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Adding Value in Construction Design Management by using Simulation Approach

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1. Introduction

This chapter focuses on a technique for integrating upstream and downstream project information from the conceptualisation, planning and implementation to the operational phases of projects. A new perspective for adding value in design management practices has been presented by emphasising a whole of project lifecycle approach. An appropriate mechanism for supporting design management practices at an early stage of project is crucial in terms of adding value over scope, time and total investment decisions. Simulation technology acts as a vehicle for analysing the strategic change management of the projects' scope and helps fine-tuning the dynamic business environments.

Increasing complexity and sophistications in construction create new challenges in design management practices. The clients are not only interested in value for money in relation to the investment in project development but costs associated in operation and maintenance over project life cycle as well. While the client's interests may be profit driven in the competitive market, the design professionals have to understand the commercial aspects in terms of design innovations, sophistications and cost effectiveness of the project. Coping with these challenges requires a full understanding of the wide variety of design parameters and technical expertise of each party to deliver the project as per original project objectives.

Most project fails due to an inadequate definition of project objective at the early stage of the project. Due to involvement of various stakeholders in the decision making process, the public sector projects are even more vulnerable compared to the private sector projects. Increasing complexity and requirements for continuous improvement of capital projects exert further constraints for adding values in both construction and project management disciplines in the competitive global environment.

Within the construction industry, there is a definite trend towards outsourcing specialise work to subcontractors, and thereby pushing the liability from one party to another. As such, with each construction project, the need for good design management and appropriate design communication between the designers, the main contractors and subcontractors is becoming increasingly important. Various methods of design management have been emerging with technology, to increase efficiency and reduce the costs and incrased values. Computers/IT has become a huge influence in this regard. The outsourcing of the design has also become a cheaper and more efficient approach to construction industry. This increases the need for efficient design development, effective design quality, information sharing and dealing with constructibity issues in deliverying the projects. The increased

trend of procuring public projects with Public-Private partnerships (PPP) procurement methods, such as schools, roads, social infrastructure etc. requires furhter attention on value for money outcomes in projects. Under the PPP contract, the contractor's resposibility extendes over substantial period of project life cycle and the impacts of design and the performane of overall project filter down to the subcontractor, engineers, architects, consultants and project end users. This greatly influences on the upstream design management process for meeting or exceeding expected benefits of project downstream. Based on research undertaken by the author over last eight years, it has been evident that the simulation is one of the best options in adding value in design management practice and to sustain in the emerging complexity in competitive project environment.

2. Objectives

Poor design management practice often leads to confusions and conflicts in complex engineering projects. Innovations in engineering design, construction and operational processes along with increasing regulations have significant contributions in resulting complexity of projects (Nicholson & Naamani, 1992). This chapter portrays how an appropriate analysis of design at an early stage and proactive management practices increase chances for adding values in projects from the operation and end users perspectives. An integrated design management framework has been presented to holistic evaluation of project selection and investment decisions based on functionality and operability of the end facility over operational phase of projects. In the evaluation process, selection of design configuration must enable meeting the target associated with business and strategic objectives of the organisation. A thorough analysis of these objectives is an important requirement to determine the optimum project selection from the available competing alternatives. Simulation based project evaluation and decision analysis adds significant value in evaluating such alternatives by reducing uncertainties in design, implementation and operations with a greater confidence (Jaafari & Doloi, 2002; Doloi, 2007).

Use of process simulation technique assists in analysing feasible design solutions based on technical, functional and operational aspects of projects. Simulation techniques allow design of mathematical-logical models of a real world system and experimentation with different alternatives digitally. It provides a basis for real time scenario analysis by analysing process level decisions at a lower level in the project hierarchy followed by the evaluation of conflicting criteria for making holistic decisions at the project level. A new design management framework, dubbed as Lifecycle Design Management (LCDM) has been discussed with examples where a set of lifecycle objective functions (LCOFs) are employed as the basis for decision making to determine the optimised solution throughout the project's life.

3. Life cycle management

Generally, life cycle management refers to management of systems, products, or projects throughout their useful economical lives. Projects pass through a succession of phases throughout their lives, each with their own characteristics and requiring different types of management. There is no complete agreement on the identification of these phases but they usually entail the following, as described by Morris (1983):

1. *Conceptual phase* – where projects are first identified and feasibility is established (financial, non-financial, and technical). This phase is subject to high-risk levels and should be examined before detailed planning. Consequently this stage includes the analysis of alternatives, development of budgets, setting up of a preliminary organisation, definition of size and location (facility site), and arrangement of preliminary financial and marketing contacts;
2. *Planning/design phase* – when all work from the conceptual phase is detailed and produced further. All major contracts are defined, and prototypes may be built;
3. *Execution/implementation phase* – when plans developed in the previous phases are turned into reality. At this stage, the number of people and organisations involved would have increased, requiring a redefinition of the project organisational structure. Estimation is replaced by performance monitoring. All construction works and major installation activities are completed; and
4. *Handover and start-up phase* – when installation is completed, final testing is done, and resources are released for the start of business operations.

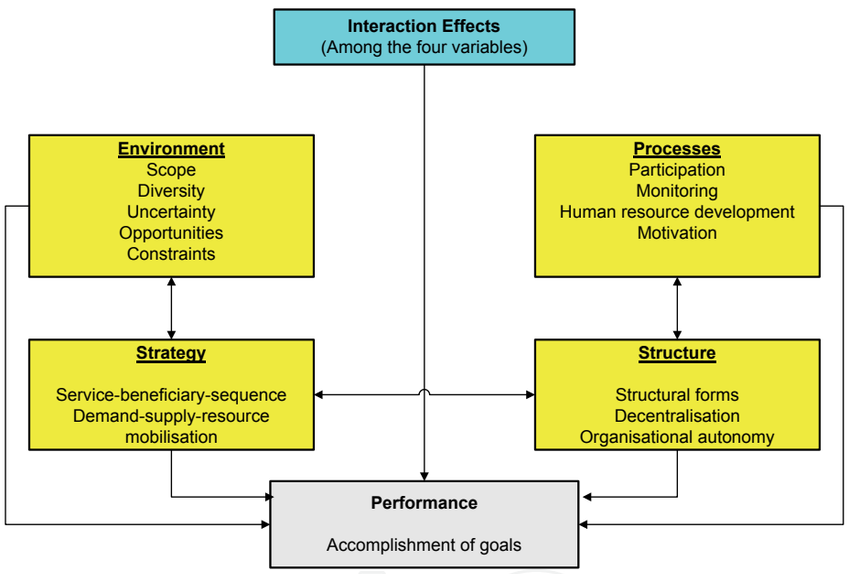


Fig. 1. Key Variables and Performances

In practice, normally these phases overlap. At the end of each phase, the project can progress forward or backward (i.e. a recursive process) depending on the amount of information gathered, produced and utilised (PMBOK, 2004). In LCDM approach as discussed in next section, the project life cycle has been extended to cover the operation and maintenance and disposal phases as well. All these phases are influenced by external and internal variables over the project life cycle (Paul, 1982). Paul (1982) identified four key variables influencing a project in his project management view. As shown in Fig.1, the four key variables are *environment*, *strategy*, *structure* and *process* (Paul, 1982). The interaction among these variables affects the project performances over the entire life cycle. The adequate interventions to these four variables of the project, and according to the specific type of project and environment, project performance can be positively influenced. It is clear that a design management approach requires well-defined strategic objectives, as highlighted in the following sections.

4. Lifecycle design management (LCDM)

Design professionals and project managers are involved in each phase of the project life cycle that entails distinct activities and skills. Failure to properly address the design issues and their underlying impacts over successive phases of the project life cycle can jeopardise the ultimate success of the project. In typical project delivery approach, there is a heavy concentration on the analysis of design and setting objectives for success in terms of three main parameters: time, cost and quality. Time with respect to project start and finish dates, cost with respect to cash flow and the project budget, and quality with respect to pre-defined standards and specifications laid down by the client or the relevant classification society.

LCDM installs a set of business and strategic objectives for decision making throughout the project life cycle in place of the traditional project development protocols. It employs an integrated and concurrent design management approach to substitute the process-based and activity-driven traditional management approach (illustrated in the current practice) for innovative strategy-based and outcome-driven project outcomes. LCDM components comprise:

- A culture of collaboration based on strategic partnership and unity of purpose;
- A life cycle philosophy and framework and an integrated single phase approach;
- An integrated project organisation structure and real time communication system among the design professionals;
- An integrated design management system linked with project information and development systems ; and
- A set of project strategic objectives, known as Life Cycle Objective Functions (LCOFs) for assessing and evaluating holistic project outcomes based in downstream operational conditions. These LCOFs are usually derived based on the Triple Bottom Line (TBL) principles (Doloi, 2007).

Fig.2 represents the perspective that Lifecycle Design Management (LCDM) takes, as opposed to the perspective adopted by the traditional design management practices. As seen, the LCDM framework embraces all the life cycle phases from conceptualisation to demolition (re-cycle) phase with a significant emphasis on the operation and maintenance phase. Such holistic view encapsulating the lifecycle in design management is a major shift in the new LCDM approach.

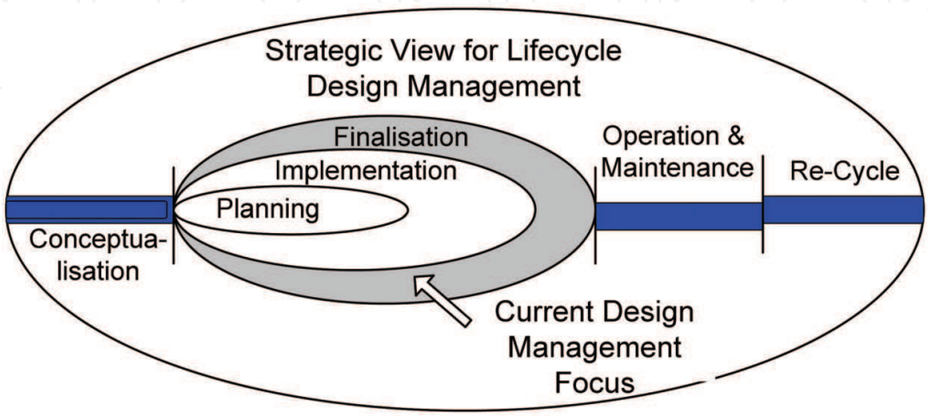


Fig. 2. Lifecycle view of design management

5. Importance of design management

Design management is a leadership activity, focused on managing the creation of an entity. An entity may be an object (motor car, building, etc.), an event (wedding, conference, etc.), a concept (such as the theory of relativity), or a relationship (such as that between employer and employee). Based on this definition of "entity", literally anything can be the focus of design management. The design manager's role includes establishing and clarifying a shared vision of the entity, defining, acquiring and allocating the resources needed to create this entity, managing the effective use of those resources, and monitoring the design team's performance (Chaaya & Jaafari, 2000).

"Design management" and "design managers" are popular expressions in most industries except the construction industry where they have been realised relatively late (mid 1980's). There is nothing innovative in the notion of design management. However, the separation of powers between designers and design managers is clearly a new synthesis in design management practice (Berk, 1994). In the construction industry, the architect used to be at the same time architect, project manager, cost manger, design manager, principal consultant and the undisputed leader of the building procurement team. Specialisation and evolution of professions led the way to a variety of consultants doing much of what architects used to do, including now the design management services.

"We are witnessing a fast migration of the value of architectural services from strictly Information Creation to the incorporation of Information, Management and Distribution. Over 25 years ago, architects gave up certain risks, rights and responsibilities of construction supervision and a new profession emerged to fill those needs of the client, the Construction Manager. Construction management has blossomed into a profession that most projects use today. We are seeing history repeat itself as most architects and other design professionals are fast losing control of their main asset, their information" (Cyberplaces, 1998).

Separating design from management is not a straightforward task since design is a process of decision-making and decision-making is a key process in management. Decision-making often involves defining a list of objectives, analysing the information, considering the alternatives, assessing the consequences of the options, judging the risks, costs, penalties and bonuses, and selling the decision. These steps are naturally reflected in management. Hence, a good designer is envisaged as a good manager and it is often concluded that bad designers are bad managers.

If it is acknowledged that design management is neither a process of managing a design consultancy or practice, nor the education of designers about the importance of the management world, then the importance of defining design management becomes apparent. Throughout this chapter, design management is defined as the effective deployment by the project management team of the design resources available to them in the pursuance of the overall project and business objectives defined at the outset of project.

The growth in new knowledge and increased customer focus has increased the design complexity in projects. Customers no longer simply settle for generic product but want customised product design and services that cater for their ever increasing needs. In today's digital age with an ever growing of consumers' appetite for more sophisticated products and services, increasing product complexity significantly impacts on design management practice. The need to integrate diverge technologies, and thus project management, has emerged as an important discipline for achieving these objectives. The functionality of new production systems to service the changing markets is crucial in responding to shorter

product life cycles and market dynamics. The definition of a product directs the added knowledge in scope management, and provides challenges for operative tools that are designed for putting the component parts and processes of the project together (Jaafari, 2000).

The need for better design management in the architectural, engineering and construction (AEC) industry has never been so high. This is due to emerging factors that reflect both changing market conditions, advent of new materials and new procurement processes (Nicholson & Naamani, 1992). To maintain profit margins, the industry needs to focus on the improvement of the design process, especially to cope with tougher competition and tighter fee scales.

Capital projects have necessitated design input from an increasing range of specialists. The increased emphasis for keeping the construction projects on time and within budget has required effective management of project scope associated with multifaceted stakeholder groups in the project (Cleland, 2004). Thus, definition of project's scope in the concept phase vastly influences the project development and its overall business outcomes. Understanding the complexity of design in both functional and operational contexts at the early stage is important in defining appropriate facility of the project.

The primary objective of this chapter is to discuss how to enhance the project's operational performance and increase project's business outcomes from an effective design management perspective. Inherent in this issue are the several sub questions such as: 1) how does the design management impact on setting a benchmark on appropriate project management practices? 2) how the process simulation approach can be used for integrating operational processes and managing design complexity upfront? 3) what will be the consequences of applying project simulation in decision making and overall business outcomes?

Focusing on the above questions, author's research resulted in a new model of project design management that can deliver a view and an understanding of the strategic objectives of projects in a proactive and explicit manner. Process simulation is employed for evaluating operational performances and managing the process complexity at the early phase of the project. Simulation based project evaluation and decision analysis allows evaluating project alternatives by reducing uncertainties with a greater confidence (Artto et al., 2001; Puthamont & Charoenngam, 2007). The approach provides a platform for real time project definition based on technical, functional and operational aspects of projects.

6. Proactive design selection and project performance

Many organisations have found design to be the key to project success in meeting growing and changing conditions. Growing pressure on design innovation and timely delivery is a fact of life for project managers and architects (Heath et al., 1994). The design phase of a project offers the greatest scope for reduction in overall project costs and adds maximum values in the project. The size and complexity of modern design with increased uncertainty requires front-end planning throughout the life of a project. Design management is an incremental continuous iterative process and as the project moves on, it provides feedback points for new information and the flexibility to assimilate and act on it. Thus initial design and planning must concentrate on building viable project bases for each principal subsystem in the context of life cycle planning of projects (Cleland, 2004). In the case of strategic planning, one takes a set of fixed interests, juxtaposes them within a fixed environment (or world, or set of conditions), and then invents a strategy for attaining one's interests given the constraints imposed by the environment (Doloi & Jaafari, 2002).

Current project management philosophy tends to concentrate on the delivery processes and associated functions of contractual scope, time and cost management (Jamieson & Morris, 2004). Traditional design selection and investment decisions in projects are based on static and simplified assumptions regarding the functionality and operability of the production processes. Economic analysis, reflecting the final customer's or investor's life cycle costs is important during decision making, particularly at the early phase of projects (Jaafari, 2000). This is because solutions devised and commitments made at the early phases constitute a major part of the downstream project costs. Modelling of technical and operational functionalities of the end deliverable supports strategic decision making in the early phase of the project. Thus, appropriate design and optimal scope definition considering the entire life cycle are the key for overall project success.

7. Design complexity and process simulation

In recent years, the concept of a modelling has become increasingly important in engineering design management practices. It is no longer sufficient to pay detailed attention to the design of the various elements of a project individually, rather, all elements must be considered in relation to others in order to make the overall system effective. However, good project design is not restricted to detailed design coupled with attention to interrelationships between physical parts and elements. Design must be analysed and evaluated at a deeper level and in relation to the project's operational environments (Cleland, 2004; Doloi, 2007). Design configuration and scope of projects must reassess and readjust to ensure that the objectives are met at the end. As a result, the overall process to reach these goals becomes iterative, involving in the design of each of the parts and products, which constitute the overall project. Simulation approach allows building a model of the proposed system capturing the salient features of the overall system.

Digital computer models facilitate analysis of complex processes associated in projects. A simulation model is a means for collecting information about the likely performance of a system, based upon user-defined conditions (Marmon, 1991). Simulation models can improve the planner's understanding of the real life situation during conceptualisation and final design or actual construction (Luk, 1990). By using the simulation model, the effect of changes in process design can be justified and fine-tuned and investment decisions are optimised over the project life cycle. The life cycle project management (LCPM) model is indeed capable of responding to the global challenges and achieving the true value on investment in the integrated project development.

8. Project development in design management context

A typical project life cycle includes phases such as feasibility, planning and design, execution, commissioning and handover (PMBOK, 2004). As revealed by Artto et al. (2001), the investment project phases are preparation, execution and operation, whereas the phases associated with the post project implementation are sales and marketing, execution and after-sales services. In front end planning, the investment project phases must be integrated with the post project implementation phase (Shi & Abourizk, 1998). Fig.3 depicts the links of three board criteria over project life cycle phases. As seen, the three broad criteria associated with project investment are Risk and Uncertainty, Financial Objectives and Facility Performance. It is important to understand that the impact of the technical and operational

functionality of the final deliverable on the end users is an important parameter that contributes to the benefits obtained from the investment (Artto et al., 2001; Dikmen et al., 2005). All these three criteria should be analysed upfront before making the final decisions on project investment and development.

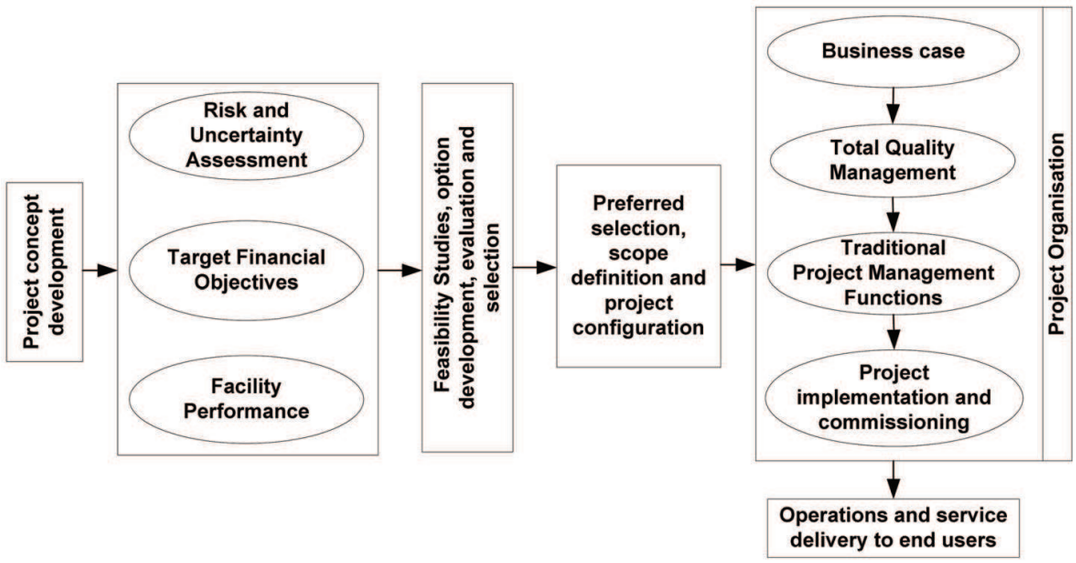


Fig. 3. Broad phases in project development

The three criteria are highly interrelated from the project's end product performance point of view. The role of total quality management (TQM) along with the traditional project management functions intrinsically governs the project development process in delivering the end product. Thus, the scope of the project is the sum of products and services produced in the project. The term 'project product' is used as a synonym to scope of the project. The purpose and benefit of project is realised only when an appropriate scope configuration is achieved. The process includes aspects of 1) quality of the project product; and 2) performance, functionality and technical characteristics of the project product (Jamieson & Morris, 2004). The implications of the scope definition are that the project scope management should focus on fulfilling individual needs of the end users of the project.

Decisions and information generated over feasibility (or conceptual design) and planning phases of projects have a great impact on the downstream activities and consequently on the overall cost (Artto et al., 1991). Understanding the project and its underlying processes, supported by relevant information and tools leads to better decisions on projects. Integration of implications of investment on product life cycle with project development cost is an important consideration in front-end planning of project (Laufer, 1999). Thus the validity of the hypothesis that the contemporary project management approach embodying process simulation technique helps proactive decision making on optimal design, scope definition and overall operating processes to achieve optimality across all phases is a significant advancement in the LCDM concept.

9. Process simulation and decision making in project lifecycle

The simulation is a numerical technique for conducting experiments on digital computers involving certain types of mathematical and logical models to describe the behaviour of a

system over extended periods of the real time (Pidd, 1984). During the last decade, discrete event simulation has gained a significant role in engineering planning and design (Doloi & Jaafari, 2002). Numerous examples reported in the literature, provide evidence how organisations can save millions of dollars and avoid major risks using process simulation (Irani et al., 2000). For instance, in early 1993, the IBM PC Company in Europe faced a number of challenges that were eroding its market share, such as frequent price cuts, rapid customer order response times, and a steady arrival of new products by aggressive competitors. The IBM management reacted to record corporate losses by emphasising the necessity of reducing operational costs and inventory throughout the company. The process simulation technique was used to evaluate different manufacturing execution strategies and to identify the lower-cost distribution policies. A strategic distribution policy was adopted based on the analysis of alternative scenarios which resulted an estimated $40 million per year savings in the distribution costs of the company (Artto et al., 2001; Kirkham, 2005).

The research on how the discrete event simulation works is not embryonic. Development of computer-aided process simulation techniques have accelerated in recent years. However, its use for project definition, management practices and life cycle investment decisions is not widespread (Doloi, 2007). The application and influence on setting the benchmarks for management practices within the complex project management framework has proven to be a significant contribution in this research. Table 1 shows how the simulation can be applied as a tool for appropriate front-end management of respective objectives over the project life cycle. As seen, most of the project objectives and the decision making subjects have a natural link to the process simulation outputs.

Definition and effective management of project scope, as well as management of the investment life cycle incorporating the dynamic considerations of the market and customers needs is a challenge within project management practice. Furthermore, simulating an individual process within a project does not add significant value for the evaluation of project level decisions in real life situations. Thus an integrated model embodying simulation capability within the hierarchical project structure simplifies the task of project managers for making strategic decisions on complex projects (O'Kane, 2003). The framework facilitates strategic decision making by defining facility characteristics and improved process design on fluctuating operational environments over the entire life of projects.

10. Project decision framework

Given the increasing use of computers as management and evaluation tools, it is natural to consider their potential applications to design information management. Much valuation work has already been done on the application of computers to understand and modelling design processes and mechanising design tasks. The attempt to reduce design complexity, increase functionality, clarity and constructability at an early stage has now been the focus among researchers in the field. Selection of an appropriate design and configuration of operational processes of project facility is an important consideration in competitive project development environment. Project level decisions are greatly influenced by the feasible alternative designs and their consequences (Goldschmidt, 1992).

Life Cycle Design Management (LCDM), as subset of the Life Cycle Project Management (LCMP) is an approach for integrating business and strategic objectives of projects throughout the project life cycle phases (Doloi & Jaafari, 2002; Jaafari, 2000). The LCPM approach employs an integrated and concurrent project management principle to substitute

the process-based and activity-driven approach in the project management paradigm. Much work has already been published LCPM methodology in project evaluation and management contexts (Doloi & Jaafari, 2002; Jaafari, 2000).

Project objectives	Subjects for decision making	Usability of simulation tools in front end management
Project concept development	- Market need analysis - Project option analysis	Supply-demand planning, optimum utilisation of resources
Project facility planning	- Decision process for project development - Product design - Project Management functions	Capacity planning and scope definition
Project implementation	- Scope control and management - Time management - Cost management	Constructability analysis, change control and alternative planning
Project operation and maintenance	- Market economics and changes - Facility operation and flexible production	Project functionality and operability of the end project product
Sales and Marketing	- Market consumption - Customers satisfaction and acceptance	Supply-demand analysis, evaluation of logistics
Research and Development	- Product design and redesign - Product innovation and process reengineering	Simulation model for 'what-if' analysis, process reengineering.
IT/IS support	- Process automation and optimum facility utilization - Waste reduction, cost minimization	Simulation model for evaluating facility utilisation, activity-based costing
Project Organisation	- Resources and skills requirements and utilisation - Self managing teams and cross cultural integration - Key performance measures and controlling - Risk resilient and uncertainty management - Change management	Simulation model for resource planning, resources levelling and optimisation

Table 1. Project objectives and front-end management tools

Fig.4 depicts an overall design management framework embodying the phases over project lifecycle. As seen, selection of design alternatives and investment decision has direct influence on the strategic project objectives and overall performance of projects (Irani et al., 2000). Thus the project's design and their underlying capability should be defined integrating optimum project's configuration and inherent business intents.

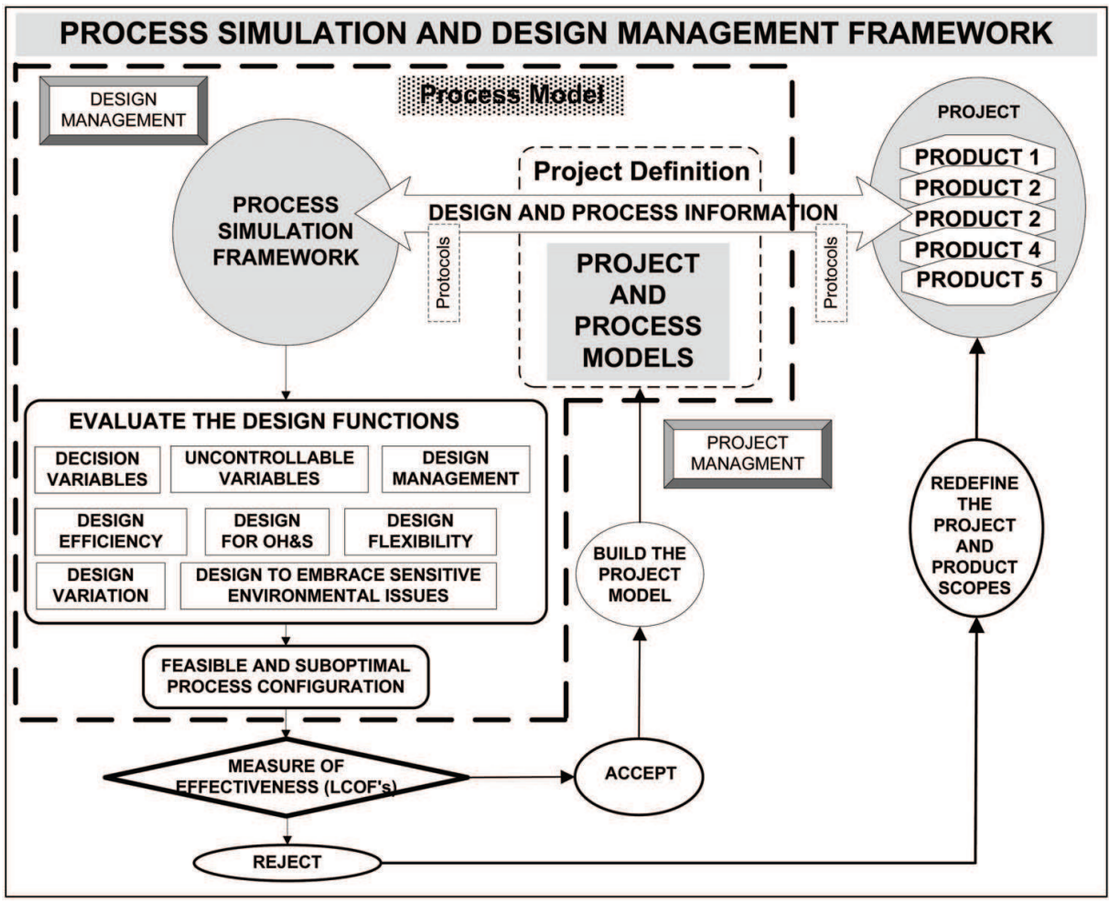


Fig. 4. Process simulation and measure of the project's effectiveness

Once the initial decision on a feasible design is made and project products are established, the underlying processes are identified for analysing feasible alternatives, selection and allocation of appropriate resources and establishment of the best project option for development. The processes of analysing alternative product configuration and selecting best project option are facilitated by the simulation technology. The projects are broken down in smaller products and process models are constructed incorporating operational scenarios for simulation analysis (Doloi & Jaafari, 2002). The outcome of simulation forms the basis for evaluation of the suboptimal configuration against the target LCOFs of the project. After the project is developed and commissioned, operation is monitored based on the performance on LCOFs, organizational strategy and competitive advantages. The dynamic scanning and assessment processes are then continued in the project operating environment.

11. Framework for simulation analysis

The simulation assists management on analysing the functionality and operability of project deliverables by focusing on the business objectives in the early phase of the project. The platform allows a real time project definition based on technical, functional and operational aspects of the project (Doloi & Jaafari, 2002).

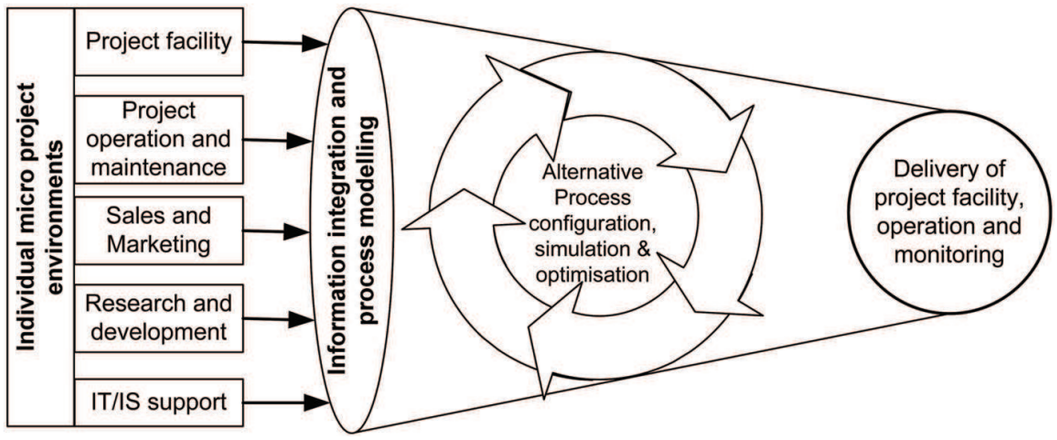


Fig. 5. Integration of functional disciplines within project operation

Fig. 5 shows how the micro project environment and their functional disciplines are scanned and relevant process information is integrated over project life cycle. Hierarchical process models are built and simulated by linking the processes and allocating available resources across all disciplines. Alternative processes are identified and tested for optimal project configuration. The project level decisions on operability, functionality, quality or performance issues are then optimised using a set of criteria known as life cycle objective functions (LCOF) (Jaafari et al., 2004).

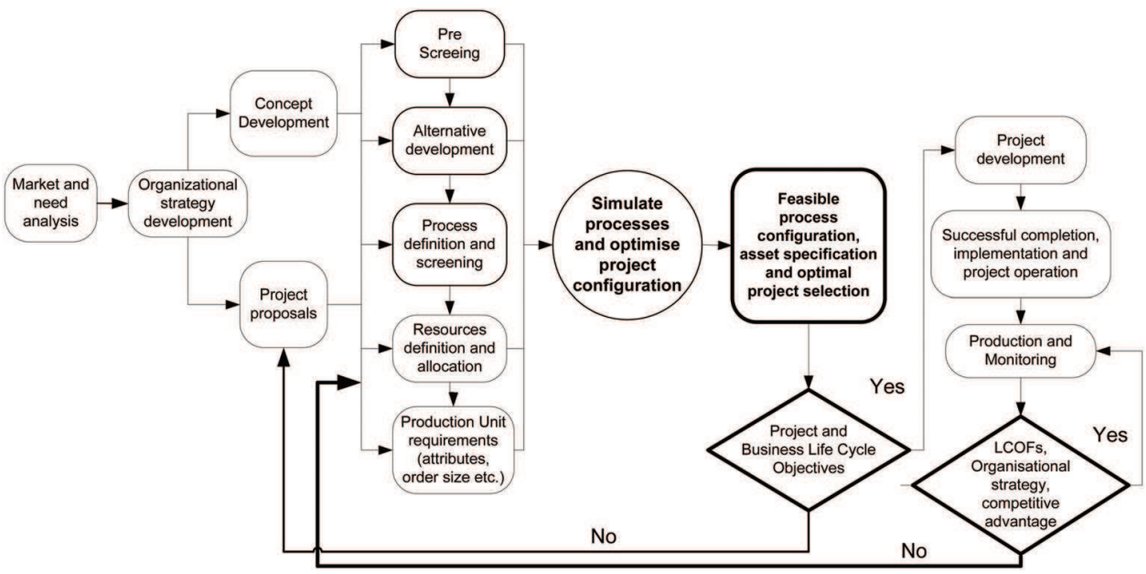


Fig. 6. Framework for life cycle decision analysis

Fig. 6 depicts the overall decision process over the life of the project. Project investment decision and organisational business intents have direct influence on the strategic planning and development of the project (Yeo, 1995). The project concept and alternatives are then identified and resources and product specifications are defined for feasible project solution. The outcomes from simulation modelling on project configuration, operational requirements and resource utilisation are used as input for analysing required management capabilities

and transformation for a project specific environment. Continuous assessment on the functionality and operability of the project product and feedback mechanism allow dynamic interaction and evaluation of the project's performance over the life cycle of projects (O'Kane, 2003).

12. Simulation enabled design management – a practical example

In order to demonstrate the use and benefits of the process simulation, a case study is presented in this section. The simulation model representation provided a key decision making platform that quantified the effectiveness of varying level of design and planning to support an optimum operational plan. A significant implementation challenge during a planning level study can be understood from the analysis flow chart shown in Fig. 7.

The selected project was a commercial Ductile Iron manufacturing plant (named hypothetically as XYZ manufacturing plant) located in a regional area of Sydney in Australia. The manufacturing plant was due for a major overhaul for which a front-end decision analysis was quite appropriate to support the strategic management decisions. The ability to quantify the impacts on alternative process design is a huge benefit of using a simulation model. Once the design is altered to suit the required service requirements, the project's life cycle objectives are assessed and validated. The framework presented provides the functionality of make such changes and adjust related variables at project levels impacted by the changes.

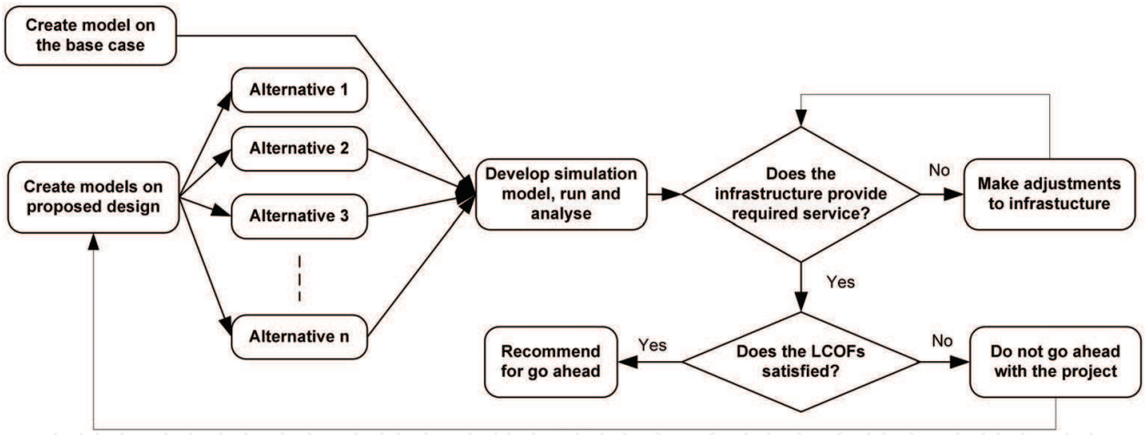


Fig. 7. Typical planning level analysis

12.1 Client project brief

The XYZ manufacturing plant commenced production in 1962 making grey cast iron pipes and was later converted to ductile iron pipe manufacturing in 1976 to take advantage of superior mechanical properties of ductile iron. Ductile Iron Pipeline Systems represent significant improvements in terms of waste recycling. Pipes and fittings are manufactured from 100% scrap steel. Raw materials used in production are selected scrap steel, ductile iron returns, ferro silicon, coke, limestone and fluorspar. Thus steel scraps are converted into valuable assets using less energy and thereby minimizing greenhouse gas emissions during the manufacturing process.

The ductile joint pipes in XYZ manufacturing plant are produced by the centrifugal casting process to a standard length of 5.5 meters in diameters of 100mm to 800mm. The overall project can be described in terms of major processes from the crane operating in the scrap storage area feeding the raw materials onto a conveyor to the final production of pipes after undergoing hydrostatic pressure testing before going through weighing and inspection processes.

12.2 Target production, budgets, and LCOFs

The main stakeholders for the XYZ Manufacturing plant is Tyco Water and the targeted customers, who are both local (40%) and overseas markets (60%). The use of the ductile iron pipes is mainly for transportation of potable water and sewage. Ductile iron pipe standards for the domestic market are the Australian/New Zealand Standard AS/NZS 2280 and for the international market is the British/European Nations Standard BS/EN 545. The total investment on assets in present worth terms is about 100 million dollars. Yearly turnover was not disclosed due to the competitive market. However, it was known that the 60% of the overseas market share was not producing any profit to the company but meeting the running cost of the plant. Current project facility and management capability have long been under increasing scrutiny for its strategic existence in the global business environment. Fig. 8 shows the current trend of utilization of the project facility and resources throughout a calendar year. According to the production manager, the plant is currently running at about 80% of its capacity on average due to falling market demand. However, there is an increasing threat for plant breakdown and higher maintenance cost due to aging facilities in the plant. The simulation study was conducted to see how the overall facility and the existing project business could respond to variable demands and how to make best use of the exiting facility optimally. Table 2 depicts the target LCOFs derived from the available financial data used for decision making at the project level (refer to Fig. 6). The target equity internal rate of return of 30% is the focus of all the decision making on this project.

12.3 Simplified case data and analysis

The case study processes have been designed in order to understand the operational context and utilization of existing facilities. Various products and major processes have been identified from information provided by the production manager and onsite data collection. It is worthwhile to mention that among many functional disciplines within the micro project environment, only the plant operation has been considered for simulation here. The plant produces a number of different size pipes on demand. Production rates vary with internal pipe diameter: smaller diameters have faster production rates than larger diameter pipes. For example, 100 mm diameter pipes can be produced at 50 pipes per hour and 800 mm pipes can be produced at 17 pipes per hour.

12.4 Scenario 1: process network

Figs. 9, 10 and 11 depict process network diagrams built on the existing capability, an alternative and the optimised alternative of the plant respectively. Fig. 9 shows part of the model for a few key processes involved in manufacturing the pipes. Overall, there are four lines of centrifugal casting machines with two annealing furnaces. After annealing, testing and finishing processes take place in three parallel lines. The workflow sequencing and connectivity between processes are shown in the figures.

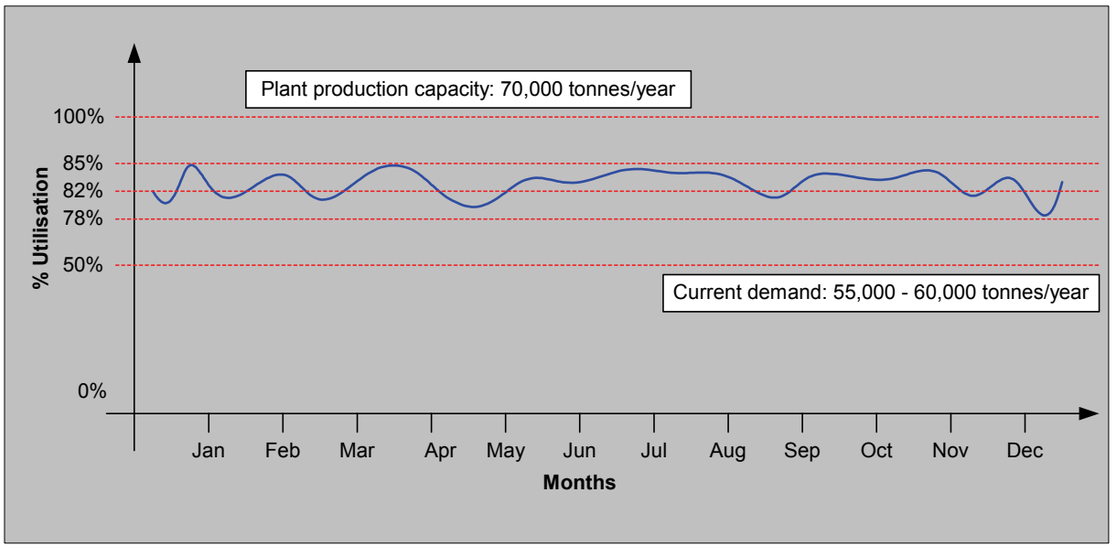


Fig. 8. Current trend of utilization of the facility

LIFE CYCLE OBJECTIVE FUNCTIONS (FINANCIAL)	TARGET
Total Life Cycle Cost (TLCC) $ in present value	A$100 million
Equity Internal Rate of Return (EIRR) %	30%
Net Present Value to Capital Investment Ratio (NPV/C)	1.50
Total Life Cycle Cost (TLCC/Po) $ p.a. to unit production output	Confidential
Cost to Worth Ratio (C/W)	Confidential
Environmental emission standard	Confidential

Table 2. Targeted LCOFs

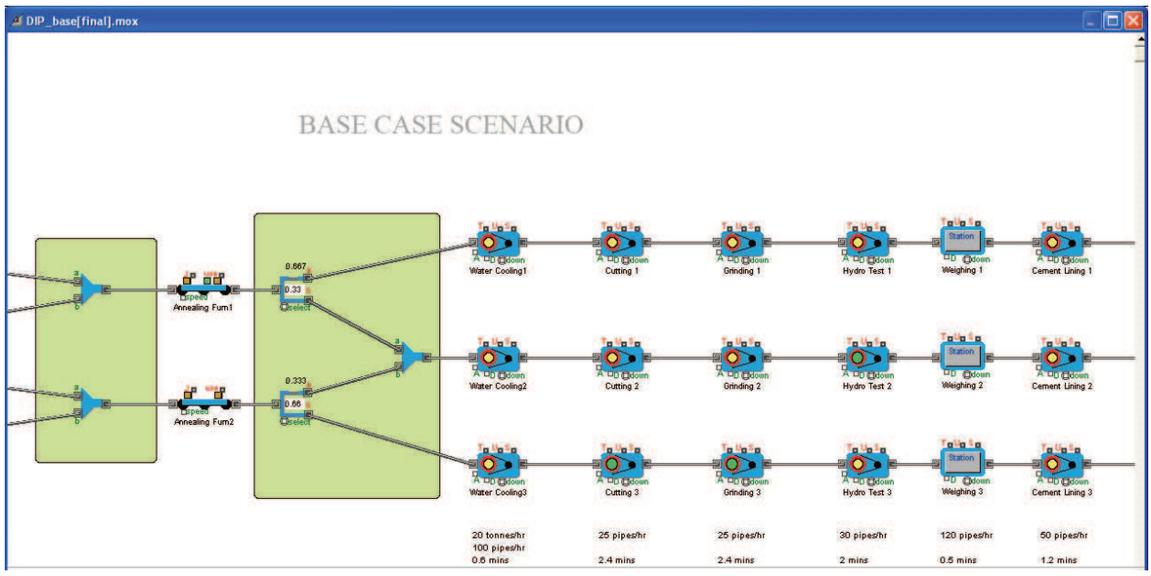


Fig. 9. Base case processes for production of ductile iron pipes

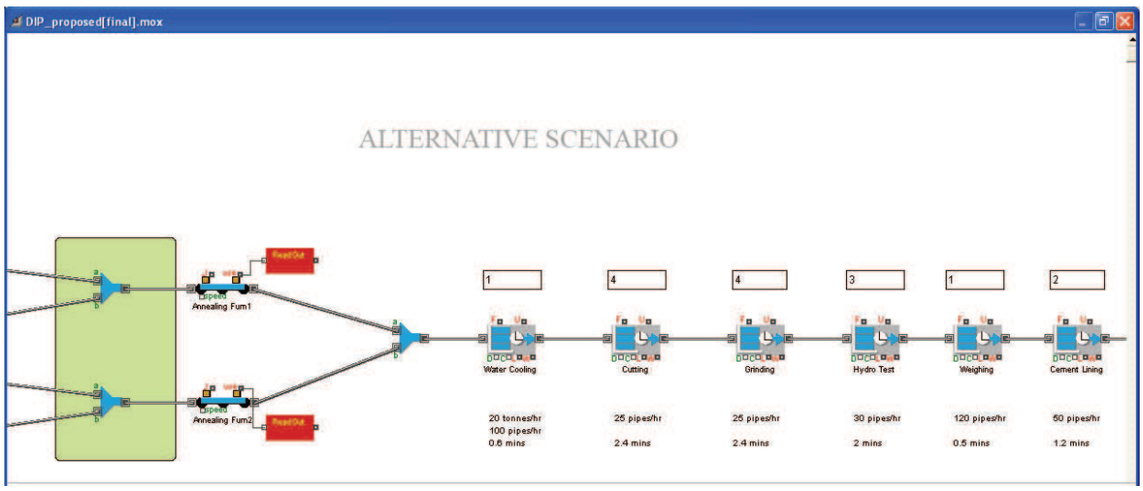


Fig. 10. Alternative scenario for production of ductile iron pipes

12.5 Simulation output and the LCOFs evaluation in scenario 1

Details of the statistical outputs from the simulation run for Scenario 1 have not been presented. The simulation model was run for 500 hrs and the average utilization of processes was found to be about 62%. In Scenario 1, seven processes: water cooling, cutting, grinding, hydraulic test, weighting, cement lining and coating processes were highlighted. It was found that while the first four processes (water cooling, cutting, grinding and hydraulic test) were utilised on average 85%, the remaining processes were utilised less than 30% on average. A severe bottleneck has been experienced near the water cooling and cutting processes.

12.6 Alternative scenario and optimization

An alternative was developed by reconfiguring some of the processes under consideration as shown in Fig.10. In this reconfiguration process, one additional cutting and grinding processes were added while weighing processes were reduced to only one and the cement lining processes were cut down to two. Cement lining processes also have been reduced from three to two as these processes were found underutilized in the base case scenario. Details of the network process diagrams have not been shown for brevity. Simulation was run for the equal time period as the base case and capacity utilization for the processes were recorded.

In order to optimise the proposed design, evolutionary optimization approach was employed on proposed scenario and impact on performance of the processes were analysed. In the optimization process, the modelling parameters were varied and best performance was monitored by defining a range of objective functions. Fig.11 shows an output of the optimiser with approximately 99% convergence for maximum output in the model. The Genetic Algorithm based optimiser produces significantly better operational performance and utilization of the proposed processes over existing situation. The optimiser includes a number of parameters such as the probabilities of crossover and mutation, the population size and the number of generations (Khral, 2002).

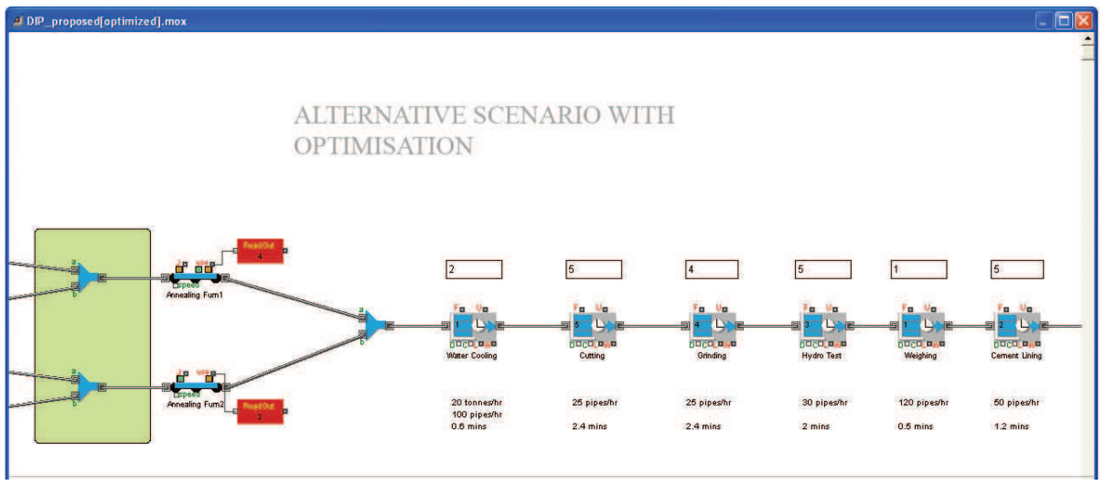


Fig. 11. Alternative case with optimization

12.7 Impact of new process configurations

Fig. 12 shows a comparative analysis of process utilization between base case, proposed and optimized scenarios. The optimized process configuration for maximum output values in

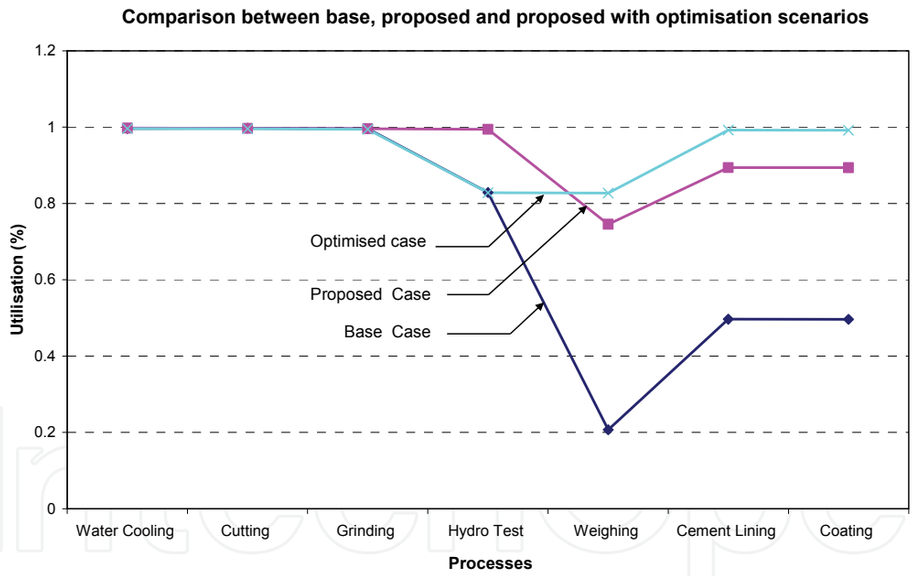


Fig. 12. Comparative impacts of new process configuration

the proposed design over the base case scenario was achieved by increasing the capacity of four processes over the proposed scenario. As seen, there is a good balance with about 95% average utilization of processes in the new optimized design. An introduction of an additional processes along with the alteration of flow sequences on processes have significant impact on overall process performances of the project. It is evident that the capability of the manufacturing facility could be enhanced by altering the current baseline operation; obviously there is a limit to what can be achieved without significant investment in new plant and facilities.

These decisions then investigated in terms of target LCOFs in the integrated framework by using the existing operations as the starting point. Management strategies and require capability are then built supporting the reengineered processes and project operation. As has been demonstrated in this example, the process simulation approach is a powerful tool in achieving this objective.

Feasible alternative scenarios (1)	% Utilization of project facility (2)	% Utilization of operational resources (3)	TLCC* (%) (4)	Strategic Business Objectives							
				Financial (5)		Facility/Asset performance (6)		Market demand (7)		Sustainability & Risk (8)	
				Unit cost (%)	ROI (%)	Waste reduction (%)	Shorter cycle, (%)	Improv e-ment (%)	New customers (%)	Sustain-ability (0 – 6)**	Reduced Risks (0 – 6)**
Base case	72	65	100	0	12	0	0	0	0	0	0
Proposed case	93	79	95	10	15	10	15	10	5	1	1
Optimised case	95	87	91	12	19	15	10	20	8	1	2

* TLCC is the Total Life Cycle Cost for scenario under consideration.
** Sustainability and Reduced Risks are measured on an index scale from 0 for no effect to 6 for highly effective.

Table 3. Holistic analysis of alternative project solutions

13. Life cycle decision analysis

Table 3 shows the overall evaluation matrix by integrating upstream and downstream information for optimal management decisions in the project. While all three options in column (1) are assumed feasible, each has an estimated total life cycle cost and a corresponding level of various high level criteria influencing strategic business objectives (LCOFs). Result of simulation analysis provides the input values in columns (2) and (3). Values in column (4) are the result of the traditional life cycle cost analysis using the raw data from Table 2 (Jaafari, 2000). In order to determine the optimal solution, values in columns (5) – (8) are used to see what tradeoffs are available against values in columns (2), (3) and (4). These trade-offs are then analysed using Multi-criteria Decision Modelling (MCDM) technique (Doloi, 2007) to locate the optimal solution among those which meet the target criteria. Details of MCDM techniques can be found in Doloi (2007) and Jaafari et al. (2004).

As already stated, an appropriate conceptual model to facilitate holistic evaluation and management of project's complexity is not currently available. Much work needs to be done to better understand and apply a project-based approach by integrating processes and operations in the front-end management practices. An optimization model was in dire need to evaluate a given operation to show if current processes are in balance within the expected present or future demand patterns while maintaining its business and environmental performances (Doloi, 2007; Cleland, 2004). This chapter has demonstrated an approach that sets a benchmark for an integrated framework enabling management of complex projects. It has shown a way forward in computational aspect of the project management approaches for sustainable project development and management practices.

14. Conclusion

Simulation modelling has been introduced as a decision support tool for front end planning and design analysis of projects. An integrated approach has been discussed linking project scope, end product or project facility performance and the strategic project objectives at the early stage of projects. The case study example on tram network demonstrates that application of simulation helps assessing performance of project operation and making appropriate investment decisions over life cycle of project.

Optimised design and maintenance of physical project facilities in competitive business environment triggers the strategic positioning of the project organisations over life cycle of the project. The preliminary research has identified the key roots of inefficient operations in terms of the capabilities and utilisation of the project facilities and resources and contributed in devising optimal solutions based on life cycle objective functions of the project. The framework assists organisations in their management decisions in respond to market dynamics, customer needs and organisational intents.

In developing the prototype, the process simulation approach has been used in the projects. The simulation based framework facilitates evaluating the functionality and operability of feasible project configuration for strategic implementation. Research by the author reveals that there has been little attempt to assess the link between the physical project's facility and the underlying business capability and ability to respond to market shifts in contemporary project management practices. The concept presented in this research has taken into consideration multiple views of project facility within a business operating environment. Process reengineering or investment decision on the existing facility depends on the target LCOFs of the project. Analysis of alternative project solutions (based on alternative process scope and configuration) rather than focusing on well designed activities for project implementation has significant contribution in supporting decision making and management of future project outcomes.

While for design visualisation, the simulation modelling is immensely valued, project selection and overall investment decisions are holistically evaluated incorporating strategic business objectives in the cycle project model. The simulation based framework put forward provides the engineering assistance in optimizing project's configuration, planning and design and investment decision on capital projects. The ability for quick exploration of the multiple scenarios of significant benefits and the capability incorporating results on design and engineering processes in devising the best possible solution on complex projects are the significant contributions in this chapter.

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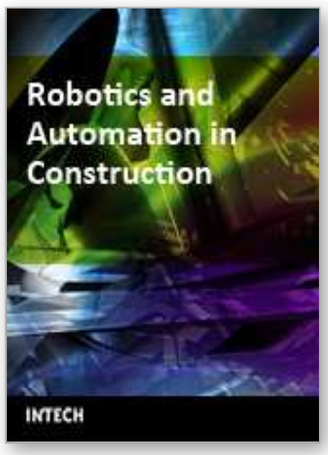
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Robotics and Automation in Construction

Edited by Carlos Balaguer and Mohamed Abderrahim

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This book addresses several issues related to the introduction of automaton and robotics in the construction industry in a collection of 23 chapters. The chapters are grouped in 3 main sections according to the theme or the type of technology they treat. Section I is dedicated to describe and analyse the main research challenges of Robotics and Automation in Construction (RAC). The second section consists of 12 chapters and is dedicated to the technologies and new developments employed to automate processes in the construction industry. Among these we have examples of ICT technologies used for purposes such as construction visualisation systems, added value management systems, construction materials and elements tracking using multiple IDs devices. This section also deals with Sensorial Systems and software used in the construction to improve the performances of machines such as cranes, and in improving Human-Machine Interfaces (MMI). Authors adopted Mixed and Augmented Reality in the MMI to ease the construction operations. Section III is dedicated to describe case studies of RAC and comprises 8 chapters. Among the eight chapters the section presents a robotic excavator and a semi-automated façade cleaning system. The section also presents work dedicated to enhancing the force of the workers in construction through the use of Robotic-powered exoskeletons and body joint-adapted assistive units, which allow the handling of greater loads.

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