TECHNOLOGY SELECTION FRAMEWORK FOR PORT DEVELOPMENT PROJECTS

CRAIG BUTCHER
University of Stellenbosch, Department of Industrial Engineering, South Africa
butcherc@xsinet.co.za

CSL SCHUTTE
University of Stellenbosch, Department of Industrial Engineering, South Africa
corne@sun.ac.za

ABSTRACT

This paper introduces a framework for the selection of technology for port development projects in developing countries. The selection of technology in the early project stages has a direct impact on the sustainability of the project in the short and long term. The intended outcome of the research is a framework that will facilitate the selection and adoption of technology for future Port Development Projects to realise sustainable returns on investments made, improved efficiencies, and improved project success in the long term.

The research process included an initial literature study to determine the applicability of frameworks and technology selection methodologies. The potential shortcomings in current frameworks were tested through the use of an initial screening survey, which was also used to determine the elements impacting the selection of technology. A later in-depth literature study was used to gain a comprehensive view of the design and application of Technology Selection Frameworks in academia. A technology framework design review survey was undertaken at the completion of the framework design to verify the applicability of the proposed framework design for the container terminal industry.

The focus of existing Technology Selection Frameworks in literature is on the manufacturing industries in developed countries and energy and infrastructure projects in developing countries, with little attention on the selection technology for ports in developing countries. Many frameworks focus on the technical process of selecting the technology without taking the overall process view from project inception to handover into account.

To encourage a systematic approach for the selection of technology in a staged manner, a process is introduced that begins with the concept phase of a project, moving through the Pre-Feasibility phase and the Feasibility phase where the final selection of technology for the project is concluded. The approach introduces the concept of system boundaries, defined outcomes at each project phase in the selection and the iterative process within each phase that allows controlled changes to assumptions made at any stage in the process.

Key words: Ports, Project Life Cycles, Requirements Engineering, Technology Selection, PROMETHEE

BACKGROUND

In the handbook for planners in developing countries by the United Nations Conference on Trade and Development (1985), it is suggested that extensive globalisation has increased the need for development of seaport infrastructure and superstructure in countries on shipping routes which serve the needs and the requirements of a country's international trade and as such investments should be planned and executed to ensure efficient flow of goods in and out of the countries served by the seaport systems'.

The development of port infrastructure and superstructure improvement projects in the port environment is a driver for the economic development in the region where the port is situated, increasing employment, labour income, and the potential for an increase in business earnings and tax revenue through increased trade according to Talley (2009, p. 7).

Despite investments in seaport superstructure in South Africa and other Southern African countries, the perceptions of business executives, interacting directly with the port system have not rated the success of these projects favourably, holding the port efficiency rating at a constant to 4.7 for the period from 2010 to 2013, raising the efficiency rating to 4.9 in 2014, out of a potential 7 points for the four year assessment period.

Table 1 offers a snapshot of the data collected by the (World Bank 2014), through personal interviews or online surveys, where the sampling followed a dual stratification process based on company size and sector of trade and activity. The data for the latest year has been combined with data from the previous year to create a two year moving average. The scores range from 1, where the port infrastructure and superstructure is extremely under-developed to 7, where the infrastructure is considered to be efficient when measured against world standards.

Table 1: Business Executives perception of the efficiency of the Country's Port Facilities (Adapted from the World Bank World Development Indicators)

Year of Assessment Country	2010	2011	2012	2013	2014
Angola	2.1	2.3	No Data	2.9	2.7
Namibia	5.5	5.6	5.4	5.3	5.2
South Africa	4.7	4.7	4.7	4.7	4.9
Mozambique	3.5	3.4	3.4	3.5	3.7

Scale: 1= Extremely Under-developed, 7 = Efficient by International Standards

CONTAINER TERMINAL OPERATIONS

The container terminal as a system can be broken down into two interconnecting systems, the quay side operation and the hinterland operation. These two systems can be further broken down into four distinct operations as indicated in Figure 1. The quayside operation includes the loading and discharge of vessels at the quayside and is the determining factor in the overall terminal handling rate and often viewed as the dominant operation in the overall container terminal system.

The transfer of containers between the quay and the storage yard regulates the ship loading and discharge operation because the horizontal transport between the ship and the container stack in the storage yard has a direct influence over the vessel loading and discharge rates.

Import and Export containers are stored in the container storage yard, which acts a buffer between the quay side and the hinterland operations, while documentary, administrative and other formalities are undertaken by the container terminal operator, tax and custom officials.

The hinterland operation includes the reception and delivery of containers, including the transfer of containers from the container stacks to road or rail. Operations at the terminal reception gate include administrative tasks, customs checks, container scanning procedures, and instructions for the drivers for container collection and delivery at locations within the container stack.

The throughput of the container terminal system is dependent on the selection of equipment, processes, tools, systems and methods, i.e. the technology. The overall system is directly impacted by the performance of each operation because the incorrect selection of technology in one of the inter-dependent operation will impact the overall performance.

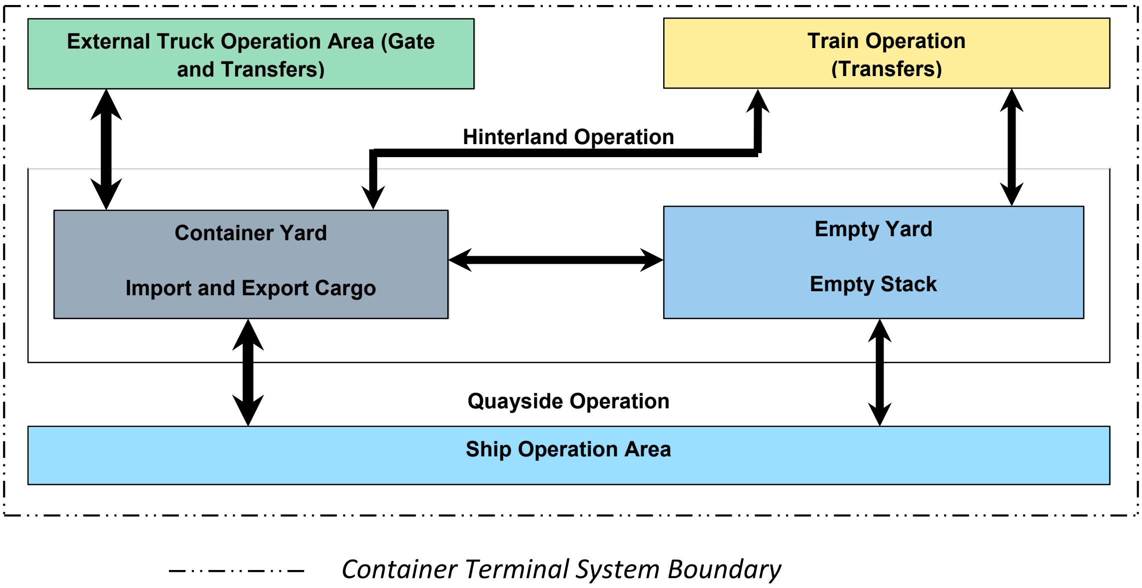

Figure 1: System Boundaries (Adapted from Steenken et al, 2004, p. 6).

PROJECTS AND TECHNOLOGY SELECTION

In a modern business environment many organisations undertake projects to meet the goals and strategies of the organisation, which in the case of port infrastructure and superstructure is the delivery of services that are efficient, cost effective and meet the requirements of the cargo owners, shipping lines and other port users.

Changes in the size of vessels and the increase in access to markets through developments in sea and land transport has meant that container terminals are required to improve the service offered to shipping lines to ensure competitiveness and the ability to retain current business or to attract new business for the terminals. These opportunities and challenges are addressed through the delivery of projects.

The project life cycle passes through a number of stages starting at the Concept phase, moving through Pre-Feasibility and Feasibility phases and finally to Execution and Handover. Decisions on the selection of technology in the Concept, Pre-Feasibility and Feasibility phases have a direct impact on the overall success of the project and the organisation that has financed the development. This is echoed by Frankel (1987), who suggests that the major focus of the Feasibility Study phase of the project has to do with the verification of the available alternatives and the choice of technology, equipment, location, capacity and financing methods.

In the technology selection process, developing countries should be well aware of the technological life cycle of the assets being proposed for a project. Martino (1993, p.299) states that ”Estimates of the proposed technology’s performance, the rapidity with which the technology will be adopted, and the ultimate scope of deployment should be understood”.

The development of a Technology generally follows an S curve from the point of new invention to a state of mature technology, passing through a number of distinct phases which include embryonic, growth, maturity and aging. The growth of the technology may be limited by some physical limit imposed by the performance parameters, such as the limits of material availability or energy requirements while the adoption of the technology is influenced by the ability of the users to maximise the output. As an example, a Ship to Shore crane used for unloading containers from the vessel may be limited by the availability of materials for construction and as such the overall functionality of the crane will be limited by the physical size. To overcome the physical limitation a number of subsystems within the crane system, such as optimum path control or continuous load sway and skew control that may be introduced to extend the technological life of the crane. Figure 2 shows multiple generations of technologies for the crane example.

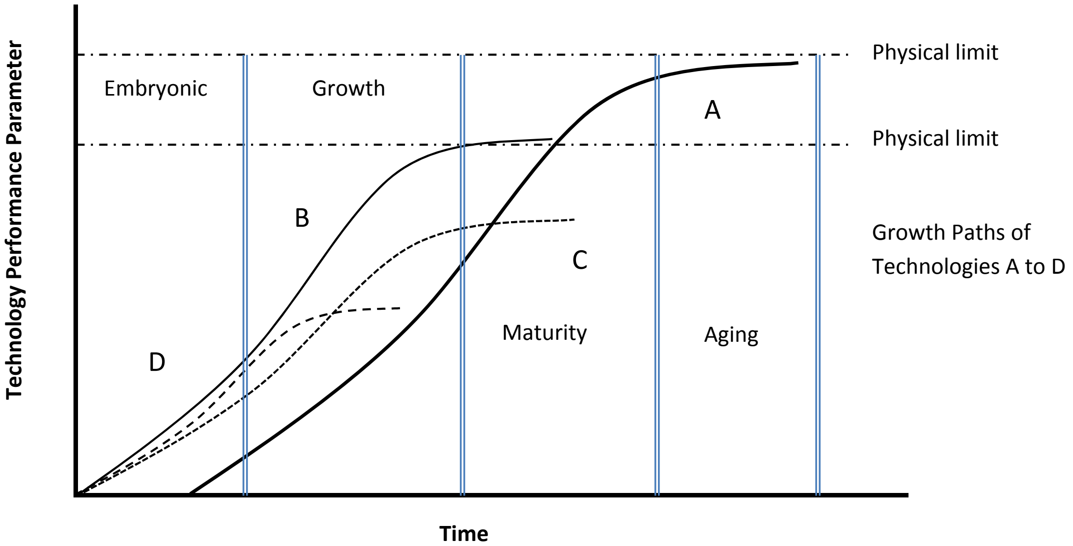

Figure 2: Multiple Generation Technologies (Adapted from Khalil, 2000, p. 81, 85)

In the development of a Greenfields container terminal, the project team may select technologies in the growth or maturity phase of the technology life cycle depending on the risk appetite of the executive management of the company. In developing countries such as South Africa, the project team may review the market for available technologies and the diffusion of the specific technology in other ports. If the executive management is risk averse the safer mature technology is usually chosen because investments in technologies that is in the embryonic phase or has little market penetration could pose a risk because the impact of the new technology could reduce the overall performance of the terminal if the technology is not completely proven or adopted by users. The backup and systems to support technologies in the embryonic phase is important, especially in developing countries because systems required to maintain the technologies employed may not have developed at the same pace as the technology.

The current state of the technology selected, within the overall life cycle, is not the only factor that could impact the overall functionality of the container terminal. In cases where a mature technology is chosen for certain operations, the selection process could be influenced by natural constraints of the container terminal, such as wind, physical constraints such as the layout of the infrastructure and the core target market of the terminal, which may include transhipment cargoes, handling of dangerous cargo or empty containers. In cases where mature technologies are chosen, factors such as obsolesce, future logistic support and skills availability should be carefully considered.

RESEARCH METHODOLOGY

The study methodology for the development of the proposed framework was based on qualitative research methods which included surveys, and literature studies. The first survey, an initial screening questionnaire, used to test the findings of the initial literature study, was completed while undertaking in-depth literature reviews of current Technology Selection Frameworks applied to various industries in developed and developing countries.

The results and insight gained from this first questionnaire were used to determine the elements important in selecting technology for the port industry and the shortcomings found in the initial literature study.

The in-depth literature study was used to determine the design and application of technology selection frameworks. A second survey was conducted at the completion of the framework for the selection of technology design to determine if the design of the framework meets the requirements of industry experts. The final stage of the research process, the validation of the framework through case studies, will be undertaken to determine the criteria used in the selection of technology and measure the impact of the framework on the selection of technology against existing technology selection processes. Figure 3, Research Methodology for Framework Development, illustrates the research methodology used in the development of the proposed framework.

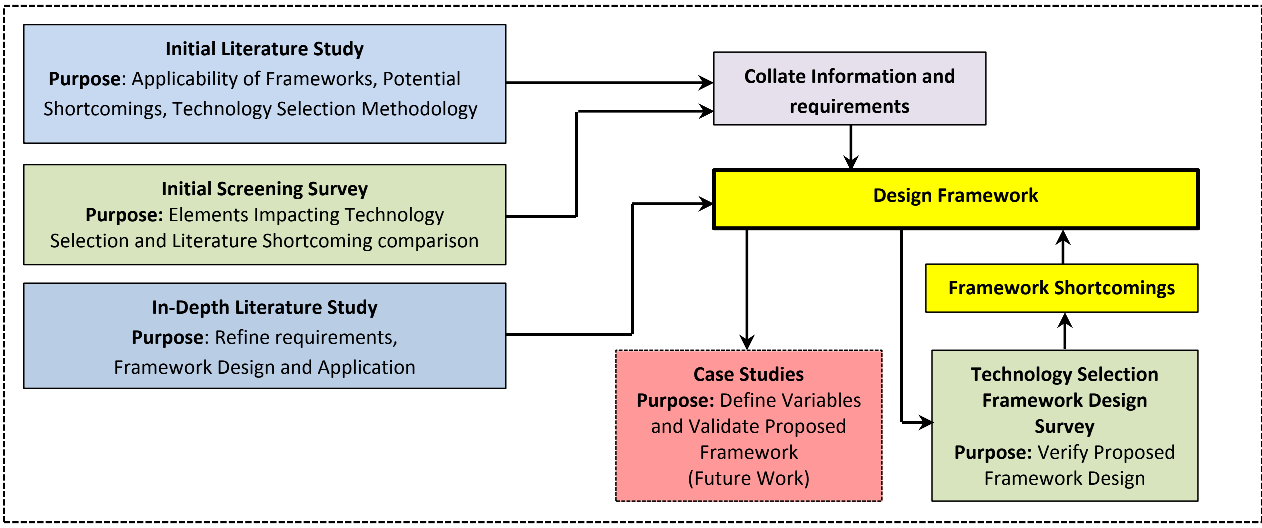

Figure 3: Research Methodology for Framework Development

Initial Literature Study

The initial literature study focusing on the applicability of Technology Selection Frameworks in wider applications, found that Technology Selection Frameworks span a wide range of industries from Information Technology to Health Care and Manufacturing in developed countries. It was also found that the frameworks and models focus on energy and infrastructure projects in less developed countries but there are no frameworks that focus on the Container Terminal Industry.

Initial Screening Survey

The first questionnaire was posted on the LinkedIn website with specific focus on the Port and Container Terminal groups to attract the widest possible range of responses from port and container terminal professionals. The questions included in the survey were based on shortcomings found in the initial literature study, where it was found that only one author had focused on technology selection methods for the port industry.

The fourteen questions were broken down into three main groups. Question two through six focused on how the respondents viewed the impact of various Actors on the selection of technology, the influence of management levels on the technology selection process and the benchmarking of technologies selected for a project.

Questions seven through nine were used to determine the factors that could influence the selection of technology and sought to understand if there is a need for a single framework for the selection of technology. The third set of questions, questions ten to fifteen were used to determine what risk methodologies and multi criteria analysis tools are appropriate for technology selection in the port industry.

The results and insight gained from the answers received from 61 respondents were to be used as inputs and checklist in the development, selection of processes and factors to be considered in the overall design of the framework for the selection of technology, to ensure all aspects are sufficiently covered.

In Depth Literature Study

The in-depth literature study focused on the design, methods and processes used in technology selection framework design. The literature study revealed that the scope of many of the Technology Selection Frameworks reviewed were narrow and focused on the process of selecting a technology without taking wider more strategic issues into account such as the applicability of technology selection in the project life cycle or the potential impact of factors to be included in the overall selection process.

Technology selection models and frameworks include mixed and mathematical models such as those proposed by Punniyamoorthy and Ragavan (2003), which combine the use of the Extended Brown-Gibson Model for the determination of the objective factors and the use of the Analytical Hierarchy process to determine and measure the subjective factors applied to technology selection. The model is used to set the overall direction of the organisation, which may not be followed for specific projects due to the nature of the solution proposed by the project team.

Table 2, Technology Selection Models, lists a number of current Technology selection models available in literature and includes the type of approach currently used, the criteria under which the technology was evaluated and the potential gaps that the author deems to be important in the overall selection of technology.

Table 2: Technology Selection Models

Name	Year	Purpose	Approach	Industry	Developing or Developed Country	Evaluation Criteria	Potential Shortcomings
Shehabudden, N., Probert, D., Phaal, R.	2006	Operationalization	Two Stage Weighting method	Manufacturing, Food Processing, Packaging	Developed	Technical, Financial, Interpretability. Usability. Supplier Suitability. Strategic. Risk	Technology growth path
Bard, J.F., Feinberg, A.	1989	Research and Development	Two Stage Mathematical Model	Research and Development	Developed	Life Cycle Cost. Maintainability. Safety	Operator skills
Ondrus, J., Bui, T., Pigneur, Y.			ELECTRE 1	Mobile Telephony	Developed	Cost, Technology Spread. Ease of Use	Local Development Opportunities
Cochran, M.	2009	Optimisation	Qualitative	Information Systems	Developed	Technical. Cost and Benefits. Organisational Fit. External Vendors	Local Development Opportunities. Interface requirements
Ruder, K.A., Pretorius, M.W., Maharaj,B.T.	2008	Technology Assessment	Multiple Attribute Utility Theory	Telecommunications	Developing	Core Competencies. Business Goals. Industry Trends.	Local Development Opportunities. Interface requirements Technology Transfer. Risk.
Sener, Z and Karsak E.E	2007	Optimisation	Decision Model based on fuzzy linear regression with non –symmetric triangular coefficients and fuzzy optimisation	Manufacturing	Developing	Yield, Routing Flexibility, Operations per Machine, Reduced Downtime, Capital and Operating Costs	Future throughput, Staff requirements, Technology growth path, TCO, Skills Transfer, Local Development. Risk. Interface Requirements
Barry, ML, Steyn, H., Brent, A.	2011	Sustainability	Literature Review, Focus Groups, Delphi. Qualitative	Energy	Developing	Technology Transfer. Adoption. Economic development. Technology capacity. Environ Benefits. Finance availability	Future requirements Technology growth path, TCO. Risks. Interface Requirements

Table 2: Technology Selection Models (Continued)

Name	Year	Purpose	Approach	Industry	Developing or Developed Country	Evaluation Criteria	Potential Shortcomings
Ballis, A., Stathopoulos, A.	2003	Operation and Performance	Multi Criteria – PROMETHEE	Port (Tranship.)	Developed	Productivity. Compatibility with Ports. Degree of Automation	Future throughput, Staff requirements, Technology Changes, TCO. Local development opportunities. Risks
Punniyamoorthy, M., Ragavan, P. V.	2003	Strategic	Extended Brown-Gibson Model and AHP	Manufacturing	Developing	Capital and Production Costs. Profits. Flexibility, Learning, Capacity Increment. Labour Unrest. Learning	Technology growth path, Total Cost of Ownership. Local development opportunities. Risks. Interface Requirements
Chan, F.T.S., Chan, M.H., Tang, N.K.H	2000		Fuzzy Logic and AHP	Not Defined	Developing	Flexibility. Quality. Financial measures	Technology growth path, Total Cost of Ownership. Local development opportunities. Risks. Interface Requirements

Chan et.al (2000) proposes the use of a fuzzy logic algorithm for the determination of technologies in a manufacturing environment. Available technologies are identified by various managerial levels in the organisation after which a linguistic scale is determined to assess the weight of criteria in triangle fuzzy numbers or indirectly using pairwise comparisons. The criteria are classified as either subjective or objective and the subjective criteria are evaluated using linguistic comparisons while the objective criterion is evaluated in monetary terms.

Multi criteria models for the selection of technology have been suggested by Ruder et.al (2008) who developed a Technology Selection Framework for developing countries, based on a staged approach. The process begins with the identification of stakeholders, followed by the identification of the organisations core competencies. The core competencies of the organisation, including the availability of suitably skilled staff have a direct impact on the overall selection of technology. The next stages in the technology selection process include the establishment of the strategy to move from the company's current position to the desired position through the identification of potential alternative technologies. The selection criteria and the determination of weights for the criteria are determined by experts, which are not defined, prior to the final assessment and ranking of the selected technologies.

Cochran (2009) proposes a pure qualitative technology acceptance model based on Earl's Strategic Grid, where a technology is selected based on the strategic and technological impact on the organisation. The model also assumes that the organisation purchase the technology, a situation that is prominent in the container industry in developing countries. Based on the theory of reasoned action, Cochran includes the Costs, Benefits and preconceived notions as inputs to the overall evaluation of the technology to be selected. Internal influences such as the technical evaluation of the product and the organisational fit are included, while external influences such as market evaluation and vendor efforts form part of the technology evaluation process.

In the development of Technology Selection Frameworks there is a strong drive to include a wide spectrum of criteria with the inclusion of a range of decision makers across the organisation. The above types of Technology Selection Frameworks were used as a basis for the development of the proposed Framework described later in this paper.

Unlike other frameworks, the proposed framework follows the project life cycle development but includes aspects of the frameworks above, such as the inclusion of internal and external influences, organisational fit based on core competencies and the use of weights for objective and subjective requirements.

THE PROPOSED TECHNOLOGY SELECTION FRAMEWORK

Framework Development

The primary objective of the Technology Selection Framework development process was to develop architecture and processes for the selection of technology based on surveys, literature studies and the author’s past experiences in the port industry. The overall design of the Framework was governed by the characteristics of good models as suggested by West et.al (2011 p. 102).

The first step in the development of the Technology Selection Framework was the definition of the overall process. The decision was made to follow a project life cycle approach because the selection of technology is integral to the life cycle of the project. The logic of the project life cycle approach meant that the technology selection process would develop from the concept phase of the project to the identification of selected technologies, an integral part of the Feasibility study.

The next step in the development process to consolidate the potential shortcomings found in current literature and the insights gained from the initial survey, to determine a number of processes to be included in the framework. The literature survey was also used to determine the location of certain processes within the framework and the potential tools that could be used to determine the outputs of a process based on the inputs. The location of the processes was based on the potential impact that particular process would have on the overall process in the next phase of the project life cycle.

The first framework iteration consisted of an overall linear process, but based on the dynamic shipping environment, the overall logic was changed and the change request process was added in a third iteration to allow for changes to requirements at all stages of the technology selection process. The addition of the change request process meant that certain inputs could be held constant while others were changed to meet changes in environment without having to go back to the beginning of the technology selection process.

THE PROPOSED TECHNOLOGY SELECTION FRAMEWORK

Framework General Overview

The framework for the selection of technology is based on the selection of appropriate technology, where appropriate technology is a good match between the technology deployed and the resources required for optimal use as defined by Khalil (2000, p. 5), and draws on principles found in systems engineering, project management and asset management.

The framework passes through a number of phases, as indicated in Figure 4, Framework Overview, from concept or initiation where the overall business need is identified and senior management develop or apply the policies to support the derived business need identified, to the Feasibility phase. The final selection of the technology, in the Feasibility phase is made based on factors such as life cycle costing, skills gaps and technology forecasting.

The identification and selection of vendors to supply or develop the technologies selected is excluded from the framework and is deemed to be a procurement function where the subject matter experts compile the detail specifications based on the selected technologies.

The detailed Technology Selection Framework is shown in Figure 5, 6 and 7.

Figure 4: Framework Overview

Concept Phase

The concept phase of the Technology Selection Framework consists of a number of inputs, processes and tools to determine specific outputs, including traffic forecasts, ownership models and Actor identification. A list of tools has been included so that the person facilitating the technology selection process is able to choose the tools most suitable to the project being analysed.

Traffic or volume forecasts have a direct impact on the technology selection process because certain technologies may be suitable for a specific volume range, while other technologies may be best suited for higher or lower cargo volumes, based on the life cycle costs, complexity and productivity range of the technology, as indicated in Figure 5, Concept Phase.

The inputs to the cargo forecast process include the determination of the split between the various cargo transport methods such as road or rail, and cargo types such as transhipment, import and export cargo because all these transport methods and cargo types will impact the technologies selected for operations such as the waterside operations, yard operations, gate and rail operations and the section of the terminal operating system requirements.

The large majority of Container Terminals in Southern Africa are owned and operated by State Owned Enterprises, or joint ventures between private Container Terminal Operators and Government Enterprises. The port ownership model will have a direct impact on the manner in which the technology is selected. If the Container Terminal is operated by a private company, that company may select technologies based on the concession period agreed, or technologies successfully deployed in other terminals under its control in other parts of the world. Container Terminals operated by public enterprises usually deploy technologies based on minimising direct investment costs.

The final output of the concept phase in the Technology Selection Framework is the identification of the Actors associated with the Container Terminal development. The selection of Technology will impact a range of Actors and Stakeholders including those who are directly impacted by the Technology selection, such as Container Terminal users, operations management and staff and government institutions such as the customs and revenue services. Actors within the organisation include four main groups, including Senior Management, Middle or Operations Management and Operational Staff. Experience has shown that union membership is strongest at the operational staff level and therefore this group of Actors is included in the larger operational staff grouping.

In the case of a single decision maker the decision about the best alternative is easily determined based on the preference of the decision maker, but the decision process becomes more complex when there are a number of conflicting preferences among the Actors (Raju & Kumar 2010, p. 149). The Author's previous experience has shown that if a decision is to made by an individual without the input of the relevant Actors, that the chosen solution will not reach the full potential due to resistance to change from certain Actors. The concept of "buy-in" from all Actors is especially significant in Container Terminals where monetary investment is substantial and the overall long term success of the project is dependent on the overall system efficiency.

The strength of the Actors has a direct impact on the decision making process because an Actor with the most power may be able to drive a decision in a direction most suited to their desired outcomes but overall group consensus can be obtained through the use of correlation coefficient ranking where the conflicting nature of the Actors and their strengths can be determined.

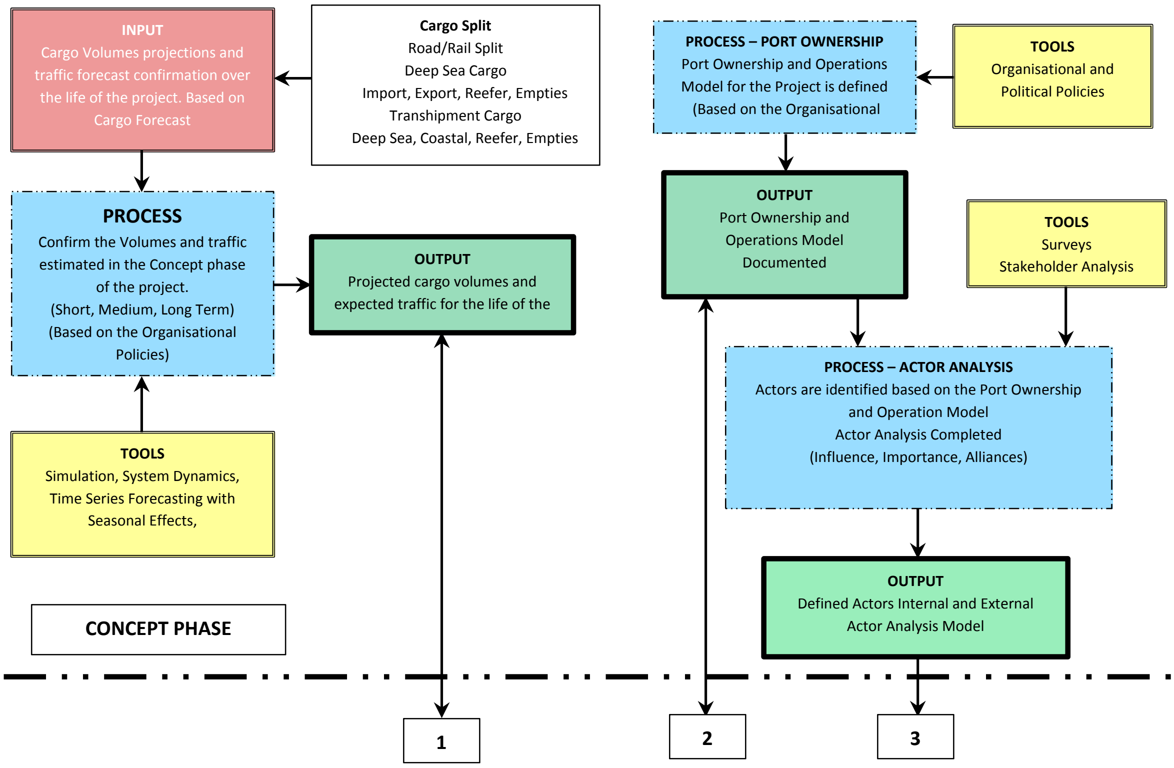

Figure 5: Concept Phase

Pre-Feasibility Phase

The Pre-Feasibility phase of the Technology Selection Framework, as shown in Figure 6, Pre-Feasibility and Feasibility Phase, consists of a number of inputs from the concept phase which are used as inputs for the development of stakeholder requirements and the derived system requirements.

Requirements are the basis of all projects and define what the actors require from the system under development Hull et.al (2010, p.2). Requirements include both functional and non-functional requirements. Results from the initial screening questionnaire show that there is a significant importance placed on non-functional requirements such as skills transfer, economic development in the form of local employment and potential manufacturing opportunities. Other non-functional requirements include the ease of maintenance, technical skills requirements and financial requirements including the total cost of ownership. Functional requirements include the operational requirements of a specific subsystem or operation, such as waterside throughput, capacities of yard equipment or process times at the terminal gate system.

Once a full and comprehensive list of all functional and non-functional requirements are derived by the various groups of actors, by eliciting the goals of each group, the weight and acceptable measures are set for each criterion by utilising the standard preference functions found in the PROMETHEE method as developed by Brans JP et al. As an example, using the U shape Criterion, the decision makers are able to set the lower limit for the value of local manufacture.

The Process of deriving the system requirements is fundamental to this phase of the overall framework because this process allows the operational requirements of the terminal to be derived based on the inputs from the concept phase, with the inclusion of other external inputs such as the integration requirements. The integration requirements are defined as the integration of internal and external operational processes, data exchange requirements or the physical interface between two distinct areas of the container terminal such as the quay side operation and the yard. When selecting technologies for a system such as a container terminal the interfaces between the overall system and the subsystems has a direct impact on operations and efficiency. Once again the PROMETHEE method is used because not all system requirements have the same importance (weighting) because the functional requirements within the system are not equally important, with some processes taking preference over others. The upper and lower bound of a derived system requirement, such as yard dwell time or gate service time can be set using the PROMETHEE preference functions. These upper and lower bounds are used as a measure to match the suitability of a chosen technology against the set parameters in the Feasibility phase of the selection process.

The details of the tools, processes and outputs of the Pre-Feasibility phase are shown in Figure 6: Pre- Feasibility Phase.

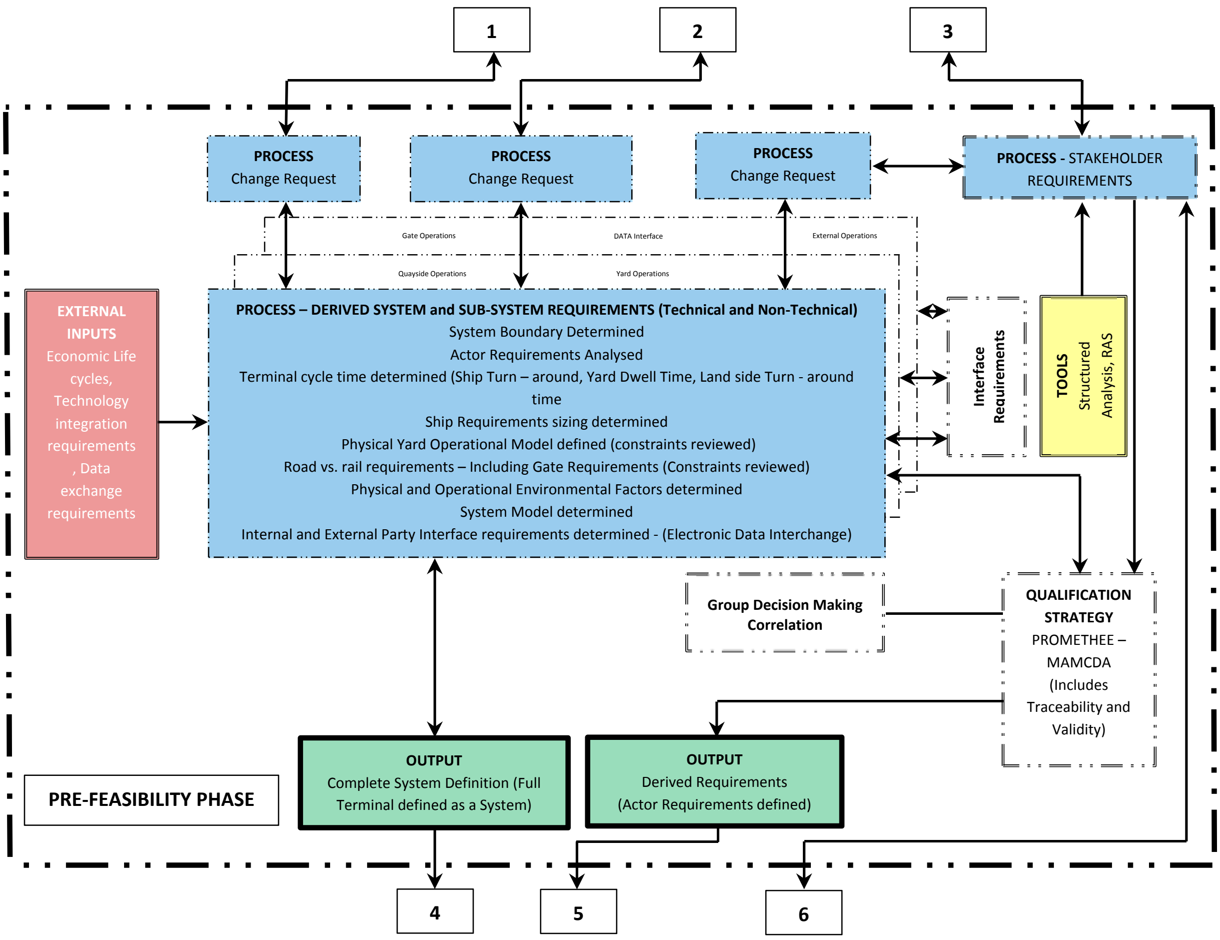

Figure 6: Pre- Feasibility Phase

Feasibility Phase

The inputs for the Feasibility phase of the Technology Selection Framework are derived from the system definition completed in the Pre-Feasibility study and the derived requirements of the Actors identified in the earlier stages if the technology selection process.

The technology selection process includes the identification of potential technologies available in the market, the matching of these technologies and the final selection based on the qualification strategies identified as indicated in Figure 7, Feasibility Stage.

Potential tools identified for the selection process include the forecasting of technologies using S curves. The position of the technology in its life cycle is important in the selection process because the risk of selecting technology that is near obsolete could have a direct financial impact on the organisation, while selecting new or emerging technologies are risky because, if unproven could reduce the overall efficiency of the operation, with associated financial burdens.

Technology matching, the process of matching the selected technologies with the requirements derived in the Pre-Feasibility phase is one of the critical stages in the overall technology selection process. A compatibility matrix has been suggested by Kirby (2001, p. 78), but the use of defined numerical limits of one and zero eliminates the ability of the decision makers to select a technology that may not be perfectly compatible with the stated requirements but may have a large majority of the attributes required. The use of correlation matrices found in Quality Function systems allow the decision maker to determine the correlation between the available technologies and the requirements derived in earlier processes. The risks associated with the selection of technologies that may have less than a strong positive correlation are identified and categorised using quantitative or qualitative risk analysis methods.

Qualification strategies associated with the technology selection include core competencies, understanding what sets the organisation apart, and skills requirements because the skills required for operating and maintaining certain technologies may not be readily available in the organisation. Without the required skills, the technologies selected will not be able to reach the full efficiencies, once again placing unnecessary financial burdens on the organisation and the overall logistics chain.

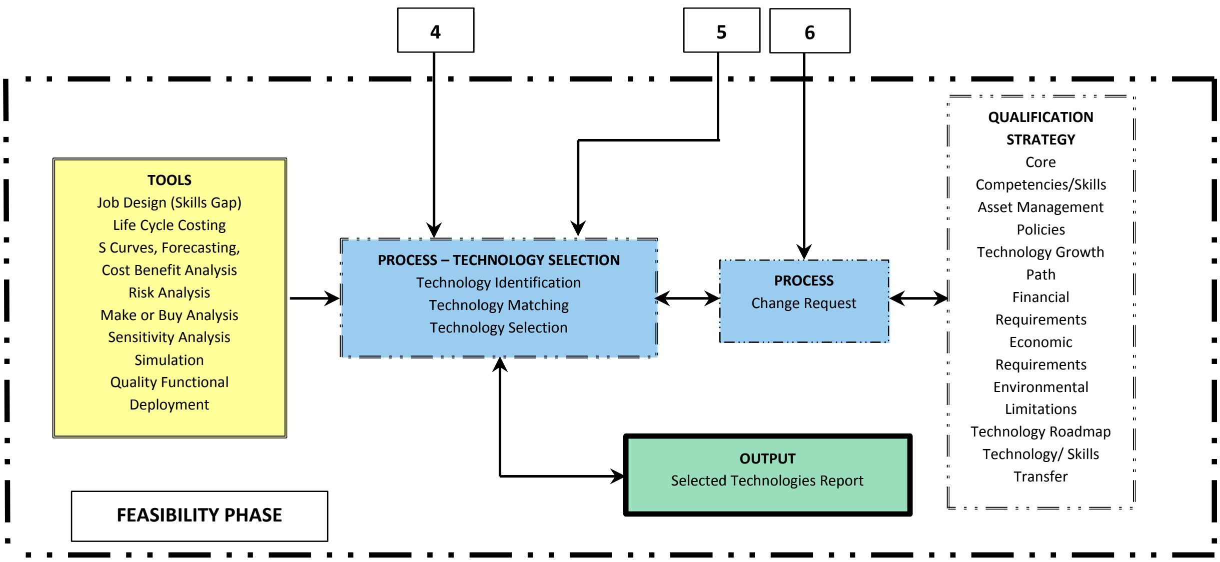

Figure 7: Feasibility Phase

Technology Selection Framework Design Review Survey

A second questionnaire was compiled to verify the design and applicability of proposed Technology Selection Framework. The questionnaire was based on the characteristics of good models as suggested by West et.al (2011, p. 102), listed in Table 3, but adapted to include elements of the proposed Technology Selection Framework.

The questionnaire was sent to a target audience of 13 individuals who have vast experience in business process modelling and container terminal design and operation, both locally and overseas. The respondents were asked to evaluate the Technology Selection Framework based on a range of closed questions using the Likert Scale, with potential answers ranging from strongly disagree to strongly agree.

Question one through five focused on the overall process depicted in the proposed model with specific focus on the overall logic of the framework, and the applicability of the processes given the inputs and required outputs from a specific process.

Questions six through ten were used to determine the robustness, the scalability, the fidelity and the applicability of the PROMETHEE method to the selection of technology for container terminals.

Table 3: Good Models (Adapted from West et.al, 2011, p. 102)

Measure	Explanation
Parsimony	Given a number of system models the simplest is the best because it is easier to understand and may require fewer and more reasonable assumptions
Simplicity	The complexity of the system portrayed does not require a direct increase in the complexity
Accuracy	The set of parameters or variables chosen should conform exactly to reality
Robustness	The framework should be representative over a wide range of inputs
Scale	The Framework should use the appropriate level of detail. The boundaries of the system should be clearly defined to ensure that other inputs that do not directly impact the system are excluded
Fidelity	The framework should represent the proposed method
Balance	An overall measure of the blend of complexity, accuracy scale and robustness

FINDINGS FROM TECHNOLOGY SELECTION FRAMEWORK DESIGN REVIEW SURVEY

The response to the Technology Selection Framework Design Survey varied across the respondents. The questionnaire, based on the characteristics of good models as suggested by West et.al (2011, p. 102) was adapted to include elements of the proposed framework which are specifically related to container terminal operations.

The targeted questionnaire was dispatched to 13 individuals and the 5 usable responses were used to evaluate and update the proposed Technology Selection Framework.

The majority of respondents to the first five questions which focused on the overall process and logic of the framework were neutral, with one respondent in agreement with the depicted logic, and a second respondent strongly agreeing with the overall process and logic presented. The majority of Respondents were in agreement with the with the set input variables used in the framework, indicating the applicability of the variables to the port environment.

Questions six through ten were used to determine the applicability of the PROMETHEE process to the selection of technology, the robustness and the fidelity of the proposed framework. Respondents were requested to review the qualification strategies applied to the stakeholder requirements. The response was equally split between neutral and agreement, which could be based on popularity of alternative methods such as Analytical Hierarchy Process. The response to the representation of the staged approach to technology selection, the fidelity of the framework , was a strong agreement.

The shortcomings identified by the limited respondents have been considered and included in the proposed framework, but due to the limited responses the overall results from the survey were not deemed conclusive and a second round of surveys will be conducted using a wider audience base.

CONCLUSIONS

Decisions around the selection of technology will have a high impact on the organisation in the short and long term. In the short term the expected production, output volumes may not be reached and costs will be incurred by the end users as operational expenses increase in an attempt to recover the investment incurred for the technology selected and implemented. The costs of training, maintenance and repair are factors that should be taken into account in the selection of technology. Staff selection process and job development methods for technology users should be adapted to ensure rapid integration of the selected technologies into the organisation’s operations.

Organisations have a new appreciation to recognise the importance of the asset life cycle, of which technology forms an integral part. The proposed Technology Selection Framework takes a staged approach to the selection of technology that follows the project development. This approach is suggested because it follows the natural development of a project and the decision makers are able to achieve specific outcomes at each phase of the project life cycle, allowing decisions such as “go” or “no go” to be made. The ability to go back to alter the assumptions made, allows the decision makers to realign the decisions made in a previous phase with potential new information that may come to light without having to restart the entire selection process.

The proposed Technology Selection Framework takes an overall systems view of the container terminal operation including interfaces between the various subsystems and operation within the terminal environment and the interfaces between the internal and external operations that form part of the logistics chain. Without an integrated view of the logistics chain, backward and forward integration may not be possible and the full extent of the potential increases in overall efficiency may not be realised.

Future work includes embedded case studies to determine the factors to be included when selecting technology and as a method of validation of the overall Technology Selection Framework through the application of the Framework to container terminal future projects. The expected case studies will range from subsystems within a container terminal to a fully-fledged terminal to identify the robustness of the framework in practice.

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