APPLICATION OF SIMULATION TOOL FOR STRATEGIC DECISION EVALUATION IN LIFE CYCLE PROJECT MANAGEMENT

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Abstract: This paper focuses on a new application for simulation as a tool specifically designed for holistic evaluation of project functionality within a life cycle project management framework. The authors describe a methodology for development of the aforementioned simulation tool, dubbed as DSMS (Dynamic Simulation Modeling System), devoted to Project Management decision making. The simulation model can act as a dynamic vehicle for optimizing technical and operational functionality at both development and operational phases of projects. Thus the simulation approach is considered as an added facility in the quest for optimizing decisions to resolve progressively market and external uncertainties associated typically with the project's environment.

Keyword: dynamic simulation, optimization, life cycle project management.

1 INTRODUCTION

This paper deals with the application of simulation model to evaluate the feasibility and viability of capital projects throughout the project's life cycle. The computer-based simulation tool will provide a basis for scenario analysis of the project in real time. Project processes during construction and operation phases can be simulated in real time and impacts on the life cycle objective functions (LCOFs) [13] estimated.

The purpose of this paper is to introduce a holistic approach to managing the project deliverables by focusing on the business objectives in the early phase of the project. This approach will provide a platform for real time project definition based on technical, functional and operational aspects of the project. Simulation modeling is introduced as a unique management tool for effective front-end planning of projects. It helps determine the optimality of decisions on operability, functionality, quality or performance issues and reduces the overall uncertainty associated with the project.

2 SIMULATION MODELING vs. PROACTIVE DECISION ANALYSIS

Continuous definition and improvement of a project, as a viable business entity is becoming an important challenge for project management in a competitive global environment [3]. Continuous improvement in one way can help increase the efficiency of current operations through better utilization of facilities and develop strategies to do the right things at the right time in project's life cycle. To deal with the growing project complexity, organizations increasingly rely upon the benefits of new technologies [6]. Technologies need to be incorporated in the end result of a project (i.e. a product, a system or a facility) as well as being applied in the management of the project (i.e. technology to support, planning, control, communication and decision-making). Key strategies in the global marketplace include the development of high-quality products at lower cost and faster commercialization. The main objective of the project definition process is to maximize the chances of successful project realization, which defines the project concepts, selection of alternatives, definition of technical contents and scope of project, and determination of financial and commercial requirements.

To cope with the influences of market uncertainties and global competition, the authors have put forward a simulation model as an additional tool for optimal management of projects. Modeling of the technical and operational functionality of the project (i.e. end results) in each production environment and simulating the operation phase in a dynamic fashion are considered useful as aids to decision-making and project definition. Simulation enables not only making the target facility optimization in terms of functionality, but also the total investment cost required can be forecast more accurately. Furthermore, the simulation tool will help fine tune the existing facilities in order to accommodate competitive market pressures in internal and external environments. Continuous project definition based on LCOFs supported by a simulation modeling approach will provide a significant improvement in planning and management of projects.

3 THE INTEGRATED FACILITY ENGINEERING SYSTEM

The Integrated Facility Engineering (IFE) project, currently under development at the Department of Civil Engineering, of the University of Sydney, is a generic system that will aid management of capital projects in an integrated project management environment. Target values set for LCOFs are used as decision criteria to guide decision-making. It has been conceptualized and designed to facilitate the uptake of life cycle project management (LCPM) methodology for the delivery of projects [7]. LCOFs comprise the following:

- the project's financial status and its profitability;
- the operability, quality or performance of the facility; and
- the project short and long term liabilities, including occupational health and safety (OH&S) risks throughout project life, environmental impacts and third party liabilities.

The IFE system comprises the following integrated modules:

- A Smart Project Management Information System (SPMIS) to facilitate the analysis of
- project management functions [7;
- A Visual Design Management (VDM) system to assist in visualization/schedule simulation and management of design process [2];
- A Construction Management Information System (CMIS) [11];
- A Dynamic Simulation Modeling System (DSMS) to enhance the strategic decision analysis for project's viability; and
- A Soft Issues Management Systems (SIMS) to evaluate soft functions such as community and stakeholders' issues [10].

The IFE system has a unified project databank that establishes a multi-access Intranet configuration, allowing information entry at the point of information generation, distributed access to the system reports and general client-server functions to aid information

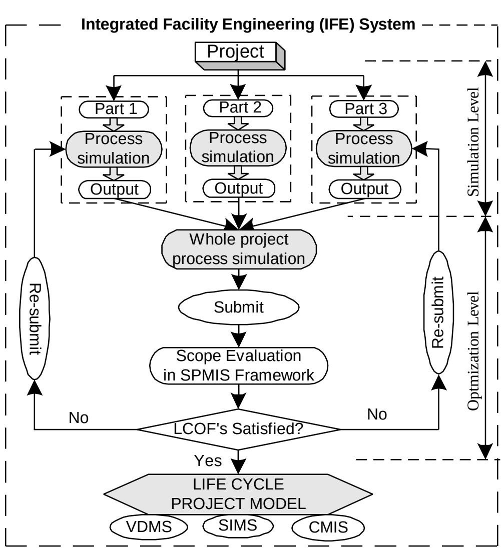

Figure 1. Simulation model integration in the IFE System

integration, expedite communication and decision processes. The work breakdown structure determines parts and products of the project. Target values set for LCOFs are used for the evaluation of decisions or alternatives to locate optimal solutions (see Figure 1). The focus of the remainder of this paper will be on the DSMS module. For further information on other modules refer to [6], [2] and [9].

4 DYNAMIC SIMULATION MODELING SYSTEM (DSMS)

The DSMS module adds a simulation capability to the IFE system for decision evaluation. The main purpose of DSMS is to facilitate the optimization of the end facility, particularly reliability, throughput times, stocks, facility utilization and optimization versus LCOFs. A comparative study of the literature also provides evidence that the throughput times, buffer sizes and interdependencies of resources cannot be determined with conventional methods. The analytical approach to the management of these characteristics is difficult due to the following factors:

- the increasing number of components and cross relationships with each other makes the project substantially complex. It becomes more and more difficult to define the system mathematically; and
- the presence of uncertainties on such key issues as market dynamics, plant breakdown, waste and rejects, etc. demands a simulation model of the facility for testing against different scenarios, each simulating probable conditions.

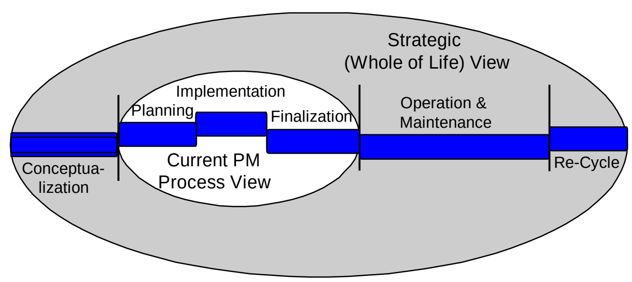

Figure 2. A generic life cycle view of the project

Figure 2 illustrates a strategic life cycle view of a project. It also shows the part, which is the focus of the current project management approach. Modeling of the technical and operational functionality of the end deliverable supports decision-making and project definition from a strategic (whole of life) perspective as opposed to current PM approaches. The current PM approaches concentrate on the delivery process and associated functions of contractual scope, time and cost as the decision criteria. Morris [13] and Artto [1] have discussed similar principles i.e. concerning an instinctive business sense associated with the project delivery. Economic analysis reflecting the final customer's or investor's life cycle costs associated with the project deliverables are important for optimal decision making, particularly in the early phase of projects [8], [12]. This is because solutions devised and commitments made at the early phase fix a major part of the project cost. For instance, Westinghouse Corporate Services Council estimates that 85 percent of the product's life cycle cost is determined before the manufacturing department becomes involved with a new product. An additional dollar spent before manufacturing can save $8-$10 on manufacturing and post-manufacturing activities [1].

The DSMS module will feed the simulation information into the IFE system in order to reflect, analyze and forecast the impact of the same on the LCOFs. The re-evaluation throughout the project life cycle will also be emphasized in the LCPM approach.

5 IDEALIZED DSMS FOR FRONT-END LIFE CYCLE PROJECT MANAGEMENT

Dynamic simulation modeling assists the performance and sensitivity studies on changing operating conditions and input-output characteristics. It allows evaluating a broad range of system conditions to monitor the consequences of altering plant processes. The benefits of an effective simulation model should include:

1. *Optimization of processes:-* the simulation model will test multiple solution for process layout. The model allows recognition and elimination of bottlenecks, optimization of queue sizes, observation of system behavior, and generation of valuable statistics on each alternative before the final investment decision;
2. *Impact evaluation for facility/plant design changes:-* the model will act as a test-bed for examination of facility/design changes including how the revised process can satisfy the demand or how the changes affect the LCOFs. The model facilitates the evaluation of the facility performance and capacity utilization based on future expansion and growth of current product lines. It will compute the sensitivity of operations to specific uncertainty variables;
3. *The ability to assess contingency and trial handling procedures:-* the model should allow the possibility to better serve customers with faster delivery rates, increase quality through quicker feedback and corrective action, what if analysis to evaluate control strategies for material flows and storage capacity;
4. *Evaluation of the effects of market variations to project scope and facility operating conditions:-* the model defines the scope of the project and evaluates the sustainability and profitability in real time based on market fluctuation. It facilitates the capability forecasting alternative operating scenarios to cope with market shifts and provide optimal solution;
5. *Proactive decision analysis with life cycle consideration:-* proactivity, as the name implies, has a specific meaning in the context of life cycle project management. It refers to the real time management of the project so that the specific target values set for LCOFs at the outset can be met or exceeded [8]. The model should be able to simulate the processes and facilitate a proactive approach for continuous assessment and reassessment based on excepted or probable events or problems. Furthermore, model capability should ensure that value addition is being achieved and the changes made to the project justify the end deliverable as a viable business entity.
6. *Systematic modeling, recording, storing, validating, retrieval and general data management in conjunction with the overall project management information system (PMIS):-* the PMIS provides a hierarchical modular framework for the project which will be initialized by the DSMS to set up the relevant processes and sub-processes of the project. The model will have the necessary degree of interoperability, compatibility and interface facilities to integrate with the main information system, or other standard software. Object-oriented database systems provide the common platform for input-output data management; and
7. *Improved staff training capabilities:-* the model should offer the facility as a learning vehicle to train staff in a realistic environment simulating extreme and other unusual conditions. It must be compatible with the latest available computer technology and facilitate distant learning via the Internet.

In short, an idealized simulation tool of the type stated will facilitate construction of a digital model of

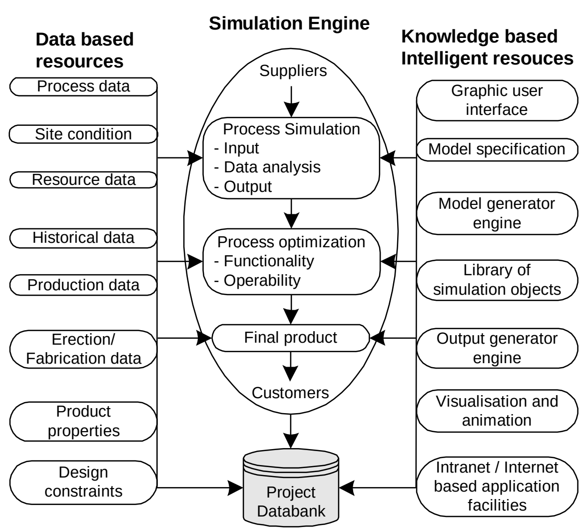

Figure 3. Broad conceptual architecture of DSMS

a project that will act as an experimental test-bed for decision making throughout the life of the project. It will furnish the capability to test diverse scenarios in order to derive the most viable solution in the project's life cycle.

6 PROPOSED SYSTEM ARCHITECTURE

Figure 3 illustrates a conceptual architecture of the simulation model. The DSMS comprises four broad sub-systems:- *1) resource management system, 2) process simulation engine 3) knowledge-based intelligent system and 4) Database management system.*

1. *Resource management system:-* the main purpose of this system is to operate and manage the overall resource data. The information on process data, site condition, resource data, historical data, production data, product properties and design constraints are needed prior to the simulation modeling. Different scenarios are combined with various constraints during simulation model construction.
2. *Process Simulation Engine:-* the simulation engine facilitates systematic sequencing of different processes and sub-processes containing events occurring in the system. The simulator manages and runs the relevant processes with input and output requirements. It provides a set of operations that can be called or invoked by the simulation model. Functionality and operability offered by different scenarios are observed and optimized based on the model behavior and simulation run statistics.
3. *Knowledge-based intelligent system:-* the knowledge-based intelligent system facilitates evaluation of real life scenarios via the digital computer model of the project. The multi-objective evaluation engine assesses alternatives within the project framework. The input analyzer refines the stochastic data using probability analysis [9]. The output generator engine provides reports and documents with visualization and animation capabilities. The intelligent system maintains the track of simulation object libraries. Note that the DSMS is a multi-user program using a client/server configuration.
4. *Database management system* or *repository system:-* the database system acts as a motherboard in the IFE system. All program modules reside in and interact with this system. The project model is created via SPMIS. The process model is created via DSMS framework for simulation. The model data is stored in the database. This system manages the infrastructure/facility condition, process information, operation conditions and resource mobilization data imported from the Data Base Management System (DBMS). The use of object-oriented DBMS extends the capability to accommodate multimedia data objects such as text files, image files, spreadsheet files, CAD drawings and project information.

7 DSMS SPECIFICATIONS

7.1 General Description

DSMS will utilize a hierarchical and modular structure. This concept will enhance the program's capability in simulating truly varied design alternatives [15]. The following steps depict the brief description of the DSMS development process:

- Develop a project information model with hierarchical breakdown structure (see Figure 1);
- Identify the major constituent parts of the project. If parts comprise complex systems, break these further down into major constituent sub-systems;
- Develop process models defining processes and operations involved in each part vis-à-vis system and input all the information via graphic interfaces;
- Develop resource libraries defining the various resources available for the aforementioned systems;
- Define the sequences and interconnectedness of all operations. These will provide links with dependent and independent activities in the process model;
- Run the process simulation engine at part and project levels and produce design solutions. Analyze the outputs for possible optimization;
- Feed outputs to the project model for further life cycle evaluation. Functions can be linked across the life cycle phases within the SPMIS environment to get a comprehensive overview of the project's status in real time. This objective-based approach will allow verifying the impact of any change(s) on project scope;
- If LCOFs are not satisfied at the project level, request re-submission of the corresponding processes for alternative solutions; and
- Incorporate the accepted solutions into the project model. The outcomes are produced into reports, barcharts, piecharts, tables, histograms, time plot variables as well as visualization and animation.

7.2 Process Interaction Approach

As stated earlier, processes are the collection of events, activities and delays with respect to time. Processes are the set of abstract data structures and entities carrying out the operation sequences within the system. Thus, the behavior of the system is represented by the set of interacting processes. The event list used with this approach is composed of a sequence of event nodes. Each node contains the respective event time and process.

The process can be in one of the several states:

- *active*, when its activities are being executed;

- *ready*, when the process is waiting to start;
- *idle*, when the process is not active; and
- *terminated*, when the process has exhausted its action and not going to be active again.

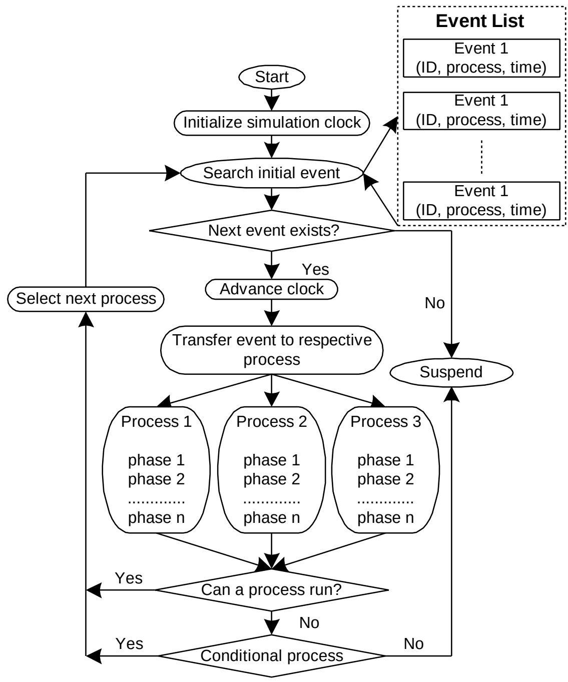

Figure 4. Process interaction mechanism in DSMS

The process interaction approach in simulation model represents the dynamic behavior of a group of processes carrying out the operations and interactions with one another. Each process maintains its own list of activities. This approach utilizes object-oriented modeling. High level processes are represented as a class and instances of the process are represented as objects [5].

8 PROCESS SIMULATION IMPLEMENTATION

Figure 4 shows the process-event interaction mechanism proposed for DSMS. The event list contains all event objects of the processes occurring in the system. Each event contains event ID, event time and the process to which the event belongs. The simulation engine manages the processes in the event list by carrying out three main tasks: process placement, process removal and process rescheduling. The engine keeps track of simulation clock and decides which process is due for immediate activation. The event time for this process becomes the new value of the simulation clock [14].

The code segments for the sequence of activities (phase) of events represent the processes as a co-system [5]. The simulation engine activates or reactivates these co-systems one at a time. The model of the system abstractly describes simultaneous activities of the real system. To accomplish the execution of co-systems, the engine facilitates the following sequences:

1. Get the next event from the event list;
2. Advance the simulation clock and activate the respective co-system;
3. Carry out the corresponding activities in the operation;
4. Update the reactivation pointer to indicate the next set of activities and place the corresponding event in the event list;
5. If process is conditional, get the next events and place into the corresponding co-system;
6. Abandon the current co-system;
7. Get the next event, activate or reactivate the corresponding co-system and facilitate activities;
8. Repeat the cycle until the event list is empty or the preset simulation time is over.

10 FUTURE DIRECTIONS

In order to verify and validate the proposed model, the authors will conduct a field (case) study. The model will focus on manufacturing, construction and or services type projects. The case study will provide a thorough understanding of how simulation techniques can be used effectively to optimize decisions on projects. It is postulated that the DSMS can be used as an interactive learning tool via the Internet.

11 CONCLUSION

In this paper the authors argued that process simulation can be a valuable tool in terms of optimizing project decisions vis-à-vis life cycle objective functions. Projects are considered as value-driven business undertakings. The simulation technology can be used to improve the project's base line value and determine project investment decisions optimally.

A review of the existing systems against the idealized system supports the proposal for DSMS development [4]. The project's functionality and operability can be simulated reflecting anticipated future market shifts at an early stage of the project. This will permit greater understanding of the project's capacity to respond to market dynamics and maintain its business competitiveness.

The hierarchical and modular structure of the model will provide a framework for process simulation of the whole project. Process interaction approach has been adopted within the DSMS framework. Alternative scenario vis-à-vis projects' processes will be optimized based on LCOFs. The DSMS is geared for generic applications that will respond to the user's instructions interactively. The DSMS will allow users to create the dynamic process models using graphic interfaces. Information derived from DSMS will support the project management team for improved strategic decision making in a dynamic environment.

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