

SEAPORT MANAGEMENT ASPECTS AND PERSPECTIVES: AN OVERVIEW

Amr Mahfouz

Researcher - 3S Group

College of Business,

Dublin Institute of Technology,

Aungier Street,

Dublin 2.

Email: amr.mahfouz@dit.ie

Amr Arisha

3S Group Director

College of Business,

Dublin Institute of Technology,

Aungier Street,

Dublin 2.

Tel: +353 1 402 3197

Fax: + 353 1 402 3291

Email: amr.arisha@dit.ie

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Amr Mahfouz
Amr Arisha

*3S Group, School of Management,
Faculty of Business,
Dublin Institute of Technology*

ABSTRACT

Ireland occupies the northern part of the western European coast which has a 70,000 Kilometres coasting along two oceans and four seas. These coasts are Europe's lifeblood and represent the trade routes, climate regulator and source of food, energy and resources. Seaports and shipping are key maritime activities which allow European coast countries to benefit from the rapid growth of international trade. Therefore, port management became the centre of governments' interest and the focal point of research to improve the efficiency. This research aims to summaries past publications of seaport systems to highlight challenges and reveal relevant research gaps. Having the objective to classify the literature, a comprehensive review of journal articles and the best practices in the field was conducted. A wide variety of management issues and opportunities to improve service delivery of port systems was discussed in a three main categories based on port authority objectives; strategic, economic and operational.

1. INTRODUCTION

Given that Ireland has an island economy; it is not surprising that trade by sea accounts for the majority of the country's international trade. The sea counted more than 84% of the total volume of the goods traded by Irish economy. A large portion of that trade would disappear without the ports infrastructure which represents the interface between maritime transportation and land transportation. The economic significance of seaport performance for the prosperity of European countries' economy is self-evident. Aiming to bring value to end customers, seaports are promoted to be a key logistic element at supply chains (Photis M. *et al.*, 2007; Ross Robinson, 2007 and Wouter Jacobs, 2007). Seaports in this context are required to evolve from traditional port functions (i.e. loading and discharging) to more advanced activities which could add complexity in managing internal port operations. In addition to ports internal complexity, seaport management faces plenty of external challenges such as; sever competition, globalisation, limited resources and variability. Hence, it is obvious that there is a need for new innovative management approaches aiming to; 1) eliminate sources of waste (Lean thinking); 2) help port system to be agile; and 3) support decision making process.

Owing the fact that most of port systems are still administrated by public authorities, many issues are needed to investigate which create further research opportunities. Various authors suggested that one of the most critical elements influencing seaport performance is port reformation process and the overlap between public and private ownerships (Sophia Everett, 2007; Ross Robinson, 2007). Port investment is another important issue facing port management. Arising from the complex nature of ports, analysing investments in ports includes: investment in port infrastructure, superstructure and hinterland connection (Hilda

M, 2005 and Ana C. Paixao, 2005). Many other aspects such as, port capacity, landside limitations (S.Bassan, 2007), port competitive structure, port regulations changes (R.O Goss, 1990), port networks (Zhaobao Zeng, 2002), port efficiency (Ximena Clark *et al.*, 2004), etc. were highlighted in port management literature.

2. LITERATURE REVIEW

Based on the literature review, this paper classifies previous publications of port management to three main areas; 1) port management perspectives, 2) port system improvement and 3) port risk analysis (Figure 1). A brief introduction of port system improvement and port risk analysis will be presented in the following two sections; however a comprehensive review of port management perspectives is to be discussed.

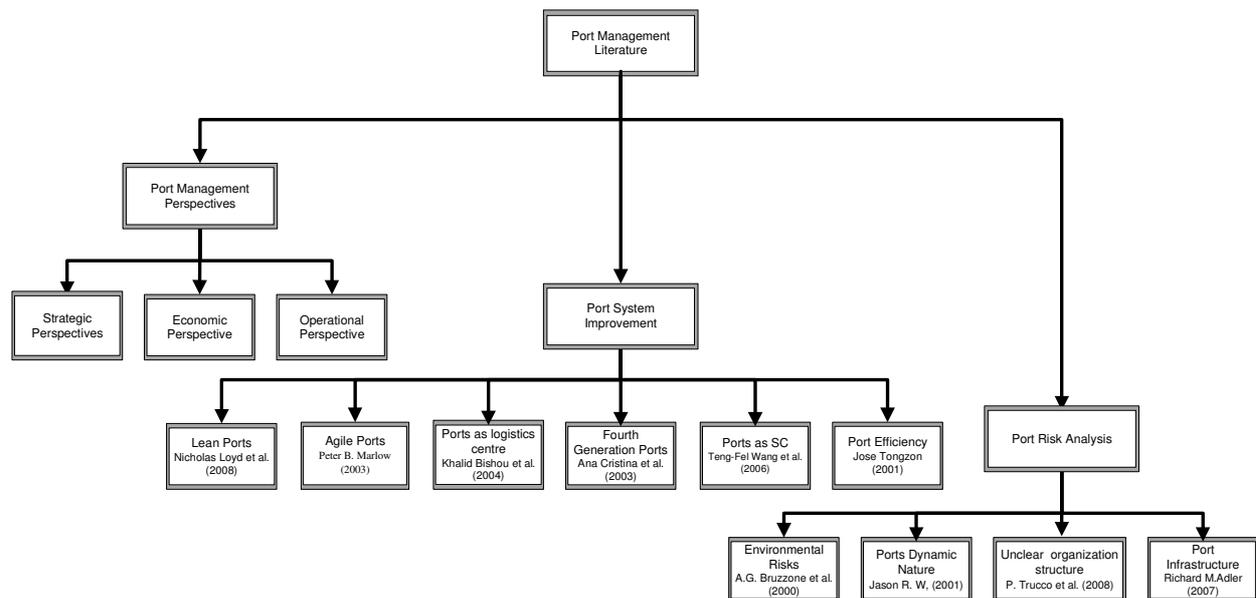


Figure 1. General classification of port management literature

2.1 Port System Improvement

Effective planning and management of complex systems are virtually overwhelming. Ireland, to remain innovative and competitive in seaport sector, must consider pioneering concepts, for the next fifty years, or miss out. This is explaining why port management is the centre of Irish governments' interest and the area which need more research efforts for improving. In reality, port system is dynamic, nonlinear in its nature, and its performance is a function of multiple/complex interactions and feedback mechanisms. Researches has been done in an attempt to provide seaport free of waste, resilient to external changes, add values to end

customers and more competitive. Therefore, several approaches like; lean port, agile port, port as logistics centre, fourth generation ports, and ports as supply chain was discussed (Figure 1) . Similarly, port efficiency is a widespread concept that is commonly used for port systems improvement process. Few studies presented assessment approaches for port efficiency using different analytical tools like; data envelopment analysis (DEA) (Jose Tongzon, 2001), stochastic frontier models (Kevin Cullinane, *et al*, 2002.), cost functions (Bruce A. Blonigen, 2008), etc.

2.2 Port Risk Analysis

These Improvement efforts for seaport systems are confronted with several types of environmental and operational risks. The downtime of the ports due to risk occurrence causes severe economic loss. Indeed, published articles showed that many types of accidents such as, earthquakes, oil spills, fires, sea accidents, etc., can seriously disrupt terminal operations. To minimize the damage of these accidents, it is extremely important to pay great attention to the various sources of risks that are to happen during the normal harbour activities within particular circumstances. Based on the literature, accidents are not the only source of risks, but also uncontrollable environmental conditions, dynamic nature of port systems, unclear organisational structure and system uncertainty create additional sources of risk (Figure 1). Basically, previous studies utilized plenty of quantitative approaches for risk assessment and its impact on seaport performance. Simulation model (A.G. Bruzzone *et al*, 2000), multi-objective programming (Elfrherios T. Iakovou, 2001) and bayesian belief network (P.Trucco *et al*, 2008) are the most common techniques used for analysing harbour risks.

3. PORT MANAGEMENT PERSPECTIVES

Nowadays, seaport management faces numerous difficulties at the current competitive markets. Many critical decisions should be taken not only for solving daily problems, but also to improve overall port performance (Sophia Everett 2007, Wayne Talley 2007, etc.). Port

management can be categorised based on different perspectives (e.g. strategic, economic and operational) (Figure 2). Due to the internal dynamics of seaport systems, these management decisions are usually taken within an environment of uncertainty, variability and limited resources.

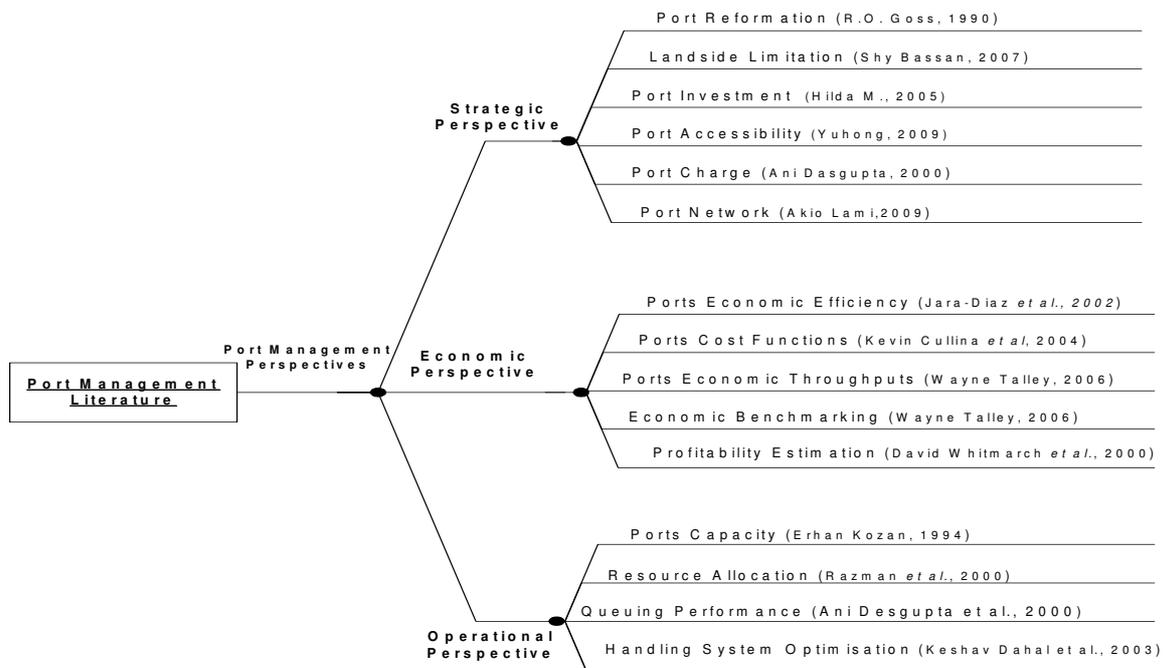


Figure 2. Classification of port management perspectives

Within the context of strategic perspectives, the impact of port administration authorities (i.e. private or public) on port efficiency, landside limitation, port investments, port accessibility, port charges determination and establishing port network are represented strategic areas that were handled by many authors (Kevin Cullinane *et al.*, 2002; Sophia Everett, etc.). From the economical point of view, few researches have focused on the analytical approaches that can be used to assess seaport economic efficiency (e.g. production function, cost functions, stochastic frontier model, etc.); whereas, the others used economic terms (e.g. profit, cost, etc.) as performance indicators reflecting the significance of management alternatives (Bernard Gardner *et al.* 2006, Erhan Kozan 1994, etc.). Finally, operational decisions take into

account the optimization of port operations as well as the best allocation of port resources in order to optimise the whole system performance. Resources utilisation, total system throughput and cycle time are usually used as performance measures for this type of problems.

3.1 Strategic Perspective

3.1.1 Port investments

Given that port infrastructure is the backbone for all port services; investment projects play a vital role for improving port services quality. Three main aspects related to port investments were highlighted by (Hilda M., 2005);

- Firstly, the involvement of public authorities in port investment projects and its impact on port competitiveness,
- secondly, the consequence of uncertainty on port investment projects,
- and finally, the complexity of forecasting for investments costs and revenues.

Decision of invest in ports infrastructure has a high level of uncertainty. This challenge is magnified as a result of the absence of appropriate model to forecast upcoming port traffic. Few articles have addressed this issue in the literature.

The economic situation and the competitive position for seaports are another two important elements for port investment projects (M.Garrat, 2001). For instance, due to huge freight market growth at Ireland and UK, a large investment projects in ports amounting to around £500 million were taken place in order to offer a wide variety of services. The author mentioned that Irish Sea has experienced very quick growth in freight traffic which led to attracted very substantial levels of investment projects.

As investment projects often involve large sunk costs with a long payback time, ports authorities pursue to provide high quality services at profitable prices in such a way that they recover their costs. Some authors studied the balancing between service costs and investment

projects costs in order to optimise port revenues. For example, an optimal balance between the opportunity cost of ship waiting time and the cost incurred in the expansion (i.e. investments) of the seaport system was analysed by (Erhan kozan, 1994). Three analytical techniques, capital budgeting approach, queuing theory and simulation model, were integrated in a framework to investigate the economic effect of alternative investment policies at different time periods.

3.1.2 Port reformation

Although most of physical services of ports (e.g. loading, discharging, etc.) and the infrastructure are almost similar, there are various alternative forms of port administration and ownership (R.O.Goss, 1990). Four different models of port administration that are applied in different countries are shown in table 1. Few ports can be described as either purely private or public. In Ireland, a debate surrounded the question of what is the best reformation model should Irish ports follow. Irish government established a ‘Review Group’ comprised different members who represented the various stakeholders’ interests. Four alternative structures for Irish ports were assigned; 1) Privatisation, 2) Regionalisation of ports, 3) A national sea ports company, on the model of *Aer Rianta* (the Irish state-owned company which operated Ireland’s three main airports) and 4) Separate state companies to operate individual ports on commercial footing. The fourth scenario was chosen to manage twelve key Irish ports. The corporatized ports have a significant success, supported by very healthy domestic economic conditions (John Mangan, 2000).

Table 1. Four Model of Port Administration (Source: R.O. Goss, 1990)

Models	Port Functions		
	Land Ownership	Regulation	Cargo Handling
Pure Public Sector	Public	Public	Public
Public/Private	Public	Public	Private
Private/Public	Private	Public	Private
Pure Private Sector	Private	Private	Private

There is no clear-cut evidence supporting the claim that improvement of port efficiency is relying on the transformation of ownership from public to private sector (Kevin Cullinane *et al.*, 2002). Port authorities found that ports reformation should be combined by changes in port regulations in order to extend port deregulation (Sophia Evertt, 2007). Sophia used an Australian Coal terminal called DBCT (Dalrymple Bay Coal Terminal) as a case study for her research. She examined the usage of single Australian national regulator regime instead of multi-regulator regimes with respect to port congestions and bottleneck. The single regulator option expedited the terminal process and decreased delay time. However congestion and bottlenecks issues are still not slightly resolved. The authors also suggested that supply chain solutions will add a significant value to ports regulatory framework. Imposition of port's regulatory framework on the chain effectively would change supply chain from ad hoc, high variability supply chain to a disciplined demand-pull supply chain, according to Ross outcomes (Ross Robinson, 2007).

3.1.3 *Port network*

Because of the important function that ports are playing in supply chain management, the past concept of port operations (that a certain cargo must be handled at a certain port with a certain limited hinterland) has totally changed to port network concept. Cost minimization and the 5 Rights-model (i.e. right place, right quantity, right time, right quality and right cost) are ultimately the main objectives of the majority of port managers. Port network structure relies on different elements such as; port accessibility (Yuhong Wang *et al.*, 2008), port charges (Meifeng Luo *et al.*, 2003), port container management (Akio Lami, 2009), investment management and individual ports contribution in network throughput (Zhaobao Zeng, 2002). Port accessibility implies to the ability that port can be reached from other network ports. It is a particular relevant aspect to port competitiveness since it is positively correlated to port throughput. It is also a function of ports' geographical location. In terms of

measuring port accessibility, a principle eigenvector method (PEM) was applied to a sample of data from various container port networks. PEM provides appropriate ways for overcoming the disadvantage inherent within the traditional mathematical methods (Garrison, 1960 and Stutz, 1973). For practical application especially for complex port networks, using those traditional methods causes an existence of redundant connections during network accessibility calculations (Mackiewicz *et al.*,1996). PEM model provides a quantitative assessment for container accessibility and also offered a numerical basis for comparing the relative geographical importance of each port (Yuhong Wang, 2008).

Since the amount of cargos (i.e. containers) transported via the nodes (i.e. individual ports) of port network has increased dramatically, a special interest is directed to container management topic. Ports' yard operations are the bottleneck for the container terminal as most of containers flow happens in yard-side. Efficient yard operation systems are required to improve the whole terminal performance. As the container assignment is the core function of yard operations, container management- container fleet size determination and empty container repositioning- represents a crucial issue for shipping network performance (Nang *et al.*, 2008). Not only limited to shipping network performance, container management has also an influence on the selection of port network structure type (Akio Lami *et al.*, 2009).

3.1.4 Port charges

Aiming to business oriented view for port systems, an optimal port charge should be determined based on port services. Port charge is a full cost recovery that is applied on port users to cover ports sunk costs (Martin and Thomas, 2001and Meifeng Luo, 2003). Beside service quality and time costs, port charges are a major factor that determines the demand for port services (Bernard Gardner *et al.*, 2006; Ani Dasgupta *et al.*, 2000). Port demand is also affected by (1) the international trade pattern, (2) the geographical location of a port with

respect to sources and markets, (3) the availability of multi-modal transportation networks, and (4) the associated general total cost (Meifeng lu, 2003).

3.2 Economical perspective

For many countries worldwide, ports are critical economic element impacting on their economic charts. If they operate efficiently, the whole economy benefit - otherwise it suffer. For instance, port capital shows a significant effect on GDP and heavy-trade economy of Japan (Tetsu Kawakami, 2004). The author applied elasticity concept – the ratio of total accumulated percentage changes of the variable to percentage changes in port capital over specific time horizon – in order to show the impact of port capital on the other variables (i.e. GDP, transportation cost and private capital). GDP and private capital are reported to have an elasticity of 0.483 and 0.551 to port capital respectively indicating a significant impact of port capital changes. On the other hand port capital change illustrated insignificant effect on transportation cost with elasticity 0.053. Ports have also an important role for the prosperity of Republic of Ireland (ROI). Currently, ROI is recognized the only EU member without a land-link to the continent (John Mangan *et al.*, 2000). Therefore, it is not surprising that trade by sea accounts for the majority of the country's international trade. In 2004, Ireland traded almost 56 million tonnes of merchandise with volume of €135.3 billion. At the same year, Irish seaports contributed €9.64 billion to Irish economy, which represents 7.8% of GNP (Report for Irish port association, 2006). The desire to get effective and economic transportation networks, forced member countries of the European Union to integrate port sector in a transeuropean transport network (TEN-T) to provide opportunity for port networks to compete against road networks.

Economic efficiency, the relation between the value of output to the real cost of the inputs, is a common measurement unit that widely used for evaluating economic performance.

Economic efficiency is also defined as the ability to achieve high performance with minimum cost (David Whitmarsh *et al.*, 2000). Much attention in the literature was given to study the methodologies that can be used to assess ports economic performance. Four main methods are suggested, (i) cost function estimation, (ii) port throughput analysis, (iii) benchmarking, and (iv) profitability estimation.

3.2.1 Cost function estimation

Port's economic cost function is a function of the different cost elements incurred in handling a given throughput in ports (Wayne Talley, 2007). Cost function provides adequate information about ports marginal cost, economies of scale and scope (Wayne Talley, 2006). Economies of scale and scope are necessary for investigating various issues such as, port reformation (Jose Tongzon, 2001), maritime transportation costs (Ximena Clark *et al.*, 2004), trade flow (Bruce A. Blongine, 2008) and port regulations (Sophia Everett, 2007). Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are two alternative methods using frontier models to accurately estimate cost functions. While SFA is a parametric approach relies on stochastic parametric regression-based methods, DEA is non-parametric approach employing mathematical programming techniques (Kevin Cullina *et al.*, 2002). Due to its ability to generate results with a relatively small set of data, DEA is extensively used in the economic analysis of ports efficiency (Wang *et al.*, 2003 and Estache *et al.*, 2004). Cost function estimation is a critical job where a suitable function form should be selected from different types of functions (e.g. Cobb-Douglas function, Quadratic function, Translog function, etc.) (Figure 3) (Beatriz Tovar *et al.*, 2007). The aim should be to choose a function form representing the required parameters to enable the analysis of all economic effects without enforcing priori restrictions. Cobb-Douglas function is relatively non-flexible function and start from very restrictive assumptions, although it has the advantage of having few parameters. Contrary, quadratic and translogarithmic functions are

flexible functions avoiding assumption restrictions and allow to a large number of parameters to be estimated (Pablo Coto-Millan et al., 2000;). The violations of regulatory conditions in the production structure, the estimation of an excessive number of parameters and the impossibility to work with observations at zero production level are the three drawbacks of flexible function forms.

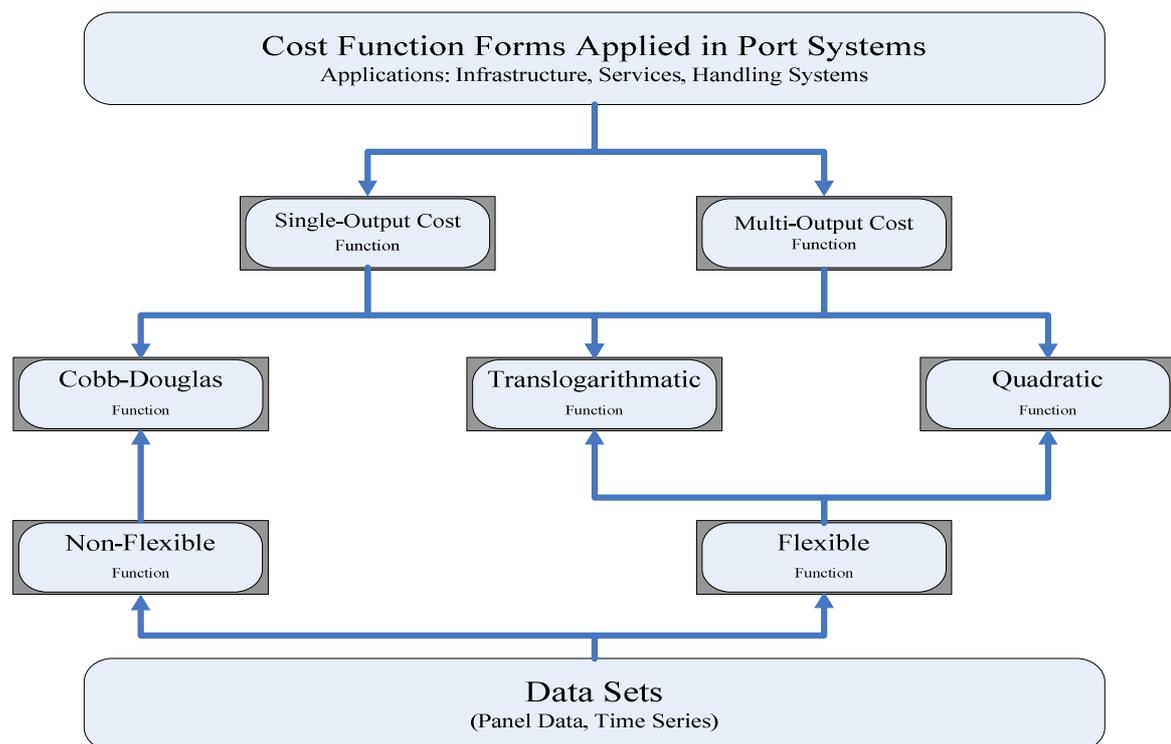


Figure 3. Cost functions types and classifications

3.2.2 Port throughput analysis

To evaluate port performance using port throughput analysis, a comparison between port's actual and optimum throughput (measured in tonnage or number of container handled) is needed. In a non competitive environment, engineering optimum throughput can be used, defined as the maximum throughput that a port can physically handle under certain conditions (Wayne Talley, 2007). Engineering throughput is replaced by economic throughput when competitive environment is taken into consideration. Economic throughput is the throughput given that the port achieves its economic objective (e.g. maximum port

profit). The determination of port throughput requires an accurate estimation of economic objective function - cost function. Cost function forms and parameter values are usually not certainly known and data may be insufficient to get reliable estimations.

3.2.3 Benchmarking

An alternative methodology for evaluating ports economic performance is the one that uses standard port performance indicators in benchmarking process. From an economic point of view, performance indicators are the controllable variables that port manager can assign their values to optimise economic objective functions (Wayne Talley, 2006). The values of the performance indicators that optimise port's economic objective are identified as performance indicator standards (i.e. benchmark). Hence, current port performance could be investigated against the standard ones. Similar to throughput evaluation method, economic objective function (i.e. cost function) has to be accurately estimated. The main advantage of this method is that performance indicators include various port elements like, port operations, ports equipments, ports labours, ports shipping-line and port maintenance which provide the ability to evaluate the performance for several port functions (Wayne Talley, 1996, 2006 and 2007).

3.2.4 Profitability estimation

The term "Profit" is often used vaguely to express two different concepts. The first refer to the income and called financial profit, while the other, economic profit, is used to measure the economic efficiency. Financial profit is used to indicate the financial performance by deducing the relevant costs from total revenues to bring out the net income. On the other hand, Profitability in economic context is calculated using the opportunity cost for labours and capital in addition to depreciation cost (David Whitmarch *et al.*, 2000). The differentiation between the two types of "profit" is crucial for policy purposes. If port owner is mainly concerned with the difference between credit and debit amounts and its impact on

port profitability, then using the first concept will provide detailed figure about this. However, if the policy question is whether a new business strategy or regulation is likely to impact on the economic performance, then measures the economic profit will be more appropriate. Using profitability as a measurement of economic efficiency is a promising research area as there is a few studies formally distinguish between financial and economical efficiencies.

Port efficiency studies are limited due to the difficulty to access to the right level of information, particularly when it comes to cost. This is unfortunate since the sector continues to have some important components of its business that have monopolistic features. Another reason for information scarcity is that most of port organizations enjoy some degree of protection from competition and they are not required to report much information relevant to the assessment of their performance efficiency, especially economic efficiency (Lourdes Trujillo *et al.* 2007). To properly study port efficiency, a strong commitment of port authorities is required to provide required information to fulfil the analysis phase.

3.3 Operational Perspective

Port operations are triggered by receiving imported or exported materials from either landside or seaside respectively. After that, these materials are stored, processed and dispatched using port components such as unloader, loader, conveyor, transfer station, cranes, etc. Ports then act as buffers between the incoming and outgoing vessel traffic. The arrival and departure of vessels from a port are the inputs and outputs of the facility (K.Dahal *et al.*, 2003; S. Bassan, 2007). The influence of uncertainty and variability on seaport performance is tremendous. Changes happen extremely fast with a high impact on operations output. It is therefore not surprising that port authorities pay a great attention to the analysis of their ports operations performance. Typical objectives associated with port operations management are mainly;

- (i) Obtain efficient utilisation.

- (ii) Optimise resource scheduling.
- (iii) Minimize maintenance/operating cost.
- (iv) Maximize terminal throughput.

Performance indicators play an essential role in assessing these objectives with future potential to adopt (Teng-Fei. *et al.*, 2003). While several authors identified different indicators for port performance, Table 3 shows five main categories of performance indicators that are listed in the literature (Peter.B Marlow *et al.*, 2003; Wayne Talley, 2006; K. Dahal, 2003; Hugh S., 2000 and Ani Dasgupta *et al.*, 2000). Analysis of loading/unloading operations (Branislav *et al.*, 2006), investigation of alternative leasing and investment policies (Hugh S.Turner, 2000), estimation for port capacity (S.Bassan, 2007) and optimisation for port resource allocation (Razman *et al.*, 2000) and port queuing system (Ani Dasgupta *et al.*, 2000) are of interest to port management. Minimizing operations cost was used as an objective function for many optimization problems (Erhan Kozan, 1994; and Hugh S., 2000). For example, simulation model integrated with genetic algorithm was developed to select the optimal operations sequence to minimize operations cost (K.Dahal, 2003). Port operation cost was also used to evaluate ships loading and unloading processes. A cost function combines many parameters such as; ship service time, waiting time, berths number, related average ship cost and the combination of berths and quay cranes is formulated to represent the objective function (Branislav *et al.*, 2006). The cost function was analytically resolved by minimising the sum of the relevant cost components associated with the number of berths/ terminals and average arrival rate. These two parameters are essential to analyse facility utilisation and achieve major improvements in container port efficiency. Another study investigated two alternative leasing policies (e.g. dedicated terminal leasing, common-user terminal leasing) using utilisation and waiting time as performance indicators for minimize carrier cost. The author tried to justify that inventory theory can be applied into port

system analysis. Inventory theory suggests that the pooling of demand of uncertainty can yield lower costs without reducing customer service level (Ever, 1994).

Table 3. Main Performance Indicators for Port systems

Classification	Performance Indicator
Ships & Vessels	Ship's waiting Time
	Ship's repair time (in case of breakdown).
	Ship's capacity utilisation
	Ships cost by unit of cargo carried
	Degree of flexibility in using ship's resource
	Ship's service time (loading, unloading,...)
	Expected probability of ship damage while in port.
Resources (Cranes, Labours,...)	Berths availability
	Number of cargo handled per resource (crane, labour,...)
	Handling rate of discharge operation
	Waiting time
	Degree of flexibility in resource usage
	Resource utilisation
	No of gangs employed per ship per shift
	Fraction of time gang idle
	Total demurrage cost
	Total operating cost
	Percentage of congestion
Materials (Containers or Cargos)	Overall time at the port.
	Tons per ship-hour in port
	Tons per gang hour
	Expected probability of ship damage while in port.
Infrastructure	Delay caused by road works
	Delay caused by congestion
	Annual average time that ports open to (navigation, berthing of ships, departure of ships,...)
Port Authorities	Degree of process adaptability according customer requirements.
	Truck queuing time at port gates.
	Facility utilisation

This concept was used in container seaport by investigating the second policy against the original one (i.e. dedicated terminal leasing). Using common-user policy, the carrier cost was declined by \$ 6.3 million emphasizing the validity of applying inventory concept on seaport

systems. The second policy increases also the terminal utilisation and decreases ships delaying time. (Hugh S., 2000).

3.3.1 Port capacity

Limitation of ports hinterland and the tie availability of their resources made port capacity management a crucial issue for port improvement process. Port capacity is defined as the amount of cargos that can be handled by a port per time period (S.Bassan, 2007). It is dependent on the number of berths, warehouse capacity, cargo handling capacity and hinterland space (Erhan Kozan, 1994). Given its role in decreasing investments cost, increasing port capacity became a common target for port authorities. Maximize resource utilisation and reduce wastes practices are considered the main strategies for increasing port capacity. There is a trend toward using quantitative models for investigating port capacity problems. Four performance indicators, 1) berth occupancy percentage; 2) congestion percentage; 3) Waiting to Service time ratio W/S; and 4) average actual annual cargo Quantity per Capacity (Q/C ratio), are introduced to develop methodology for deriving the optimal port capacity based on cost optimization (S.Bassan, 2007). Simulation modelling was used to compare between five different seaports. Simulation outputs shows that increasing port capacity by improving terminal operation rules and minimizing waste elements drive positive impact on both, performance indicators and cost function. On the other hand, it illustrates that increase the capacity by new investments and purchasing more equipments doesn't always improve cost function. Another framework contains queuing analysis, simulation model and cost-benefit analysis was developed to balance between opportunity cost of ships waiting time and cost incurred in capacity expansion projects (Erhan Kozan, 1994). Four expansion policies were investigated in this study; 1) no capacity expansion, 2) add additional berths, 3) construction of new port, and 4) construction of a new port after an

additional berths. Using simulation modelling to analyze the four strategies against three different discount rates and five alternative ship waiting cost, the policy 2 & 4 achieved the maximum performance. For all discount rates, the second policy is the optimal for the lower waiting cost while the 4th becomes the optimal with the increasing of waiting cost.

3.3.2 Resource allocation

Two main types of resources are used at port systems, berths and quay cranes. Berth planning is considered to be the very first level of terminal planning. While quay crane is a very important element in controlling the ships service rate. Two individual simulation models are developed for planning berth assignment and crane allocation by (Razman *et al.*, 2000). The first model, berth allocation model, investigated different berth priority assignment strategies for different ship types using ship throughput, ship turnaround time, berth utilisation, queue length and time spent in the queue as performance indicators. The basic strategy was to give a priority to mainline ships as they are bigger in size and carry more containers. However, it was noticed that many feeder ships carry more containers than mainline ships. Hence, the priority was changed and assigned according to the biggest ship load. This priority assignment policy reduced ships turnaround time by 0.6 hour, and increased berth utilisation by 4 percent in average. The second model analysed the best crane allocation in order to optimise cranes utilisation. The authors investigated the influence of crane numbers on crane utilisation and on berth hours per ship. By shut down one crane the utilisation increased slightly from 36 percent to 39 percent, while berth hours increased by 2 hours. Although, optimizing the performance of each individual operation was fundamental to overall terminal efficiency, the interrelation between various operational decisions should also be reviewed. A unified approach was developed to simultaneously consider two management issues- container assignment and yard crane deployment. Two yard crane deployment policies were illustrates; 1) 'no sharing yard crane policy', assuming that each berth has its own yard crane,

2) 'sharing yard crane', assumes that yard crane can move around different berths. The model aimed to optimise container flow through port yard and to minimize the overall storage and handling cost. The using of second policy in all terminal operating conditions (i.e. light-load day, medium-load day and heavy-load day) achieved the minimum cost with smooth container flow (Nang *et al.*, 2008).

3.3.3 Queuing performance

Queuing performance is a vital indicator for various production and service systems (i.e. manufacturing systems, restaurants, etc.). It also plays a crucial role for improving port services performance. Many publishers use simulation modelling to examine the queuing system performance through detailed monitoring for the movement of entities, assuming stochastic but fixed arrival pattern. However, few attempts are made to study the feedback effect of queue performance on the arrival process. To clarify this feedback relation, a framework joined simulation model in conjunction with simultaneous equation estimation approach was applied on port system of Calcutta, India (Ani Dasgupta *et al.* 2000).

3.3.4 Analytical Frameworks

Simulation modelling technique is a common approach that was used by aforementioned port operations studies (S.Bassan, 2007; Branislav *et al.*, 2006, etc.). Some other techniques like; queuing theory, cost benefit analysis and genetic algorithm are integrated with simulation modelling to form analytical frameworks in order to investigate port operation problems (K. Dahal, 2003). Due to port system complexities and dynamic nature, more advanced techniques are required. System Dynamics modelling is one of the most appropriate approaches for modelling such complex systems as it has the capability to model the complicated relationships between system's entities and to analyse system strategic problems (Warren k. Vaneman *et al.*, 2007). Despite its potential for modelling complex systems, none

of the reviewed publications in port management literature have reported using system dynamic modelling approach.

Integration between traditional approaches (e.g. simulation, cost functions,.. etc.) with system dynamic modelling is likely to attract researchers' attention. This integration can possibly create advanced frameworks with an ability to support decision makers by considering their decisions' impacts on operational, economical, and strategic performances.

4. CONCLUSIONS

Given the recent EU economic reports and trade statistics, maritime transportation is counted as a vital element for Irish economy. Sea-based transport accounted for 84% of the total volume and 58% of the total values of goods traded by Irish economy in 2004. Irish government realised that the effective management of seaports is important for efficient maritime trade flow. Despite that, very few peer-reviewed articles were found reporting Irish seaport management challenges. This paper presents a comprehensive classification of port management issues into three main categories; strategic, economic and operational.

Many port management topics such as; port investment, port reformation, port networks, port accessibility and port charges were studied from strategic perspective. This paper illustrated alternative strategies for these topics and also showed their influences on both strategic and economic seaport performances. Seeking to find the best method for assessing port economic efficiency, literature presented various approaches and techniques. Cost function, throughput analysis, benchmarking and profitability estimation were investigated.

Limited resources, uncertainty and the dynamic nature of seaports are features of seaport systems that require effective strategies to manage seaport operations. Many objectives such as; achieve best utilisation, optimise resource scheduling, minimize maintenance/operating costs and maximize terminal throughput were analysed in port operation management context. Analytical frameworks that integrate simulation modelling with queuing system,

genetic algorithm, simultaneous equations system and cost benefit analysis were used for resolving different seaport operational conflicts (e.g. port capacity, resource allocation and queuing performance).

More research efforts are needed to introduce innovative frameworks which integrate system dynamics with other traditional techniques in order to provide decision makers with a strategic model. Forecasting models for port traffic are another critical requirement for better port investment and performance management.

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