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A DYNAMIC SIMULATION MODELLING SYSTEM FOR PROCESS REENGINEERING AND OPTIMISAION

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ABSTRACT

The challenge faced by most designers and facility planners is to determine the required size of a major facility and the associated main parts that work most effectively in a fluctuating operational environment. Process simulation, if carried out realistically, provides clear insights into the working efficacy of a given process. The information generated can be used to reengineer the same. Reengineering is widely used along with advanced information systems to automate and or improve an existing or a planned operation. It involves establishing a digital process model of the project and subjecting the same to the operational scenarios expected during the life of a facility.

This paper puts forward a Computer-Integrated Simulation technique that will respond to the above challenges dynamically in a construction, service or production environment. The developed system, dubbed Dynamic Simulation Modeling System (**DSMS**), is unique in the sense that it provides a facility for determining project operability and process efficiency within a whole-of-life business approach. Through the definition and use of only 2 building blocks a process can be defined and then the model run to test the same. The information can be fed to an Integrated Facility Engineering (**IFE**) system for overall optimisation purposes. The system enables analysing alternative process designs reflecting the associated external uncertainties. A brief case study will be used to demonstrate and discuss the model's capabilities.

KEYWORDS

Simulation, Process Reengineering, Process Modelling

1. INTRODUCTION

In today's global business environment, competition is marked by volatile demand, decreased customer loyalty, shorter product life cycles and mass customisation. It is important for businesses to gather vital information beforehand and act quickly for continuous improvements with a strategic viewpoint. Success in business relies heavily upon selecting the initial investment options (Mohamed and McCowan, 2001). A project is deemed economically feasible, if the expected outcome meets or exceeds an acceptable predetermined Life Cycle Objective Functions (LCOFs'). The estimation of values of investment parameters is undoubtedly crucial to the success of the Life Cycle analysis of the whole project. Most of the time the traditional investment decisions reflect the short-term economic benefits. Disadvantages with the traditional investment decisions are due the static and simplified assumptions without reflecting the underlying businesses needs. The project decisions are based the conservative assumptions or worst-case scenarios (Artto, et. al. 2001). The current approach emphasise that the project management concepts and process must be utilised in proactive planning of the processes. The technique involves reengineering processes with and innovative ideas and therefore more effective ways of doing business. In order the achieve the overall business goals of the project as a viable business entity, management needs to adopt the market dynamics, operability and functionality of project facilities, total quality management of end products and customer satisfaction (Morris, 1998).

This paper suggests an approach that enables maintaining a strategic view on the final project deliverable considering the whole projects' life cycle. This approach supplements traditional static approaches by using simulation modelling for managing the functionality and operability of the project scope. The authors have put forward a discrete event simulation model as a tool for optimal management of projects. Simulation enables not only in making the target facility more realistic in terms of functionality, but also the total investment cost required can be forecasted more accurately. This paper introduces a holistic approach for effective front-end planning and management of the project deliverables by focusing on the business objectives during the early phase of the project. The methodology proposed in this paper enables project managers meeting some of the business challenges and allow design, evaluation and visualisation of new and existing processes throughout the project lifecycle. Processes are simulated and optimised during planning , implementation and operation phases and the impacts of change on the overall LCOFs are estimated (Manivong and Jaafari, 1999).

The information provided is invaluable in terms of the design of the facility and the optimum balance between the various constituent parts. Process reengineering should not be carried out in isolation but as part of a total approach to improve the end-to-end business performance of a particular system of production within a whole-of-life decision framework. Ordinarily, the reengineering process must identify bottlenecks, queues and obstructions between related processes and unnecessary redundant steps that become candidates for improvement. However, demand fluctuations typically occurring during the life of a facility dictate the need for constant process re-examination and or re-balancing of the major constituent parts to ensure overall system performance for least total life cycle cost outlays under expected or prevailing operation conditions. This implies that the model developed for a project or process should be a vehicle for process reengineering not only during the development phase but also during the operational phase and for training of the operators.

2. DSMS AND IFE SYSTEM

Numerous examples in literature provide evidence how the process simulation technique has been utilised in cost saving and risk minimisation programmes of oganisations around the world. However, it must be realised that while development of computer-aided process simulation have been accelerated in recent years, its use for project definition, management of project end deliverable and end management of investment life cycle is not widespread. Simulation in project management is limited to only project management education and training (Tsuchiya, 1997). Due to existence of economic constraints and traditional barriers, dynamic modelling and simulation tools play little or no role in defining business objectives of the project. The complexity of simulating a process typically acts as a constraint to the utilisation of simulation for evaluation of real life situation. Fragmental analysis of smaller processes with local optimisation criteria does not signify the true functionality of the project facility within the overall project environment. Thus a simulation model in an integrated project environment envisaged helpful to test bed the project concept against fluctuations in operational environments and process design (Heindel and Kasten, 1996).

The Integrated Facility Engineering (IFE) project, currently under development at the Department of Civil Engineering, 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 the decision criteria to guide decision-making. It has been conceptualised and designed to facilitate the uptake of life cycle project management (LCPM) methodology for the delivery of projects (Jaafari and Manivong 1998). LCOFs comprises 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 entails the following integrated modules:

- A Smart Project Management Information System (SPMIS) to facilitate the analysis of project management functions (Jaafari and Manivong 1998);
- A Visual Design Management (VDM) system to assist in visualisation/schedule simulation and management of the design process (Chaaya and Jaafari 1999);
- A Construction Management Information System (CMIS) (Jaafari et. al. 2000);
- A Dynamic Simulation Modelling System (DSMS) to enhance the strategic decision analysis for project's viability (Doloi and Jaafari, 2001).

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 integration, expedite communication and decision processes. The work breakdown structure determines the so-called parts and products of the project. Individual teams will be responsible for the delivery of a specific part in concurrent fashion (Jaafari and Manivong 1998). IFE facilitates an iterative planning process undertaken by each individual team to assemble and evaluate information, solutions, effectiveness and the impact on the project. The project management team presides over the entire process and evaluates all decisions or alternatives to locate an optimal solution in order to meet or exceed the target values set for LCOFs.

The Dynamic Simulation Modelling System (DSMS) is an integrated module in the IFE system. The DSMS adds a simulation capability to the IFE system for decision evaluation. The main purpose of DSMS is to facilitate the optimisation 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.

Modelling 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 (1998) has 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 (Jordanger 1998). This is because solutions devised and commitments made at the early phase fix a major part of the project cost.

The DSMS module is geared to feed the output information into the IFE system in order to reflect, analyse and forecast the impact of the same on the LCOFs. The re-evaluation of the project definition throughout the project life cycle will also be emphasised in the LCPM approach.

3. MODEL ARCHITECTURE

Figure 1 illustrates a conceptual architecture of the simulation model. The DSMS comprises four broad sub-systems:- 1) Process generation module 2) Knowledge-based intelligent system 3) Simulation and optimisation module and 4) Database management system.

Process generation module:- this module facilitates the hierarchical process generation following the top-down approach. The processes are decomposed into sub-processes in the next level of the hierarchy model. The progressive decomposition continues until a sufficient level of details is achieved in describing the behavior of the sub-processes. Activities in the sub-processes are defined in a different interface and resources are allocated as required. The resource library maintains the overall resource data.

Knowledge-based module:- the knowledge-based intelligent system facilitates the establishment of logical links between processes and sub-processes based on the expected scenarios via the digital computer model of the project. The queues are generated between processes and sub-processes and properties are defined using interfaces. The multiple objectives of the process alternatives are assessed within the process-modeling framework. The input analyser refines the stochastic data using probability analysis. The output generator engine provides reports and documents with visualisation and animation capabilities. The intelligent system maintains the track of simulation object libraries.

Simulation and optimisation module:- the simulation engine facilitates systematic sequencing of different processes and sub-processes in the overall model. The simulator manages and runs the relevant processes with input and output requirements. The simulator maintains the simulation clock. 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 optimised based on the model behavior and simulation run statistics.

Database management system or repository system:- an object-oriented database system acts as a motherboard in the IFE system. All program modules reside as segments in the database and enable interactions with one another in the real time. The object data from the process models are stored persistently in the Object-Oriented Data Base Management System (OODBMS). The use of OODBMS extends the capability to accommodate multimedia data objects such as text files, image files, spreadsheet files, CAD drawings and project information.

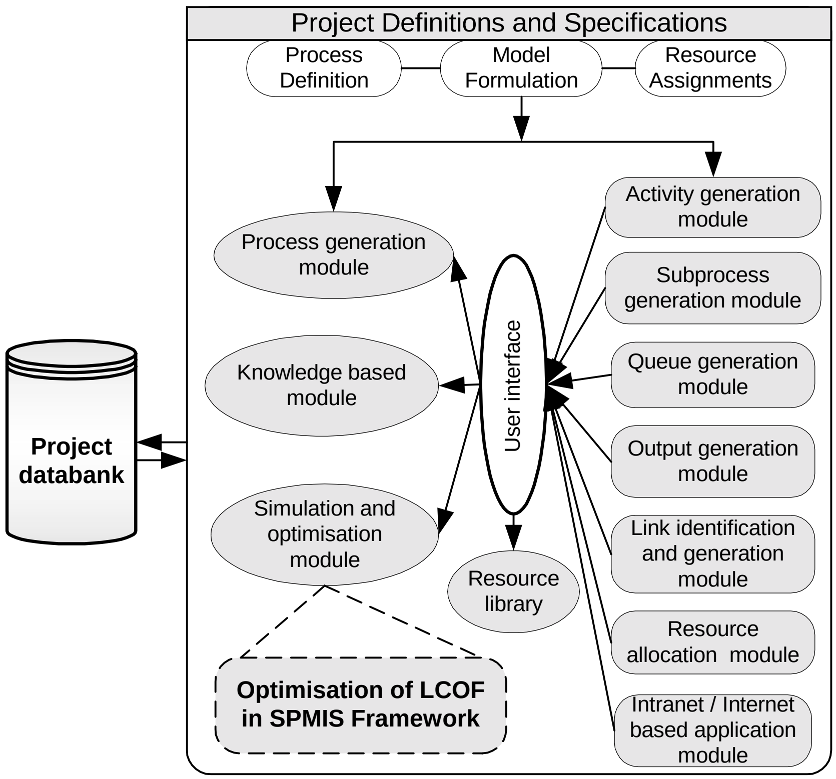

Figure 1: Architecture of DSMS.

4. MODEL ELEMENTS

The DSMS has been geared to simulate the service and production processes throughout the project's lifecycle. Total of six broad elements are being utilised to construct the process model. These are (a) *Entities (b) Processes (c) Sub-processes (d)* Queues *(e) Activities* and (f) *Resources*. Different block symbols are used to represent these processes. Sets of total 9 activities with unique block symbols (*Generate*, *Delay*, *Assemble*, *Release*, *Replenish*, *Block*, *Batch*, *Unbatch and Interruption*) are being used to represent the behavior of processes and sub-processes in the model.

Figure 2 shows generic relationships between modeling elements in DSMS framework. Processes involve logically and sequentially related set of activities on selected entities. The entity undergoes different change of states and produces an output at the end. If a process involves more than one function within the system and it become too complex, the process needs to further decompose into sub-processes. Activities take place within processes and sub-processes. Queue establishes the necessary logical links between processes and sub-processes. Resources are allocated for each activity within processes from the resource library. It is postulated that this methodology can be utilised for generic applications in various service situations. User-friendly interfaces in DSMS will allow users to construct the real life situations into the simulation model without prior simulation training.

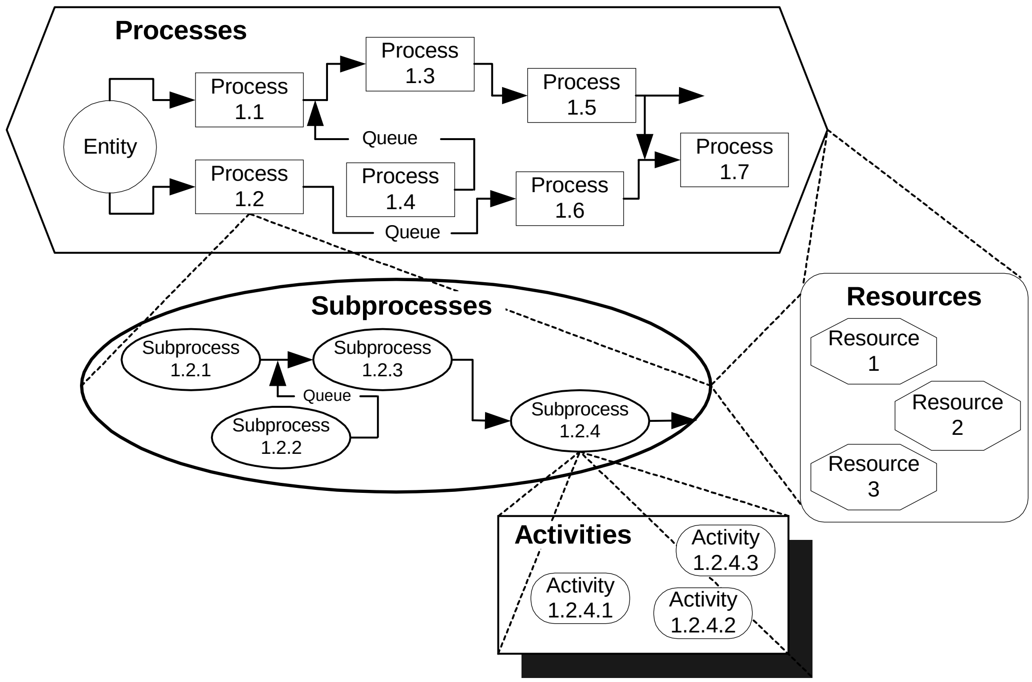

Figure 2: Process modelling elements and their relationships in DSMS

The DSMS model utilises a hierarchical and modular structure (Zeigler 1987). This structure enhances the program's capability in simulating varied design alternatives. The work breakdown structure (WBS) adopted to construct the process model for each project facilitates the above requirement. The WBS used in DSMS is based on the following hierarchy:

Project level:- the project is considered to be the highest component in the hierarchy model and focuses on the gross project attributes. At this level, attributes are project ID and overall management issues from start-up to the end of the project.
Part level:- a part is considered to be a sub-project and defined either as a physical part of the project or an associated soft deliverable. Major parts are identified at this level.
Process level:- at this level processes for each constituent part are identified. The dynamic composition for a part is described as a system in terms of activities, events and processes. If the processes are not easily identifiable at part level, parts are further broken down into products (i.e. sub-systems). Processes are used to represent whole or part of the life of temporary entities in the real system. Usually, a number of processes exist in a system model at any point in time. The process level is very important within the project hierarchical structure and defines functionality of the project.

Operational and technological sequencing of the processes need to be identified in process level. These processes are further decomposed into sub-processes and logical links are established using user-defined interfaces. It is worthwhile to mention that the logical links between processes and sub-processes in DSMS methodology are treated as "*Queue*" (see Figure 2). Every queue stands as an individual unit with its own specific properties. The queue links adopted in DSMS are one of the unique innovations in process simulation theory. The activity is the smallest piece of operation with a finite execution time. A sequence of activities (i.e. an operation) is initiated when an event occurs. One or more activities transform the state of a system. A basic set of activities constitutes the sub-processes and allows modeling the sequence of events in chronological order.

Modelling variability associated with uncertainties or randomness such as activity times, interarrival times, time-to-failure and time-to-repair values are achieved using statistical distribution functions. The model outcomes are produced in the form of reports, barcharts, piecharts, tables, histograms, time plot variables and text files. The model outputs are utilised in terms of performance analysis, capacity analysis, comparison study, sensitivity analysis, optimisation study, decision/response analysis, constraint analysis and visualisation. The accepted scenario from the model output is further analysed for life cycle impact evaluation. Functions can be linked across the life cycle phases within the IFE environment to get a comprehensive overview of the project's status in real time. This objective-based approach will allow planners to verify the impact of any change(s) on the subject project. If LCOFs are not satisfied at the project level, the corresponding process needs to be re-evaluated for alternative solutions and the procedure is repeated.

5. IT APPLICATION

The capital projects and its associated processes tend to be complex, with hundreds of thousands of activities and resources. Effective implementation of IT within the projects allows automation, integration and communication of activities and processes over the project's life cycle. The object-oriented environment using C++/Visual C++ programming languages have been used for development of the DSMS as well as the IFE system. The DSMS is designed to set up automatically project-based process models against instructions from the users and using information extracted from the IFE system. Interactive Windows facilitate users to determine the association between each object class in the DSMS. Data exchanging and dynamic linking of library capabilities allow integration of DSMS into the IFE system. Furthermore, DSMS's interfacing capabilities provide an added facility for entering and modifying system inputs, reviewing facility needs, redefining project scope, producing reports and maps. A database management system (ObjectStore) is being utilised to capture the entire project and process data within the IFE framework.

6. DSMS CAPABILITIES - A HYPOTHETICAL CASE STUDY

Figure 3 shows a network model for a bottling and packaging line. Total of 10 processes (e.g. process "Prs1" to process "Prs10") have been identified to represent the overall operation in logical sequence. The links between processes represent the path of workflow and named as "Queue". Each Queue has its unique ID (e.g. Prs1_Prs2_Q1) with its own properties. Windows interfaces allow user to define the properties as necessary. The identified processes in DSMS framework behave like a black box. The activities are assigned to processes and are responsible to execute the necessary operations. Entities and resources are associated with each activity as required.

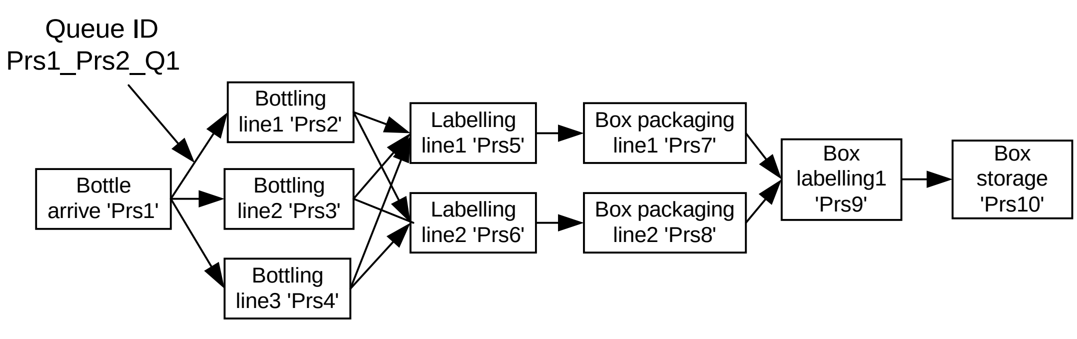

Figure 3: Network model for a Bottling and packaging line

Figure 4 shows a digital modeling construct using the DSMS interfaces. DSMS's interfaces are window-oriented. It utilises pop-up and pop-down menus, dialog boxes, selection lists and mouse-based editors for developing process logic. Interactive graphic user interfaces allows users to build process models by filling simple forms without prior simulation training. The user can customise the reports by selecting statistics for resources, locations, entities, variables and so on. Additionally, graphical reports of the outputs can be displayed, printed and plotted in the form of pie charts, histograms, time-series plots, etc.

The figure shows the dialog boxes provided for interactions between process data and database in the DSMS application. Dialog 1 shows the main menu and a floating palette bar on the left hand side. User can create activities by clicking on the palette bar icons. Dialog 3 shows the case study database file for simulation of a bottling and packaging line. The process data file stored in the ObjectStore database can be retrieved as shown in dialog 2. Processes can be defined using the general project-process sheet (dialog 3) and subprocesses can be assigned further in edit dialog box of the respective processes. Resource libraries and entity characteristics are defined by using the resource and entity dialog boxes as shown in the dialog 3. If the processes are complex, the additional operation within the processes can be represented defining subprocesses. The logical links between process to subprocess and subprocess to subprocess are similar to the link as defined for process to process. For the sake of brevity, details of the other functionality of the model have not been mentioned in this article.

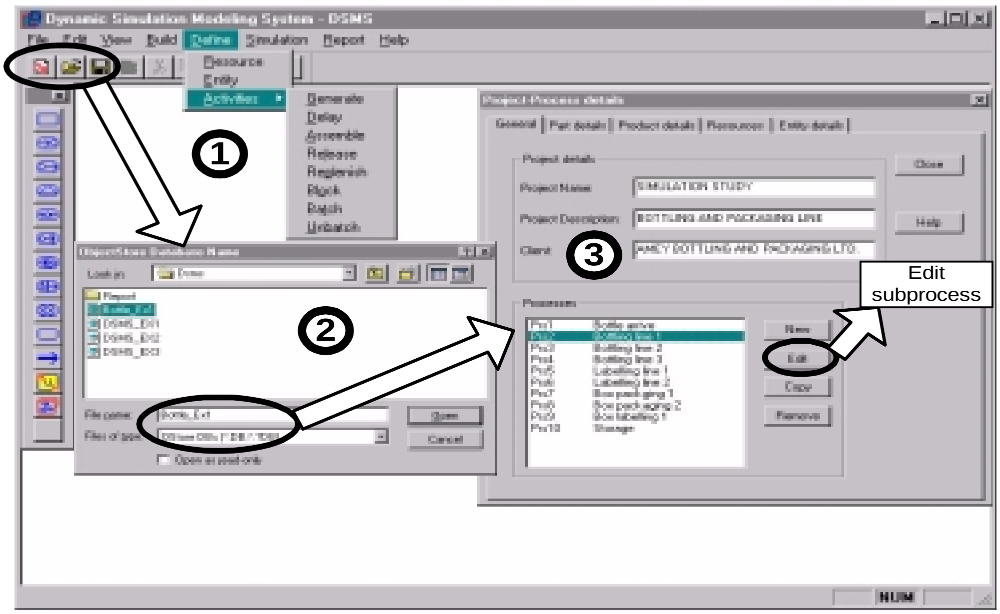

Figure 4: User interfaces used in DSMS

Once the process model is constructed, the necessary simulation run statistics are defined using simulation run interface. User can choose to record various statistics of the processes, subprocesses and queue links over the entire simulation run. Table 1 shows a statistics derived from a trail run of the above model. Percentage utilisation of processes and queue size developed, have been determined over a 10 hours simulation run. Performance measure of the process network needs to be considered in the overall process reengineering exercise.

Table 1: Average Performance Measures Of Processes And Queues

Processes	% Utilisation	Queue	Max. queue size (Run time: 10 hours)
Prs1	65	Prs2_Prs1_Q1	4
Prs2	78	Prs3_Prs2_Q1	5
Prs3	89	Prs4_Prs3_Q1	4
Prs4	64	Prs5_Prs4_Q1	7
Prs5	68	Prs6_Prs5_Q1	8
Prs6	72	Prs7_Prs6_Q1	5
Prs7	59	Prs8_Prs7_Q1	3
Prs8	69	Prs9_Prs8_Q1	2
Prs9	87	Prs10_Prs9_Q1	3
Prs10	78		

7. FUTURE DIRECTIONS

At present, development of DSMS is almost completed and the functionality of the model has already been tested using hypothetical data. In order to validate the model in real life situation, the authors have started to conduct a set of field (case) studies. The model focuses on manufacturing, construction and or services type processes throughout the project lifecycle. The case study will provide a thorough understanding of how simulation techniques can be used effectively to optimise decisions in every stage of the project. It helps in forecasting the impacts of business process re-engineering or changes due to benchmarking exercises. The integration of DSMS within the IFE system will facilitate life cycle project management through real time evaluations and optimisation of the project's LCOFs

8. CONCLUSION

This paper discussed the management of project scope as a viable business entity considering the end product of the project. The authors argued that process simulation in an integrated project information framework could be a valuable tool in terms of optimising 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 logistic investment decisions optimally. The article introduced discrete event simulation as a tool to support major decisions associated with early management of the end deliverables of the project. This permits greater understanding of the project’s capacity to respond to market dynamics and maintain its business competitiveness proactively.

The hierarchical and modular structure of the model provides 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 can be optimised based on LCOFs. The DSMS has been developed for generic applications that respond to the user’s instructions interactively. The DSMS allows users to create the dynamic process models using graphic interfaces. A hypothetical case study has been used to briefly discuss the models functionality.

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