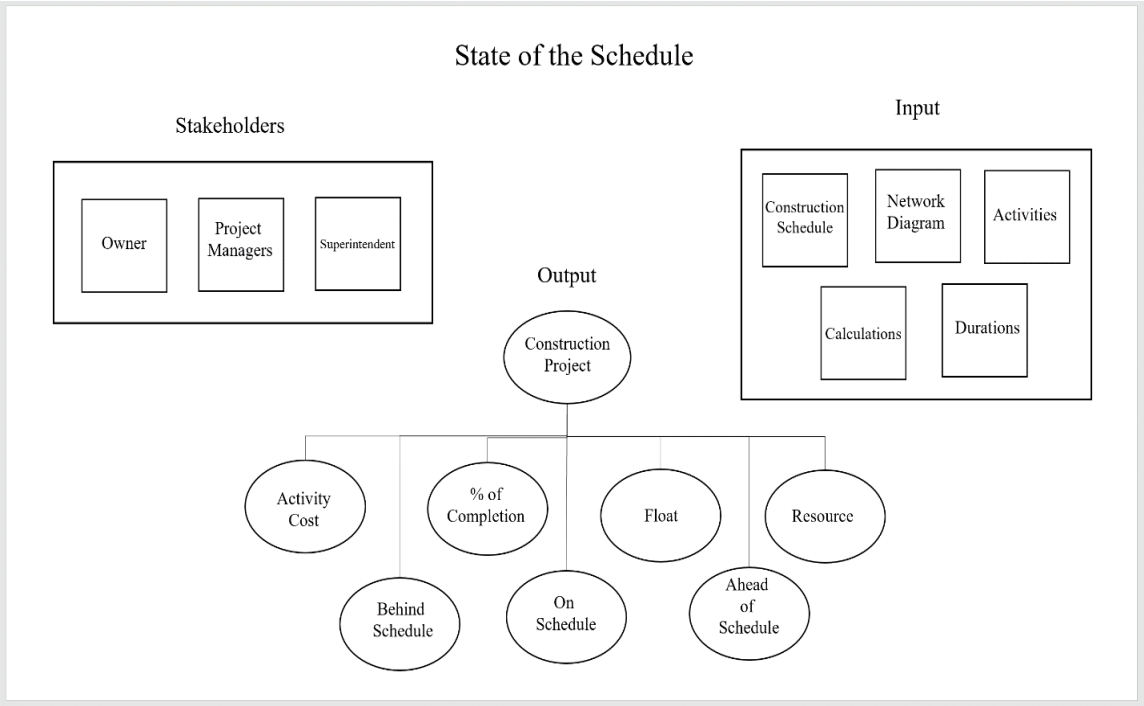

Figure 3. State of the Schedule

Figure 3. This figure demonstrates how important it is to initially represent the State of the Schedule graphically. The State of the Schedule identifies the primary functions that exist in this modelling process. It highlights what and who this process is important to, the Stake Holders, what is needed within the schedule that will set up the functionality, and the outcome of the framework provides on the backend. This representation shows the contributors of the schedule/conceptual model.

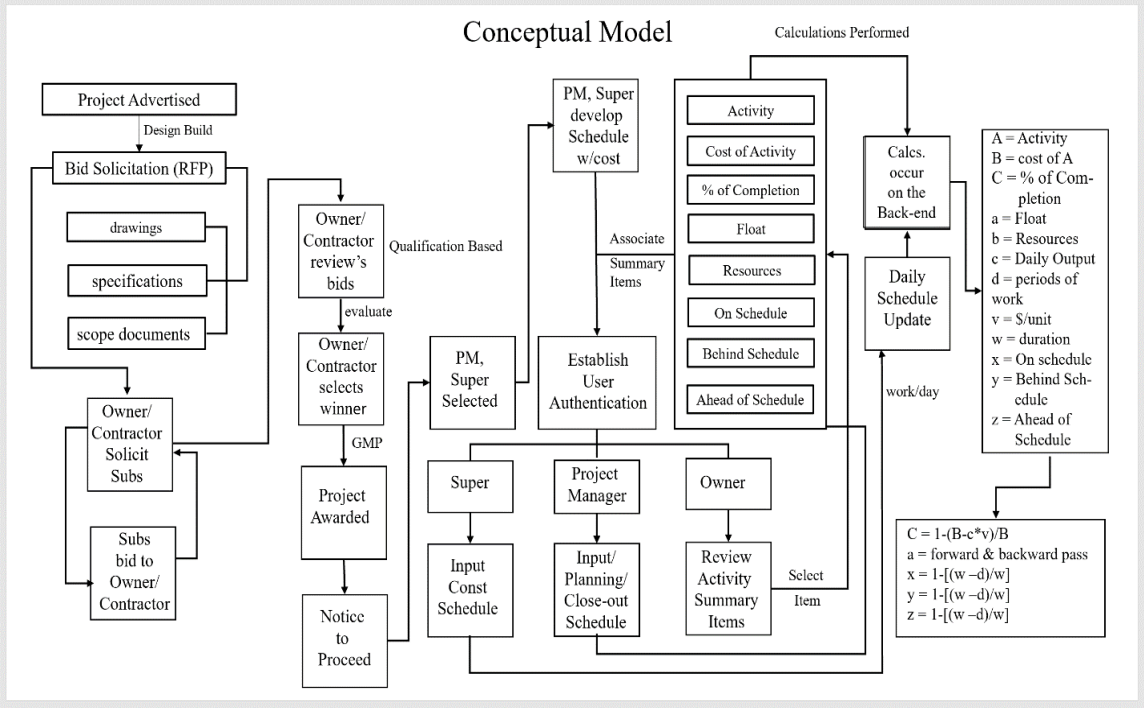

Figure 4. The Conceptual Method

The Conceptual Model is developed after the conceptualization or generalization process. They are often abstractions of things in the real world whether physical or social. It is very important to, when expressing a concept, the entire concept should be visualized. As shown in Figure 4, the conceptualization process starts initially through the actual construction bid process. It started from the three decisions that are important to Owners/Prime Contractors. These three decisions are major. The owner must consider:

- The Project Delivery Method; whether it is a Construction Manager at Risk (CMR), a Design-Bid-Build (DBB), or a Design-Bid (DB).
- The Procure Method; whether the project's procurement is based on, the Best Value, Low Bid, Negotiated, Qualifications-Based (QBS) or a Sole Source.
- Contract Type; whether the contract will be a Cost-Plus Fee, Guaranteed maximum Price (GMP), Lump Sum (Fixed Price) Target Price or Unit Price.

Regarding the Conceptual Model in Figure 4, the Design-Build Delivery method was used by the Owner. An Owner contracts with one entity of which one price will cover both of two phases, design and construction. This entity is considered design-build Contractor. Another reason the Owner finds the D-B delivery method appealing is because the D-B Contractor can subcontract out various portions of the work instead of doing it all in house. The thing is, all subcontractors, etc. work together on the same team. This collaborative idea is an advantage over other delivery methods.

As seen in Figure 4, Request for Proposals (RFP) packages were put out to perspective bidders. Those RFP packages were comprised of, drawings, scope of work and specifications. These packages are distributed to Contractors interested in performing this work.

Figure 4 cites the Qualifications-Based procure method is best for this Concept Model. It was important to the Owner not to just solicit to Contractors based on price alone. The ability to perform is just as important, if not more important than just the price. This is a bidding process where, based on technical qualifications, the Owner will create a short list. The Contractors whose bids pass the first round move to the second round. These Contractors were considered to have submitted qualifying bids. Meaning, they have met the technical expertise requirements of the owner.

Because of the type of work the was perceived in this Conceptual Model, it was decided that the best type of contract to use was Guaranteed maximum Price (GMP). This type of contract will set a ceiling on how much an Owner will pay. Any excess beyond the preset ceiling the Contractor is responsible for. The Contractor is only not responsible if there has been a formal agreement on a change in the scope of work.

After the Delivery Method, Procure Method and Contract Type are set, the project is advertised, and bids are received. After the bids are received, the project will be awarded. After award there, some preliminary contractual obligations that must happen, i.e., Bond, Insurance. Then a notice to proceed (NTP) will be given. Amidst all the previous happenings, the Contractor has had to have an idea who their Project Manager and the Superintendent would be.

In the Conceptual Model Figure 4, The Project Manager (PM) and the Superintendent (Super) have the responsibility of developing the project schedule.

The project Manager is responsibility of developing the Planning and the Close out activities (tasks) in the schedule. The Superintendent is responsible for developing the sequence of construction of all activities. The PM and the Superintendent in conjunction with the Contractor will develop the cost loaded schedule. To gain entry to the schedule, as it shows in Figure 4, there needs to be an electronic authentication (user name & Password). The PM and the Superintendent give input to the task summary items by way of daily updates. The summary task items are predetermined and implemented as part of the framework during the development. Those summary items are the gate-way to what the Owner wants and needs to continuously be made aware of the progress of their construction project(s). Each day the schedule will be updated as depicted in Figure 4. The Owner through those daily updates will have the ability to review a segmentation of the schedule revealing the predetermined summary tasks. All the calculations will occur on the back end.

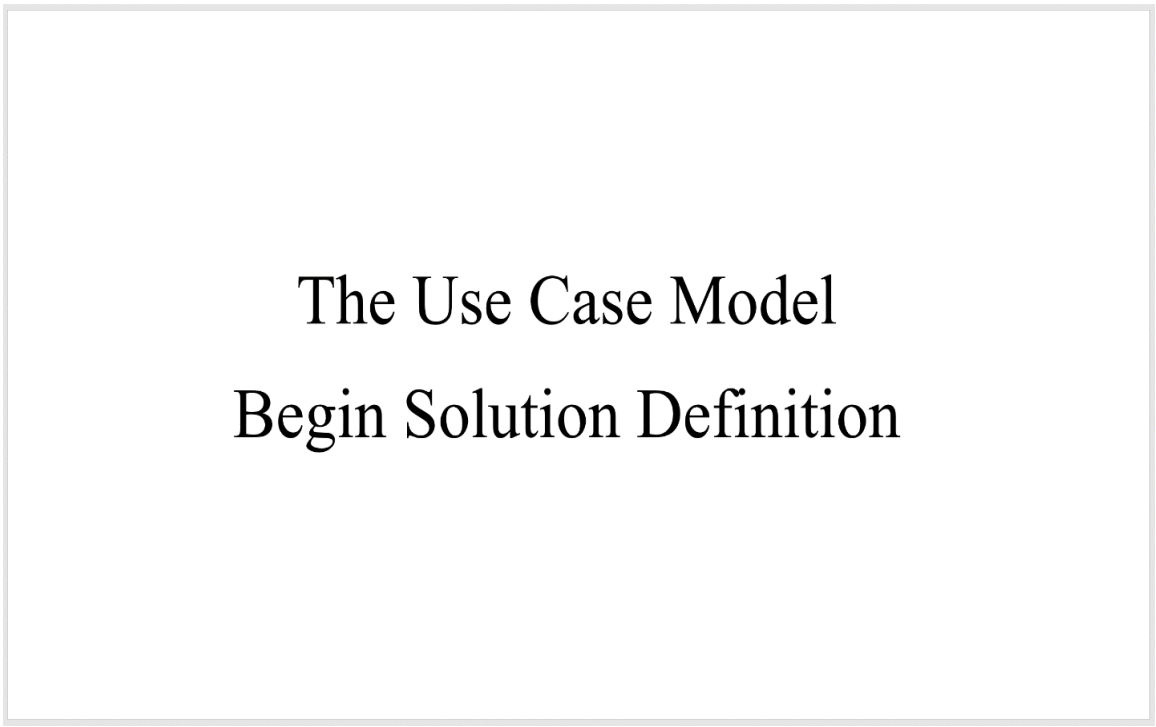

Figure 5. The Use case Model – Begin the Solution Definition

The Use Case Model describes the proposed functionality of the new system. A discrete unit of interaction between a user (human or machine) and the system is represented by a use case. It is a single unit of meaningful work; e.g., login to system, register with system and create order are all Use Cases. Functionality that will be built in the proposed system can be described with a descriptive use case. A Use Case may 'include' another Use Case's functionality or 'extend' another Use Case with its own behavior. They are typically related to 'actors'. An actor is a human or machine entity that interacts with the system to perform meaningful work. A user of the system is called an Actor. Human users and other computer systems are included as Actors. An Actor's overall role is defined by the set of Use Cases that an Actor has access to.

Use Case Diagram

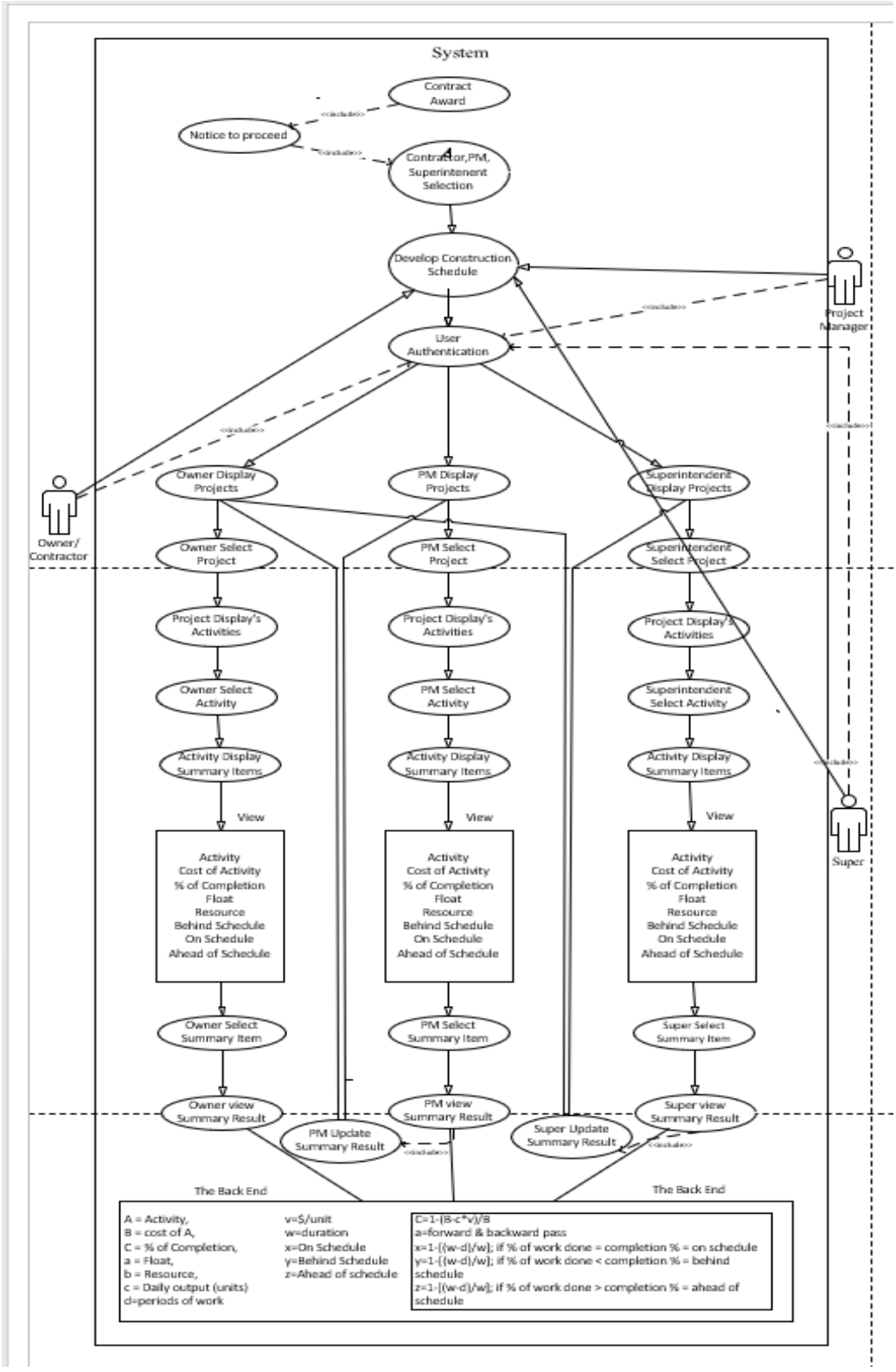

Figure 6. The Use case Diagram

The use case diagram is a representation of the user's interaction with the system. It shows the relationship between the different use cases and the user in which the user is involved. They are also referred to as behavior diagrams that are used to describe a set of actions (use cases) that some system or systems (subject) can or should perform in collaboration with one or more external users of the system (actors).

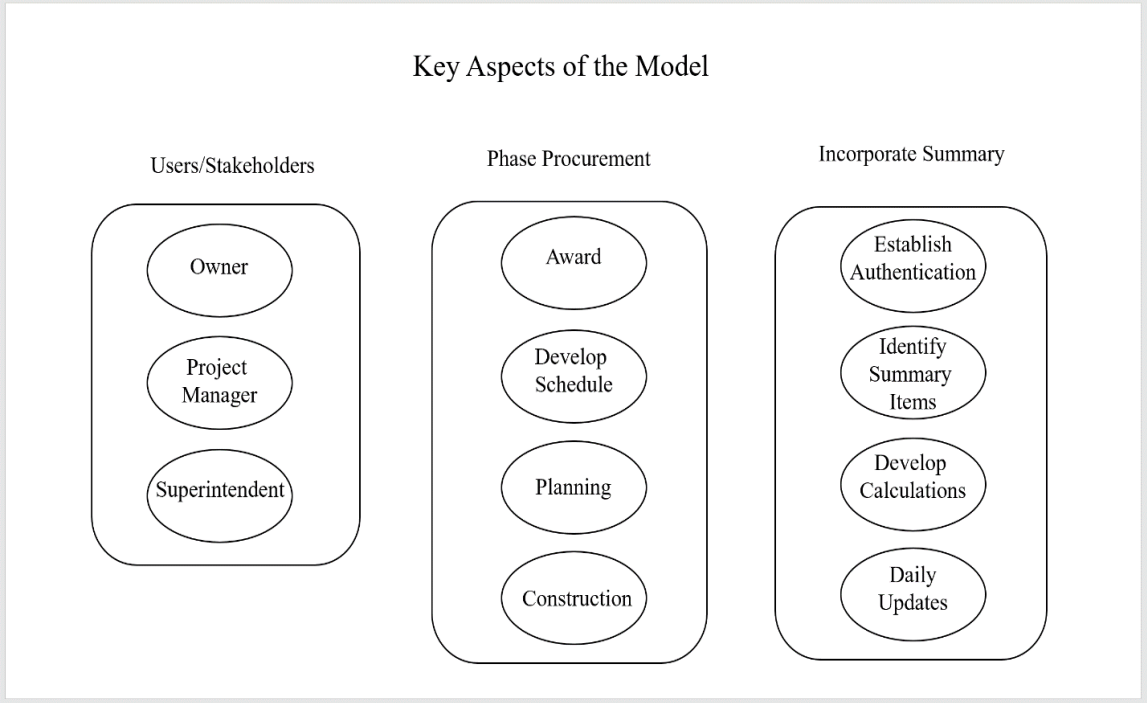

Figure 7. Key Aspects of the Model

Figure 7 shows the parts and/or features of the proposed system. It is important to understand that Users/Stakeholders are going to dictate the success of the operation. The effort here is to be able to use this model and capture what is summoned with the touch of a button from any place at any time.

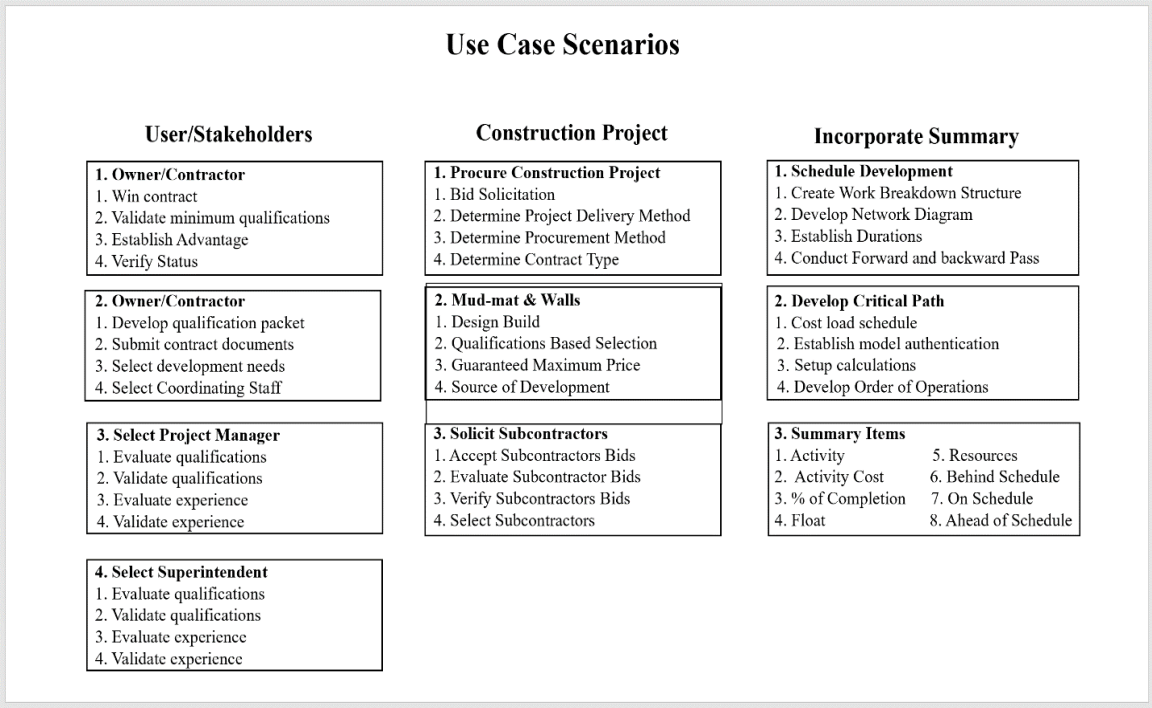

Figure 8. Use Case Scenarios

These use case scenarios are a representation of the path through the Use Case to the Analysis Model, Object-Oriented Analysis & Design (OOAD).

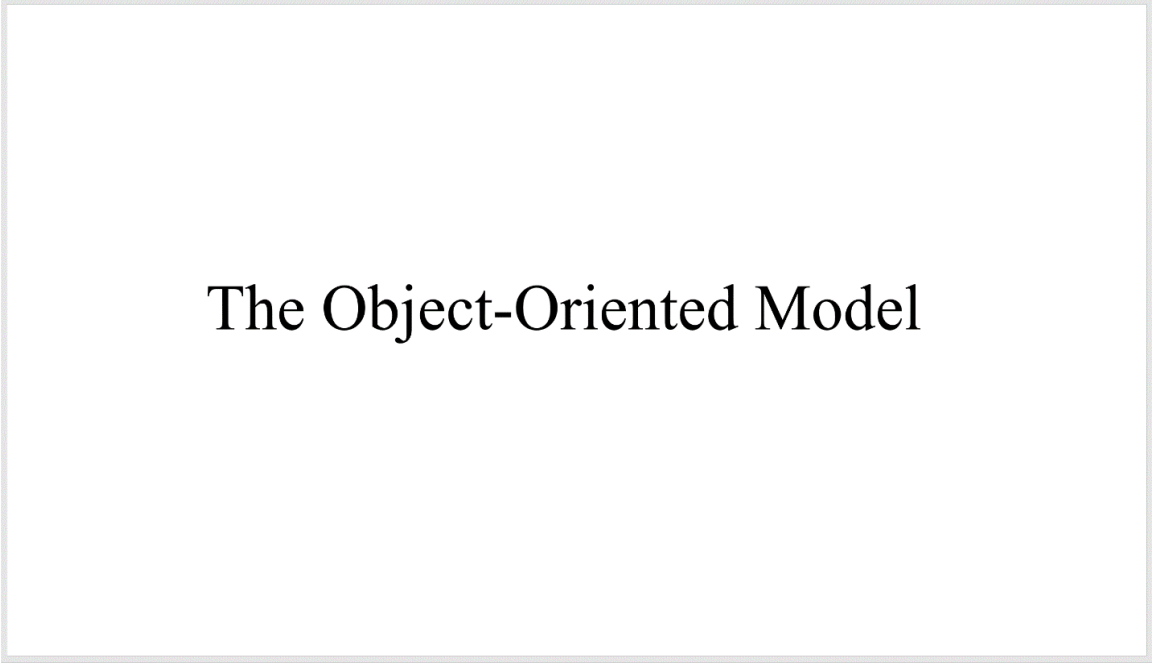

Figure 9. The Object-Oriented Model

The Object-Oriented Model is a technical approach that's used for analyzing and designing an application. It is also used for analyzing and designing different systems, or businesses by applying object-oriented programming as well as using visual modeling throughout the development life cycles for fostering better stakeholder communication and product quality. Using an object-oriented approach is an approach that is used at the beginning of the software development cycle. The purpose of using the object-oriented model process at the beginning of the software development process is to communicate before writing the code.

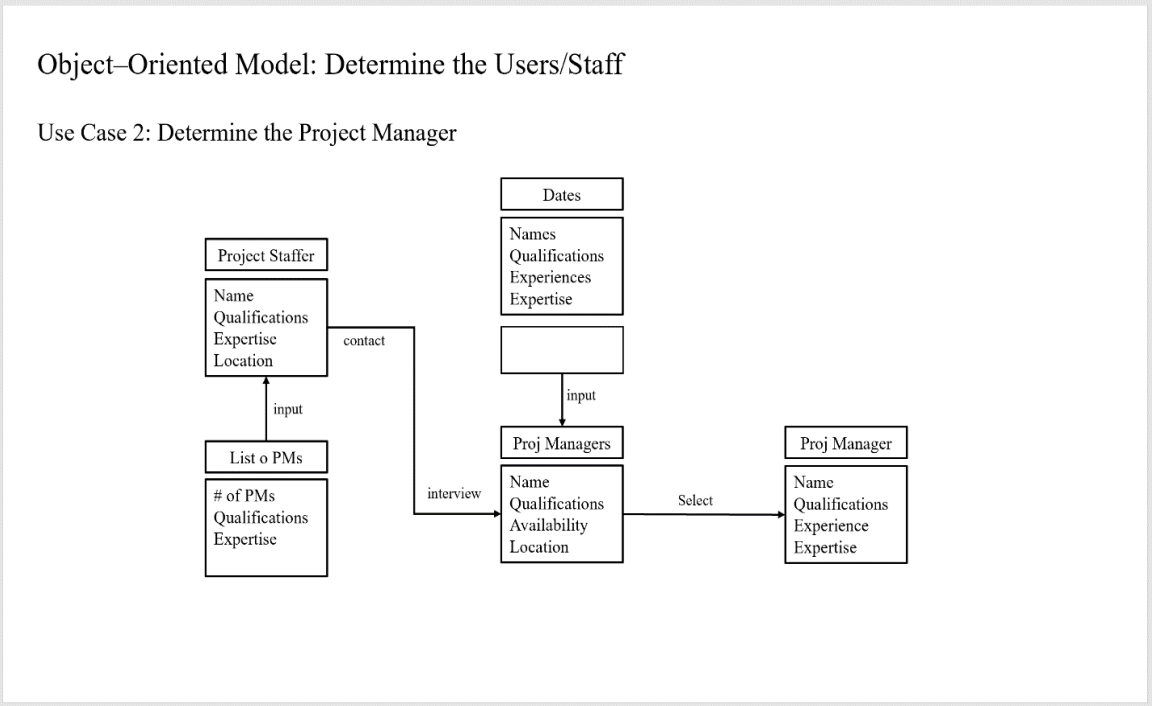

Figure 10. Object-Oriented Model: Determine the Users/Staff – Project Manager

In use case 1, Figure 10, the Owner and the Contractor may possibly be one in the same. They are the entity that is responsible for procuring the work. They will put the bids together. They have taken into consideration various concerns before deciding whether they want to embark upon the endeavor to take on certain construction projects. They

must consider the entire bid process, i.e. the Delivery Method, the Procurement Method and the Type of Contract. These must be considered before a Contractor, Subcontractor, etc. are selected.

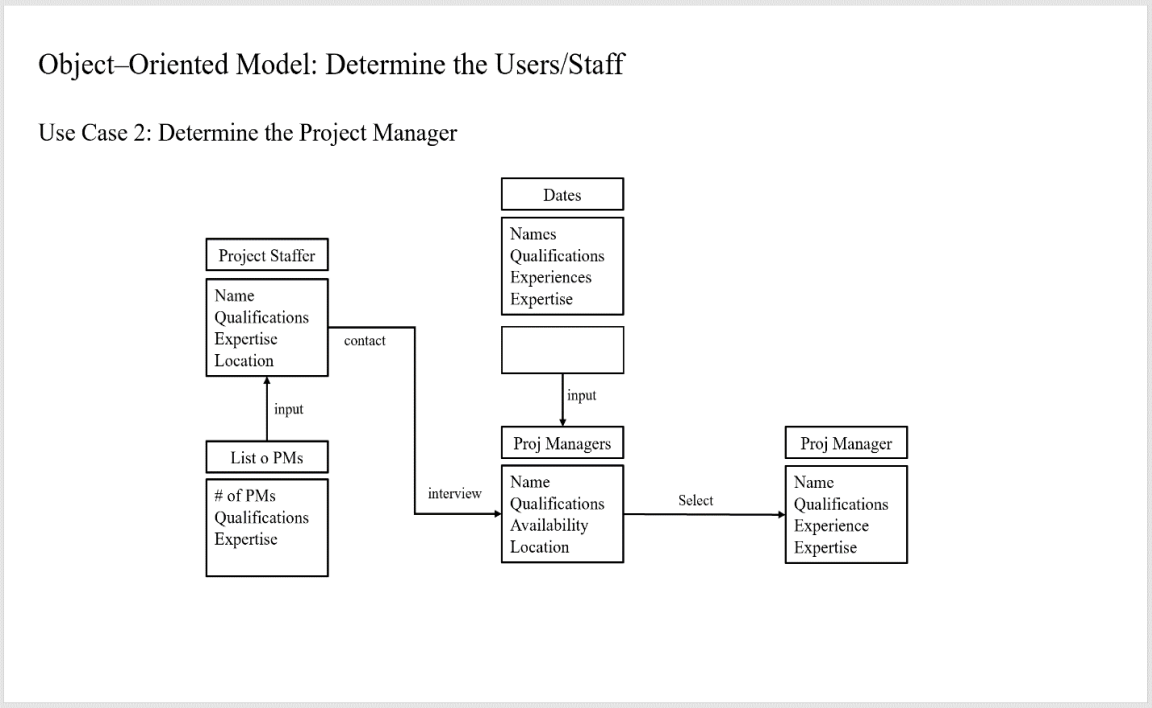

Figure 11.

Use Case 2, Figure 11 establishes the professional staff process that an Owner will have to undergo to ensure a successful completion of a construction project. They would begin with the selection of the Project Manager (PM). A project staff person creates a list of PMs and go into the hiring or assigning process. When qualifications are met, availability is agreed upon and the location is acceptable, the applicable PM will be assigned to a project.

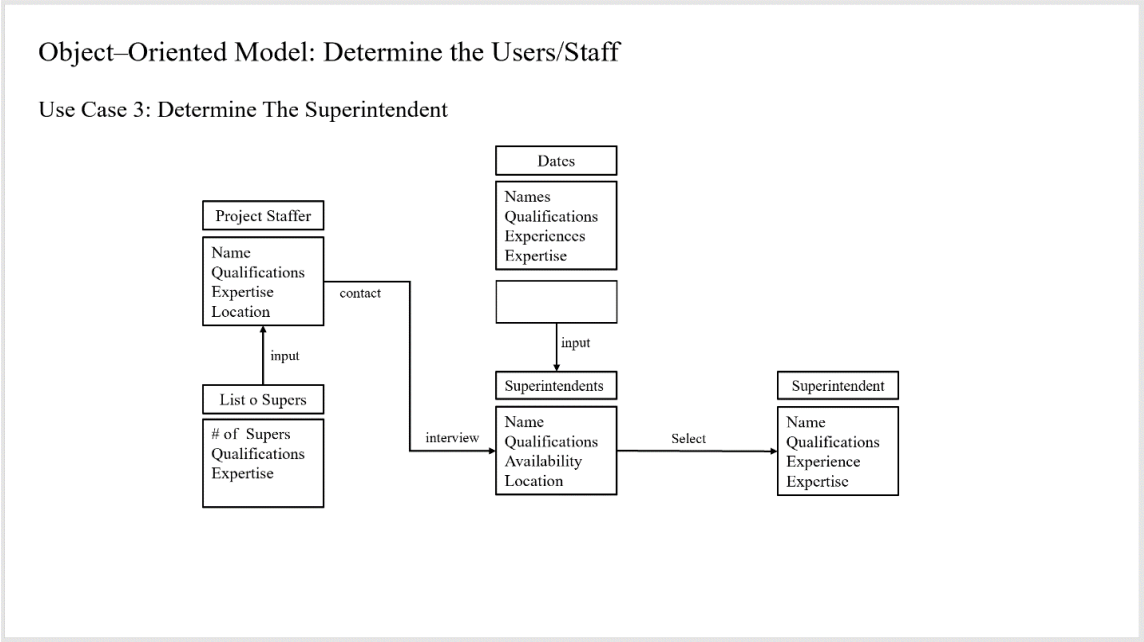

Figure 12. Object-Oriented Model: Determine Users/Staff-Superintendent

Use Case 3, Figure 12 establishes the professional staff process that an Owner will have to undergo to ensure a successful completion of a construction project. After a PM is selected they would select a Project Superintendent. A project staff person creates a list of Superintendent and go into the hiring or assigning process. When qualifications are met, availability is agreed upon and the location is acceptable, the applicable Superintendent will be assigned to a project.

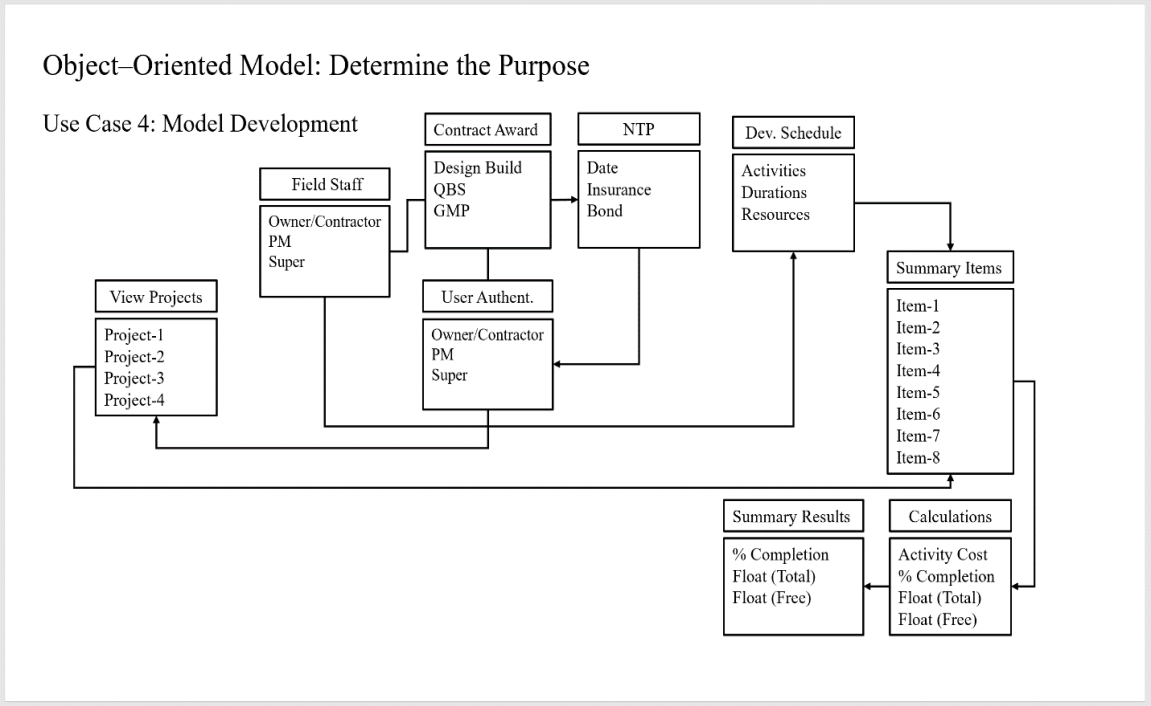

Figure 13. Object-Oriented Model: Determine the Purpose

Use Case 4, Figure 13, lays out the Object-Oriented version of the development of the model. It goes through the process of establishing the construction project through the authentication process into the implemented framework. The Owner can view the project activities, the costs of each activity and the associated status of each activity.

Chapter 5: SUMMARY AND CONCLUSIONS

The process started with System Development Life Cycle (SDLC). The SDLC will call together the needed participants to brain storm the problem. They established a problem description; problem definition and they developed a High-Level System Diagram. The function of this diagram is to explain the architecture that would be used for developing a software product. After describing the problem, the associated models were developed, i.e. the Concept Model, the Use Case Model and the Object-Oriented Analysis & Development Model. Pursuant to modeling the desired system various artifacts were included, i.e., the Use Case Diagram and the Object Diagram. The Use Case Diagram allows the opportunity to view the users input/functionality into the system. It's understood that a part of the SDLC are additional models i.e., Design, Implementation, Test, System Evaluation. But they are used by a different tasked individual. It should be noted that continuous evaluation and analysis should through the SDLC to ensure a fine working system.

In the case of unforeseen conditions (i.e., jurisdictional fees and prerequisites, hazardous materials, damaged items, subgrade issues, homeowner scheduling, etc.) it should also be noted that the model does not account for them. The only way for them to be brought to light is to observe how it they affect the schedule.

The development of this model will give the prospective Owner the ability to look at specific segments of a project's construction schedule at any time from any location simplistically. Owners do not always have the know-how and the technical ability to use a convoluted construction scheduling system. As long as there is a web-based construction schedule, the development of this model will provide a novice Owner the

ability to review segments of the construction schedule and have real-time progress status remotely. Again, the highlight of this idea is how simple it would be for an Owner to view what is most important to he/she, their money.

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Appendix

Project WBS

Mud Mat & Walls Project

1. Planning	**0001**
1.1 Create Preliminary Scope Statement	0002
1.2 Determine the Project Team	0003
1.3 Project Team Kickoff Meeting	0004
1.4 Develop Project Plan	0005
1.5 Submit Project Plan for approval	0006
1.6 ***Milestone:*** Project Plan Approval	0007
2. Execution	**0008**
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2.3 Obtain Permits	0011
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3.1 Establish LOD (Limits of Disturbance)	0018
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3.2.1 Install Silt Fence	0020
3.2.2 Install Runoff Ditch	0021
3.2.3 Install Hay Bayles	0022
3.3 Site Layout	0023
3.3.1 Clear & Grub	0024
3.3.2 Construction Boundary	0025
3.3.3 Subsurface Investigation	0026
3.3.4 Site Access Road	0027
4. Excavation	**0028**
4.1 Install Sheet Piles	0029
4.2 Cut & Haul	0030
5. Set Rebar Cages	**0031**
5.1 Set Mat Cage	0032
5.2 Set Wall Cage	0033
5.3 Set Wall Cage Forms	0034
5.4 Set Mat Cage Forms	0035
6. *Milestone:* Place Concrete	**0036**
6.1 Place Concrete at Mat	0037

WBS Dictionary Level	WBS Code	Element Name	Cost Control Numbers	Resource Assignments	Responsibility Assignments	Definition
1	1	Planning	0001	Project Manager	Owner/CM	Plan all work necessary to implement the installation of a unified Mud Mat and four Concrete Walls
2	1.1	Create Preliminary Scope Statement	0002	Project Manager	Owner/CM	Author the complete preliminary Scope of Work statement
2	1.2	Determine the Project Team	0003	Project Manager	Owner/CM	The Owner and CM will collectively determine the members of the Project Team.
2	1.3	Project Team Kickoff Meeting	0004	Project Manager	Owner/CM	CM conducts the Project Team Kickoff Meeting
2	1.4	Develop Project Plan	0005	Project Manager	Owner/CM	CM will develop the Project Plan
2	1.5	Submit Project Plan for approval	0006	Project Manager	Owner/CM	CM will author & submit the Project Plan
2	1.6	***Milestone:*** Project Plan Approval	0007	Project Manager	Owner/CM	The CM will be responsible for the approval the Project Plan
1	2	**Execution**	0008	Superintendent	Owner/CM	The Superintendent will formally initiate the execution of the project.
2	2.1	Project Kickoff Meeting	0009	Superintendent	Project Manager	Superintendent will conduct the Kick off Meeting and assign Contractor and Subcontractor responsibilities.
2	2.2	Start/Complete Design	0010	Superintendent	Contractor	The Contractor will be responsible for securing all necessary permits.
2	2.3	Obtain Permits	0011	Architect	Architect	The Owner will initiate the direction and assign responsibility for the Architect to perform the design
2	2.4	Develop Shop Drawings	0012	Contractor	Detailer	Contractor will hire detailer to develop shop drawings
2	2.5	Order Rebar	0013	Contractor	Contractor	Contractor will place the order for the rebar delivery

2	2.6	***Milestone:*** Deliver Rebar	0014	Contractor	CM	Contractor will be responsible for the delivery of the reinforcing steel
2	2.7	Shake-out Rebar	0015	Contractor	Rebar subcontractor	Rebar subcontractor for shaking out the steel.
2	2.8	Build Rebar Cages	0016	Contractor	Rebar Contractor	The Rebar Contractor will direct the construction of the rebar cages
1	3	***Milestone:*** Site Development	0017	CM	Contractor	Contractor is responsibility for hiring subcontractor for site development.
2	3.1	Establish LOD	0018	CM	Contractor	CM will establish, through the Contractor the Limits of Disturbance (LOD)
2	3.2	Erosion & Sediment Control	0019	Contractor	CM	Contractor will establish locations of E&S as per specifications
3	3.2.1	Install Silt Fence	0020	Contractor	Contractor	Contractor is responsible for installation of silt fence
3	3.2.2	Install Runoff Ditch	0021	Contractor	Contractor	Contractor is responsible for installation of the Runoff Ditch
3	3.2.3	Install Hay bales	0022	Contractor	Contractor	Contractor is responsible for installation of the Haybales
2	3.3	Site Layout	0023	Contractor	Geo Sub	The Contractor through the Architect will facilitate Borings, Test pits
3	3.3.1	Clear & Grub	0024	Contractor	Earth work Contractor	The Contractor will facilitate Clearing, Grubbing and Stump removal
3	3.3.2	Construction Boundary	0025	Contractor	Surveying Firm	The Contractor will hire a Survey Party to establish the construction boundary
3	3.3.3	Subsurface Investigation	0026	Contractor	Geotechnical Engineering Consulting	The Contractor will hire a Geo Consulting firm to conduct the Subsurface Investigation
3	3.3.4	Site Access Road	0027	Contractor	Road work Subcontractor	The Contractor will hire a road Sub to install an excess road as per the specifications
1	4	Excavation	0028	Contractor	Contractor	Install Super/Silt Fences, Install Runoff Ditches, hay bales
2	4.1	Install Sheet Piles	0029	Contractor	Contractor	Earthworks Contractor will implement the Install/Drive steel Sheet Piles

2	4.2	Cut & Haul	0030	Contractor	Contractor	Earthworks Contractor will implement the Cut & haul
1	5	***Milestone:*** Set Reinforcing Steel	0031	Contractor	Contractor	Remove all top soil to 10", Remove trees and tree stumps to 24".
2	5.1	Set Mat Cage	0032	Contractor	Rebar Subcontractor	Implement all excavation necessary to successfully complete site construction
2	5.2	Set Wall Cage	0033	Contractor	Rebar Subcontractor	Rebar Subcontractor will execute the process of setting the wall cage
2	5.3	Set Wall Cage Forms	0034	Contractor	Concrete Subcontractor	Concrete Subcontractor will execute the process of setting the wall cages
2	5.4	Set Mat Cage Forms	0035	Contractor	Concrete Subcontractor	Concrete Subcontractor will execute the process of setting the wall cages
1	6	Milestone: Place Concrete	0036	Contractor	Contractor	Contractor will implement placing the concrete at the cages
2	6.1	Place Concrete at Mat	0037	Contractor	Concrete Subcontractor	Contractor will implement placing the concrete at the mat
2	6.2	Finish Concrete at the Mat	0038	Contractor	Concrete Subcontractor	Concrete Subcontractor will implement finishing the concrete at the Mat
2	6.3	Place Concrete at Walls	0039	Contractor	Concrete Subcontractor	Concrete Subcontractor will implement placing concrete at the Walls
2	6.4	Strip Mat Forms	0040	Contractor	Concrete Subcontractor	Concrete Subcontractor will implement the stripping of the forms at the Mat
2	6.5	Finish Concrete Walls	0041	Contractor	Concrete Subcontractor	Concrete Subcontractor will implement finishing the concrete at the Walls
2	6.6	Strip Walls forms	0042	Contractor	Concrete Subcontractor	Concrete Subcontractor will implement finishing the concrete at the Mat
2	6.7	Backfill Walls	0043	Contractor	Earthwork Contractor	Earthwork Contractor will backfill and tamp at construction perimeter

2	6.8	Tie-back Walls	0044	Contractor	Foundation Subcontractor	The Foundation Subcontractor will install tie-backs for this project
1	7	Landscape	0045	Landscaping Subcontractor	Contractor	Contractor will implementation of the Restoration the construction site to its standard
1	8	Punch List	0046	Contractor	Contractor	Establish a list of inadequacies in construction activities e.g. concrete, rebar, backfill, etc.
2	8.1	Develop Punch List	0047	CM	PM	PM Will be responsible for the developing the punch list
2	8.2	Address Punch List Items	0048	CM	Contractor	The Contractor will be responsible for addressing all punch-list items
1	9	Close Out	0049	CM	PM	PM will be responsible for closing project out
2	9.1	Audit Procurement	0050	CM	CM	The CM is responsible for the Audit Procurement
2	9.2	Document Lessons Learned	0051	CM	PM	PM will be responsible for documenting the lessons learned
2	9.3	Update Files/Records	0052	CM	PM	PM is responsible for updating Files/Records
2	9.4	Gain Formal Acceptance	0053	CM	CM	CM get acceptance from Owner and prepare to turn over property
2	9.5	Make Final Payments	0054	CM	PM	PM will be responsible for making final payments
2	9.6	Archive Files/Records	0055	CM	PM	PM will be responsible for Archiving Files/Records

Hierarchical Structure - The hierarchal structure is similar to the outline view but without indentation. Although this format is more difficult to read, it may be useful where you have many levels and indenting each level would make the table too large to fit into a document.

Level	WBS Code	Element name	
1	1	Widget Management System	
2	1.1	Initiation	
3	1.1.1	Evaluation & Recommendations	
3	1.1.2	Develop Project Charter	
3	1.1.3	Deliverable: Submit Project Charter	
3	1.1.4	Project Sponsor Reviews Project Charter	
3	1.1.5	Project Charter Signed/Approved	
2	1.2	Planning	
3	1.2.1	Create Preliminary Scope Statement	
3	1.2.2	Determine Project Team	
3	1.2.3	Project Team Kick Off Meeting	
3	1.2.4	Develop Project Plan	
3	1.2.5	Submit Project Plan	
3	1.2.6	Milestone: Project Plan Approval	
2	1.3	Execution	
3	1.3.1	Project Kickoff Meeting	
3	1.3.2	Verify & Validate User Requirements	
3	1.3.3	Design System	
3	1.3.4	Procure Hardware/Software	
3	1.3.5	Install Development System	
3	1.3.6	Testing Phase	
3	1.3.7	Install Live System	
3	1.3.8	User Training	
3	1.3.9	Go Live	
2	1.4	Control	
3	1.4.1	Project Management	
3	1.4.2	Project Status Meetings	
3	1.4.3	Risk Management	
3	1.4.4	Update Project Management Plan	
2	1.5	Close Out	
3	1.5.1	Audit Procurement	
3	1.5.2	Document Lessons Learned	
3	1.5.3	Update Files/Records	
3	1.5.4	Gain Formal Acceptance	
3	1.5.5	Archive Files/Document	

Tabular View - The Tabular View is a nicely organized table view of the WBS. Its application is specifically designed for creating this organizational chart structure. It is a good option for organizations which prefer table formats.

Level 1	Level 2	Level 3
1 Widget Management System	1.1 Initiation	1.1.1 Evaluation & Recommendations
		1.1.2 Develop Project Charter
		1.1.3 Deliverable: Submit Project Charter
		1.1.4 Project Sponsor Reviews Project Charter
		1.1.5 Project Charter Signed/Approved
	1.2 Planning	1.2.1 Create Preliminary Scope Statement
		1.2.2 Determine Project Team
		1.2.3 Project Team Kick off Meeting
		1.2.4 Develop Project Plan
		1.2.5 Submit
		1.2.6 Milestone: Project Approval Plan
	1.3 Execution	1.3.1 Project Kickoff Meeting
		1.3.2 Verify & Validate User Requirements
		1.3.3 Design System
		1.3.4 Procure Hardware/Software
		1.3.5 Install Development System
		1.3.6 Testing Phase
		1.3.7 Install Live System
		1.3.8 User Training
		1.3.9 Go Live
	1.4 Control	1.4.1 Project Management
		1.4.2 Project Status Meeting
		1.4.3 Risk Management

		1.4.4 Update Project Management Plan
	1.5 Close Out	1.5.1 Audit Procurement
		1.5.2 Document Lessons Learned
		1.5.3 Update Files/Records
		1.5.4 Gain Formal Acceptance
		1.5.5 Archive Files/Documents

Tree Structure View - The Tree Structure View is the most popular format for the WBS. It presents an easy to understand view into the WBS; however, it is also tricky to create without an application specifically designed for creating this organizational chart structure.