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HARMONISATION OF PORT TRANSFORMATION USING SUPPLY CHAIN ARCHITERATURE: SCOR CONVERGANCE WITH LEAN AND SIX SIGMA

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ABSTRACT: Global demand for containerized traffic has recently increased. Hence, ports are required to increase their capacity. Many ports have responded with a traditional focus on establishing new infrastructure or geographical expansion. But, ports aim to improve their performance and increase their productivity to capture the business opportunity to cope with an increase in demand and to have competitive advantage. Port authorities, investors and operators work scarcely to optimise the overall performance of their terminals, to get a clear strategy and to focus on delivering higher total returns to stakeholders. Port authorities move toward investing in the capability improvement in order to achieve high performance. Leung (2008) claimed that there are three areas of business capability that can achieve a high port performance namely, terminal performance management, terminal operations management and terminal enterprise management. This paper focuses on improving terminal performance management as it helps port not only to understand earning-based figures, but also to manage factors that drive business growth. This requires optimising port value drivers, supported by back-end business algorithms such as Balanced Scorecard, Six Sigma and SCOR.

The purpose of this paper is to manage port transformation in order to improve performance of terminals using supply chain architecture. Three models were combined in the proposed architecture including SCOR, Lean and Six Sigma. Exploratory approach is conducted in this paper as it helps build strength around the linkage between process elements, metrics, best practices and features associated with supply chain execution.

KEYWORDS: **TERMINAL PERFORMANCE MANAGEMENT, PORT PERFORMANCE MEASUREMENT, SUPPLY CHAIN ARCHITECTURE.**

INTRODUCTION

Nowadays, shipping lines and logistics service providers are willing to partner with ports that can consistently meet their own growth. Therefore, port authorities are concerned to invest in expanding their capabilities. Three areas of capability can be improved including terminal performance management, terminal operations management and terminal enterprise management. Terminal performance management helps port to manage factors that drive business growth. While, terminal operations management requires ports to align their operations with shipping lines' requirement and moving from port-to-port carrier services to door-to-door logistics service. There is a need to focus on mass customisation, supply chain integration and capacity flexibility. Ports should rely on measures such as integrated planning strategy, maximising equipment utilisation, and reduction in non-adding value movement. For terminal enterprise management, it involves process integration of multiple business units and locations such as hinterlands.

This paper has sought to answer the following question: ***How can supply chain architecture be designed for improving generally port performance? and terminal performance particularly?*** In order to answer this question, this paper starts to discuss different supply chain models, to investigate the potential architecture of these different models, and examine the impact of these designs on port performance.

METHODOLOGY

Exploratory approach was conducted in this paper to help understanding the question and providing significant insights into a given situation. It relies on secondary research such as reviewing available literature, qualitative approach. This approach helps build strength around the linkage between process elements, metrics, best practices and features associated of three different models (SCOR, Lean and Siz Sigma) with supply chain execution. The challenging goal to achieve competitiveness in modern markets begins from business process integration. This paper explains how some methodologies can be woven together in order to support this approach. In particular, the focus is to consider the combined use of SCOR, Lean and Six Sigma principles to enhance the management of the entire supply chain in ports.

PERFORMANCE MEASUREMENT

Over the last twenty years, researchers have shown an increasing interest in improving performance measurement systems (Eccles 1991; Kaplan and Norton, 1992; Beamon, 1999; Neely et al., 1995; Neely, 2005; Elazony et al., 2011). Marlow and Casaca (2003, p. 192) generally defined performance as: "An investigation of effectiveness and efficiency in the accomplishment of a given activity and where the assessment is carried out in relation to how well the objectives have been met". In a supply chain context, suppliers, manufacturers, distributors and customers are interlinked by a network that provides a reliable flow of information and materials. Hence, supply chains can be characterised by their complexity and uncertainty in their operations (Beamon, 1999; Beamon and Chen, 2001). Braz et al. (2011) defined a performance measurement system as a set of measures used to measure the performance of actions taken. Three stages are required to develop a new performance measurement system, including design, implementation and use. Also, they argued that adding new measures to existing measures in any system will increase complexity and consequently, it will lead to outdated systems. However, increasing the number of measures helps to define the scale because a measurement system depends on the extent of items and variables (Brahma, 2009). Also, increasing the number of measures in a system helps to provide more information about all aspects of utilities in the port (UNCTAD, 1976; Tongzon, 1995; Fourgeaud, 2000; Marlow and Casaca 2003; Bichou and Gray 2004; Cullinane et al 2004; Gray, 2005; Taylor 2007). Different approaches to measuring performance have been developed using different techniques and metrics to produce systems and frameworks, such as balanced scorecard (BSC) (Kaplan and Norton, 1992), performance pyramid (Lynch and Cross, 1990), the macro process model (Brown, 1996), the performance prism (Neely et al., 2002) and a macro-micro framework of performance measurement (Rouse and Putterill, 2003).

SUPPLY CHAIN PERFORMANCE MEASUREMENT SYSTEM

In a supply chain context, different performance measurement systems have been recently developed using different techniques and for different purposes. The Balanced Scorecard is the most widely applied system (Braz et al., 2011). Kaplan and Norton (1992) provided a measurement concept to integrate financial and non-financial indicators in a first generation balanced scorecard approach (BSC). However, Paranjape et al. (2006) claimed that the balanced scorecard is limited in that: it focuses only on managerial needs; is not service-oriented; it fails to indicate the competitors' perspective; people, suppliers, environmental and social issues are omitted. Neely et al. (2002) developed a performance prism framework that comprised five integrated perspectives as discussed earlier. Neely and Jarrar (2004) developed the Performance Planning Value chain framework (PPVC). The focus is on what will add real value to the organisation by comparing performance with competitors. Table 1. shows the common performance measurement systems and frameworks applied in the supply chain context.

Table 1. Supply Chain Performance Measurement Systems

Framework/System	*Author*
Performance Measurement Matrix	Keegan et al. (1989)
Time-based competition system	Azzone et al. (1991)
Determinants framework	Fitzgerald et al. (1991)
Balanced scorecard (BSC)	Kaplan and Norton (1992)
Performance Pyramid	Cross and Lynch (1992)
Macro process model	Brown (1996)
Activity-based cost system (ABC)	Kaplan and Cooper (1997)
Performance Prism	Neely et al. (2002)
Performance Planning Value Chain	Neely and Jarrar (2004)
PMS Review	Najmi and Fan (2005)
CCP	Cuthbertson and Piotrowicz (2011)

Most studies have stressed the need for new measurement systems and metrics (Neely et al., 1995; Beamon 1999; Beamon and Chen, 2001). New measurement systems need to investigate a number of important issues such as, the factors influencing the successful implementation of a performance measurement system (Bourne et al., 2002), how performance measurement impacts on business performance (Bourne et al., 2005), the factors which shape the performance measurement systems design (Kennerley and Neely, 2002; 2003), examining the relationship between port performance and commodity variety (Ducruet et al., 2010), and using multi-criteria decision making techniques such as fuzzy to design an effective performance measurement system (Valmohammadi and Servati, 2011).

PORT PERFORMANCE MEASUREMNT

In ports, using a reliable and efficient performance measurement system provides many benefits for both the port itself and port clients. Notteboom et al. (2000) applied a Bayesian approach based on the estimation of a Stochastic Frontier Analysis (SFA) model. The aim was to evaluate the productive efficiency of 36 European container terminals. Tongzon (2001) applied Data Envelopment Analysis (DEA) to provide an efficiency measurement for four Australian ports and twelve international ports. Estache et al. (2001) measured the efficiency gains of eleven Mexican container ports applying the stochastic production frontier approach- for the period of 1996 - 1999. Valentine and Gray (2001) applied the DEA model to 31 container ports. They examined the relationship between certain types of port properties, such as waiting time, ship turn-around time, and organisational structures, with efficiency.

Itoh (2002) analysed the efficiency changes for eight international container ports in Japan, during the period of 1990-1999. The primary purpose was to determine which port had a high efficiency score. He applied DEA to evaluate the efficiency of a current evaluation system that is called Decision Making Unit (DMU). Labour and infrastructure were the main inputs.

Cullinane and Song (2003) applied the SFA model to assess the improvement in productive efficiency for those Korean ports which had been privatised. The study focused on container terminals, using cross-sectional data and panel data. They provided a distinction between productivity and efficiency measurement. However, they focused on measuring the impacts of privatisation, ownership and deregulation on port efficiency, neglecting other key factors, such as the economic environment, political status and investment incentives. Also, the SFA technique cannot estimate technical inefficiency by observation and it is difficult to ascertain precisely the error structure. Furthermore, SFA does not help to examine the relationship between variables that influence a port's performance, nor investigating the impact of these variables on performance. Wang et al. (2003) analysed container terminal efficiency using two techniques, DEA and Free Disposal Hull (FDH) models. They applied these models to a sample size of 30 container ports. They used throughput as output, and quay length, area, quay crane and yard crane as inputs. However, data concerning labour inputs were unavailable. They focused only on container terminals in ports. Also, they suggested that port efficiency is not significantly influenced by its size, and they considered terminal infrastructure and facilities as key measures. Also, the FDH approach focuses on measuring efficiency as a distance of a particular plan to the dominating production plan (DMU).

Park and De (2004, cited by Choi, 2011) focused on the measurement of productivity, profitability and marketability of eleven Korean ports. They used the congestion and factor efficiency with CCR and BCC models for 2001 data. Berth capacity and cargo handling capacity were the inputs, while cargo throughput, number of ships, and revenue and customer satisfaction were the outputs. Turner et al. (2004) applied DEA to measure port infrastructure productivity, and used Tobit regression analysis for examining the determinants of port infrastructure. They considered a port infrastructure as a primary performance measure. They included time effects into regressions to clarify that rail service is a critical determinant between ports and the rail industry. Vanags (2004) developed a managerial system for measuring the effectiveness of the port performance at Riga port, Latvia. He used port cargo turnover as an indicator to measure the port performance in relation to five predictors, including territory of the port, the number of berths, the length of berths, the maximum draft of several ships and the total square metres of the warehouses.

Ng (2005) developed two dynamic programming-based heuristics to solve scheduling problems in container ports. He considered a terminal turn-around time as a key performance measure in terms of how long a vessel stays in a terminal. The focus was on yard crane schedules to minimise the sum of truck waiting time between berths and storage yards. However, he focused on container terminals with no regard to other terminals. Barros (2006) applied DEA models. The purpose was to evaluate the performance of 24 Italian seaports for the period of 2002 to 2003. The outputs measured were liquid bulk, solid bulk, number of containers, number of ships, and total receipt, while the inputs were the number of personnel, the capital invested, and the value of operational costs. Cullinane et al. (2002; 2004; 2006) concluded that the two more appropriate holistic approaches concerning the measurement of port performance are DEA and SFA. These approaches have their individual strengths and weaknesses.

Roh et al. (2007) defined the boundaries of a port cluster system using the ‘Structured Analysis and Design Technique’ (SADT). SADT is used to provide a robust structured method to model hierarchical systems, and to define and analyse the cluster in terms of the port logistics process. This helped to model the systems that explain how port users and port cluster companies engage in the port logistics process, which consequently affect port performance. Also, it defined those variables that affect a port's performance through breaking down the clusters into seven groups, and defining the components and sub-levels under each group.

Simulation has been used as a method in measuring port performance. Many simulation models of port operations, especially container port operations, have been developed (Tahar and Hussain, 2000; Bielli et al., 2006). Simulation models have been used for different purposes such as:

the planning of future berth requirements of a third-world port; proposing a method that uses buffer space to reduce container loading times and optimise equipment utilisation; studying the impact of work crew schedules on container port productivity; and as a supportive tool for evaluating and improving port activities. Tahar and Hussain (2000) used a simulation model, for example, to improve the logistics processes in a port. The importance of their research was that it simulated all the processes required to operate the seaport efficiently and provided detailed statistics on the seaport throughput and utilisation characteristics with a high level of accuracy. The quay cranes allocation, the resource allocations and the scheduling of the different operations were modelled to maximise the performance of the Kelang port in Malaysia. The simulation was carried out using ARENA software.

Goodchild and Daganzo (2007) developed a formula to examine the impacts of crane double cycling on turn-around time. They argued that using double cycling will lead to improved port throughput, berth productivity and vessel productivity. The focus was to determine the number of cycles required to minimise a vessel's time in port. Also, they considered the elapsed time required to move a container from berth into storage areas. In-port transportation and the number of vehicles required were also considered. Bichou (2007) argued that current measurement approaches are incompatible with the port industry. Based on a benchmarking purpose, three broad categories of performance measurement were established, including individual metrics, economic impacts studies and frontier approaches. He claimed that few approaches have linked and integrated operations, design and strategy with port functions. He developed an integrated supply chain framework for port performance benchmarking.

Barros and Managi (2008) examined the technical efficiency of Japanese ports from 2003 to 2005 through two stages. In the first stage, they applied DEA to rank ports according to their efficiency. In the second stage, the Simar and Wilson (2007) procedure is applied to analyse dependency between the efficiency scores and other variables in ports. The number of personnel and number of cranes were the main inputs, while the number of ships, tonnes of bulk and number of TEUs were the main outputs. Liang and Rong (2008) applied a probability distribution of cargo throughputs determined by time spent by a ship in port. They applied the Wald equation, which is based on the relationship between time required by a ship in port and the operational capacity of handling equipment at the port. Gonzalez and Trujillo (2009) grouped measurement approaches for port efficiency into three groups. The first group comprised the partial productivity indicators. The second group included engineering approaches such as queuing theories, while the third group involved the technical frontier techniques. They argued that an efficiency concept is directly derived from productivity. Sharma and Yu (2010) claimed that the traditional DEA approach was not helpful in ranking Decision Making Units (DMUs) based on their relative degrees of efficiency and inefficiency, nor did it identify those variables that have great impacts on efficiency. Hence, they applied the decision tree approach based-DEA on 70 container terminals.

Ducruet et al. (2010) applied a multiple regression analysis, Ordinary Least Square (OLS), to examine the relationship between commodity variety and port performance. A commodity diversity index was the response variable and the predictors were divided into three groups including: port performance predictors, such as, total traffic; geographical predictors such as, latitude; and regional economic predictors such as, the labour market. Significant variables were only considered in their model and multicollinearity was tested. They concluded that there is a strong impact of demographic size, traffic balance, accessibility to and distance from main economic cities and position in maritime networks on port performance.

Zouari and Khayech (2011) argued that port performance can be assessed using a three-dimensional measure method that is known as 'Cost-Quality-Delay' method. The method aims to reduce total costs of cargo stopovers, to improve the service levels and to lower delays of cargo and ships at ports. Also, they discussed six dimensions of port performance, namely commercial, operational, financial, organisational, social and citizen dimensions. Taneja et al. (2012) discussed the incorporation of flexibility measures in port infrastructure design. They argued that this measure provides a port with a plan to cope with a changing environment and uncertainty. They recommended using financial techniques such as discounted cash flow analysis (DCF), return on assets (ROA) and enterprise risk management (ERM). A three-layer infrastructure model (inframodel) was developed to provide flexible options to port planners and decision makers. Dorsser et al. (2012) investigated port performance through forecasting the port throughput. They developed a very long term forecast of the Le Havre-Hamburg region throughput up to 2100. They argued that this forecast will help infrastructure planners to consider suitable capacity in the future. The port throughput was the response and the economic activity measured in GDP was the predictor. Table 2. summarises these common supply chain approaches that have been developed for assessing ports' performance.

Table 2. Performance Measurement Approaches Applied in Ports

Applied Model	Focus	Limitations
Throughput model	Containerised ports	Average inputs
SFA	Port efficiency	A single year of data
Simulation	Crane productivity	Missing key factors
DEA	Controllable inputs (land – labour – capital)	Poor data availability
SFA	Containerised ports	Limited inputs
DEA	Containerised ports	Not clear in practice
DEA	Container ports	DMU system focus
DEA-CCR, DEA-BCC, FDH	Throughputs	Unavailable data
SFA	Productive efficiency	Privatised ownership focus
BCC, CCR	Throughputs	One year of data

SFA, Liner Regressions	TEU's measurement	Simple model
TEU	Containerised ports	Irrelevant parameter
SADT	Efficiency	Port users focus
Panel Survey	Benchmarking	Container port focus
DEA	Port efficiency	Missing key variables
SFA and DEA	Efficiency	No clear methodology
Decision-tree Approach	Terminal attractiveness	Container terminal
‘Cost-Quality-Delay’ method	Logistical port performance	Commercial and operational focus
inframodel	Port flexibility	Theoretical model
Regression analysis	Port throughput	Ignoring other factors

SCOR, LEAN, SIX SIGMA

In this paper, three models are selected and combined as proposed supply chain architecture in order to manage and improve a port performance. SCOR can assist ports in making many of the major decisions that will affect the general construct of their supply chain and such decisions will have a major impact on the resulting Supply Chain and its performance and offers a relatively quick ROI. Lean and Six Sigma complements and strengthens the SCOR-based strategic decisions by providing a continuous improvement philosophy that can be effectively used to map the workflow and transactions which are specific to each port, adding considerable detail to support a deeper understanding of current and future processes (Loyd et al, 2009). It is quite evident that these methodologies are complimentary and their individual weaknesses are resolved by their convergent strengths. It is recommended to start with SCOR and using the Supply Chain Excellence (SCE) approach to understand various supply chains, their construct and priorities (Stephens, 2001). Bring a Lean flavor to the strategic discussions and incorporate what is valued and voiced by the customer, identifying disconnects and waste. When identifying the improvement projects use a Six Sigma approach for data collection to present the current state performance and highlight the defects and disconnects within the supply chain.

Lean is a philosophy of production that emphasizes the minimisation of the amount of all the resources (including time) used in the various activities and operations in ports. It involves identifying and eliminating non-value-adding activities in design, production, supply chain management, and dealing with customers. It contains a set of principles and practices to reduce cost through the relentless removal of waste and through the simplification of all operations. Lean philosophy can be applied in port industry following the key principles, such as understanding the true demand, shifting the emphasis form failure to prevention and seeking to build trust, with supplier and customer. Seven wastes can be controlled including waste of over production, waste of waiting, waste of transportation, waste of over-processing, waste of inventory and waste of defects. Different tools can be used to control previous wastes such as Value Stream Map (VSM), Mistake Proofing, JIDUKA and Informative Inspection, Visual Controls, Total Productive Maintenance (TPM) and KAIZEN.

Six Sigma at many organizations simply means a measure of quality that strives for near perfection. Six Sigma is a disciplined, data-driven approach and methodology for eliminating defects (driving toward six standard deviations between the mean and the nearest specification limit) in any process – from manufacturing to transactional and from product to service (Kumar et al., 2008). The statistical representation of Six Sigma describes quantitatively how a process is performing. A Six Sigma defect is defined as anything outside of customer specifications. A Six Sigma opportunity is then the total quantity of chances for a defect. The fundamental objective of the Six Sigma methodology is the implementation of a measurement-based strategy that focuses on process improvement and variation reduction through the application of Six Sigma improvement projects. This is accomplished through the use of two Six Sigma sub-methodologies: DMAIC and DMADV. The Six Sigma DMAIC process (define, measure, analyze, improve, control) is an improvement system for existing processes falling below specification and looking for incremental improvement. The Six Sigma DMADV process (define, measure, analyze, design, verify) is an improvement system used to develop new processes or products at Six Sigma quality levels (Kumar et al., 2008).

INTEGERATING SCOR WITH LEAN AND SIX SIGMA

The integration of SCOR, Lean, and Six Sigma principles have only recently been understood and recognized. Treated separately, they each have value as shown in Table 3; but merging all three into a comprehensive productivity plan could earn benefits ten. The convergence of Lean, Six Sigma and SCOR, requires vision. This paper seeks to understand the power of this convergence.

Table 3. The strength and weakness of each model

Methodology Strengths		
SCOR	**Lean**	**Six Sigma**
• ctured methodology for ment of Strategic and Operational metrics and goals to identify business improvement opportunities • Standardized Supply Chain process reference model and framework • Standardized multi-level process performance metrics • Industry and competitive benchmark data sources • "Macro-level" approach for identification of improvement opportunities • Level 1-3 material, work and information flow analysis • Source for best-in-class supply chain management practices • Can be use to identify enabling IT capabilities to optimize the Supply Chain • Opportunity and project portfolio with detailed ROI analysis	• Structured methodology for diagnosing and executing waste elimination projects in any process • Typically focused on a factory / cell / process level scope • Focus on workplace organization (5S) and preventative techniques (TPM) • Level 4+ material, work and information flow analysis • Concurrent training / projects – applied skills development • Best-in-class operating practices at a factory and cell level • Standard Work Development • Visual Controls and Cell Management Tools for Control of new processes • Very effective at rapidly reducing cost – through waste elimination	• Structured methodology for diagnosing and executing defect and variation reduction projects in any process • Dedicated roles, responsibilities, and Program Infrastructure • Top-to-Bottom Organization training and development • Highly structured problem solving approach (DMAIC) • Level 1-4+ variation and defect reduction techniques • Concurrent training / projects – applied skills development • Customer and data driven decision making • Unique methodologies for product development, operations, and transactional applications • Rigid project tracking and financial accountability for results
Methodology Weaknesses		
SCOR	**Lean**	**Six Sigma**
• Inadequate organization-wide training and development • Few analytical tools for cause-effect analysis and problem solving at the "macro-level" • Inadequate tools, methodologies, or techniques to focus on executing projects identified by the SCOR efforts • Little programmatic infrastructure for organizing and managing concurrent project activities	• Few tools for focusing Lean efforts on strategic and operational process priorities • Inadequate program infrastructure and training to drive breakthrough improvement • Poor capability for addressing support system issues and transactional processes • Inadequate analysis of financial expectations and accountability for bottom-line results • No tools or capability to remove bottlenecks driven by process variability / defects	• No specific methodology for aligning strategic and operation priorities with project execution and candidate selection • No methodology to develop understanding of the confounding relationships between projects • Inadequate "macro-level" analytical techniques to validate projects • Data dependent tools and techniques difficult to use in poorly controlled and wasteful operating environments

Source: Recker (2003)

Figure 1. shows that there is a natural linkage between Lean and Six Sigma both at the program-level as well as the project execution level. Design for Six Sigma (DFSS) tools insures that products are designed to be robust to known sources of process variation and defects. Transactional Six Sigma tools insure transactional processes and systems optimally support process flow with minimal variation or defects (Kumar et al. 2008). Six Sigma tools and methodology provides Lean the means to resolve critical process bottlenecks that impede flow by eliminating process variability and minimizing process defects. Likewise, Lean provides Six Sigma the necessary methodology and tools to eliminate non-value added process waste and surface the rocks or bottlenecks that lie underneath – ideal targets for Six Sigma (Loyd et al, 2009) .

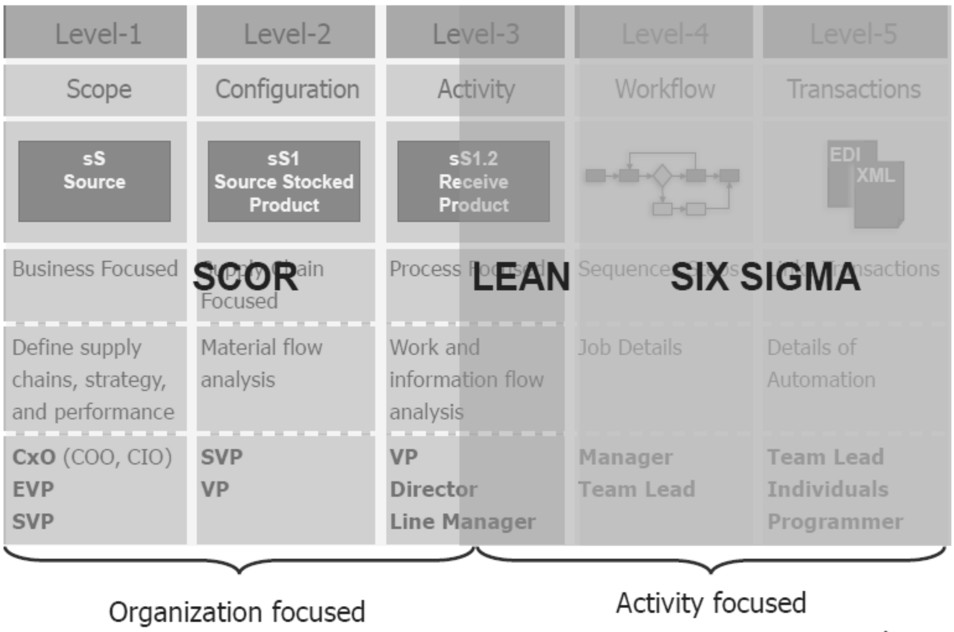

Figure 1. Supply chain Architecture

Source: Recker (2003)

METHODOLOGY FOCUS	SCOR	LEAN	SIX SIGMA
Establishes common architecture and language across multiple supply chains	x		
Creates ability to visualize the supply chain system as a whole and in its entirety	x	x	
Develops supply chain level metrics for system measurement and benchmarking	x		
Instills a continuous improvement culture across the organization		x	x
Illuminates waste and non-value added activities and identifies specific actions for improvement		x	
Implements process and system improvements		x	x
Deploys systematic methodology for problem solving			x
Emphasizes quality and reduction of errors and variability			x
Direct customer-centric focus across entire organization	x	x	x
Prioritizes process improvements across supply chain system	x		

Figure 2. A complete Convergence Design
Source: Handfield and Nochols (1999)

Measurement is the establishment of some type of criteria or performance metrics by which one can gauge and effectively manage the activity being measured. Once that criterion has been established, the first step in determining a port's current state of performance is benchmarking. While SCOR, Six Sigma and Lean methodologies each depend on measurement to diagnose improvement opportunities and evaluate results, practitioners of these methodologies embrace different concepts about how to measure, what to measure, and how to display those measurements. Each of these perspectives adds clarity to overall business process improvement efforts.

Key objectives of Lean improvement techniques are to eliminate time traps, waste and other inefficiencies by identifying and eliminating process steps or actions that don't add value, thus maximising flow efficiency - speed (Loyd et al, 2009). The most important aspect in determining flow functionality and efficiency is a port's ability to produce a mechanism to measure value. To measure it, one must use the most prominent tool within the Lean toolset, Value Stream Mapping. This process begins with the selection of value streams (integral process flows) whose improved performance will have the greatest impact on a port's predetermined objectives. Once mapped and benchmarked, process efficiency measurements are gathered for each step within the value stream to determine steps that are value-added versus non-value added.

SCOR concentrates on benchmarking and improving material flow and work and information flows. Successful analyses of both are necessary (Stephens, 2001). Material flow examines and focuses on optimising internal and external material movement (raw materials, WIP, finished goods). The model builds its strength on the linkage between process elements, metrics, best practices, common terminology, and features associated with effective supply chain execution. It aligns strategic with operational goals and focuses on process definitions and metrics hierarchy. This is done using SCOR's predefined metrics in recording port's actual performance, current industry benchmarking data, and gap determination

For six sigma, DMAIC (Define, Measure, Analyze, Improve, and Control) are the well-known steps or phases of the Six Sigma methodology. Six Sigma helps to identify and apply the defect and variation reduction techniques on critical bottlenecks. If waste elimination or cycle time improvement is on the top of your results list, then Lean is well suited as your improvement toolset. It is a structured approach, aimed at locating and eliminating non-value added process events to create product flow through the process. However, like Six Sigma, this methodology does not provide a clear view of gaps at a strategic level, and is dependent upon your company's ability to identify where to focus your project attention, typically missing much of the waste in your supply chain. Lean targets transactional level processes with the objective of eliminating non-value added waste, which is considered anything not necessary to produce the product or service, regardless if the product is FGs or WIP.

Once value has been clearly defined, value stream mapping and pull production systems are designed to enable and maintain local flow. The Lean toolkit contains several possible improvement approaches, but all are focused on tactical Process Cycle Efficiency (PCE), control of Work In Process (WIP), and waste elimination, that is reducing the negative effects of the inefficiencies within process flows.

Results and experiences with Lean vary greatly. Notable weaknesses with the Lean methodology are typically related to the alignment of the improvements to strategic and operation business needs, sub-optimal application with quick-hit approaches, inadequate substantiation of bottom-line expectations and validation of financial impacts, and poor ability to resolve critical variations and defects generating bottlenecks within the flow which slow the process.

Lean deals more with transactional-level processes, a bottoms-up approach. So its ability to define and understand results upfront other than cycle time and inventory efficiencies is highly limited. If product flow isn't your motivation, you will only have the ability of defining and understanding the results upfront by commencing a project and mapping your company's value streams. Then you can begin examining event sequences, or operations necessary to other activities that add value, such as essential steps. From this point, you might be able to define and understand the results as you progress.

CONVERGANCE STRENGTHS

Each approach brings specific strengths to help reach predetermined results. Taken together, though, each approach actually can mitigate the weaknesses of the others making them dovetail nicely. Strengths and weaknesses of each approach, which, when taken collectively, can highlight those areas where synergies and results might be enhanced by hand off between one or more of the others.

Convergence Adds Value in Results Definition and Understanding

The ability to measure improved performance in Ports will help to provide highly service levels and keep improving performance. Use of all three of these highly recommended toolsets may result in the ultimate toolset or, one that can identify burning platforms and eliminate problem areas, help identify other areas to focus on, and be a means for future-state benchmarking and performance measurements.

CONCLUSION

SCOR can assist decision makers in ports in making many of the 'major' 4 decisions that will affect the general construct of their supply chain and results in a major impact on its performance. Lean and Six Sigma complement and strengthen the SCOR-based strategic decisions by providing a continuous improvement philosophy. Value Stream Mapping (VSM), part of the Lean methodology, can be effectively used to map the workflow and transactions of port operations, adding considerable detail to support a deeper understanding of current and future state processes. For ports' managers, using all the three approaches leads to a holistic process improvement methodology. It is quite evident that these methodologies are complimentary and their individual weaknesses are resolved by their convergent strengths. Using the proposed supply chain architecture in this paper, it is recommended to start with SCOR to understand port supply chain. Second, a Lean is incorporated to identify wastes. Finally, using a Six Sigma approach helps to better present the current performance and highlight the defects and disconnects within the supply chain.

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