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Simulators Port Operation and its Effect of Container

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ABSTRACT

This paper reviews the relevant literature and provides some background information on the development of marine container terminals and their operations. It aims to address topics closely related to this research and provides overview information of world trends towards container developments, technological changes, terminal operations, logistics processes, and types of resources used in container terminals. It also describes an overview of decision problems at terminals; ways in which these problems are being dealt with including computer simulation, and presents methods used in simulation modelling of container terminals.

1. Introduction

A 'port' can be defined as a "*gateway through which goods and passengers are transferred between ships and shore*" (Wang, Cullinane, & Song, 2005, p. 14). Ports have been natural sites for transhipment in order to transfer goods from one mode of transport to another (King, 1997). They have historically provided the link between maritime and inland transport, the interface between the sea and rivers, and roads and railways (Dowd & Leschine, 1990). At present, ports play an important role in the management and co-ordination of materials and information flows, as transport is an integral part of the entire supply chain (Carbone & De Martino, 2003).

2. Port Terminal Development and Technological Change

Port industry is constantly evolving over time (Ircha, 2001). The evolution of the global ports sector is normally divided into three stages (Hayuth & Hilling, 1992). The first generation port constituted merely the cargo interface between land and sea transport. The second generation of ports emerged between the 1960s and the 1980s and involved their development into transport, industrial and commercial service centres. The third generation in port development emerged in the 1980s, principally due to a worldwide trend towards containerisation and greater intermodal transport, combined with growing requirements of international trade (Hayuth & Hilling, 1992).

3. Changes in Shipping

Fast-growing international seaborne trade in the 1950s and 1960s imposed demands which the shipping industry could not meet with existing technology (King, 1997). Previously, shipping was inadequate, in terms of capacity and efficiency, for transporting the growing volume of cargo across borders (Blumel, 1997). Increased demand in shipping with the existing labour intensive, low productivity cargo handling methods, resulted inevitably in longer delays, growing port congestion and rising costs (Hayuth & Hilling, 1992). Ports became the bottlenecks in the trading system and pressure for change mounted (King, 1997). The shipping industry started changing ship design and building methods to accommodate the increase in demand, with larger dimensions for ocean carriers especially in bulk trades, with a range of new technologies for handling cargo between ship and shore (Cullinane & Song, 2007). Even though the ship designs have changed over the years, little had been done to improve cargo handling (Cullinane & Song, 2007). As shipping lines are the most important clients of a port, the revolutionary changes in shipping forced ports in recent years to change physical design, operations, organizations, and external relations (Cullinane & Song, 2007; Hayuth & Hilling, 1992).

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4. Containers and Ports

The growing use of internationally standardised containers provided the basis for dramatic changes in ports (Blumel, 1997). Perhaps more than any other technological change the container has imposed itself on the internal geography of ports and on the inter-relationship between ports (Peters, 2001). In the early days small numbers of containers could be carried by conventional vessels and handled by high capacity shore cranes or ships' gear (Dekker & Verhaeghe, 2008). As the number of containers increased, specialised ships with gear were used and ports provided gantry cranes for container handling (Dekker & Verhaeghe, 2008). Simultaneously, traditional sheds were replaced by open storage space (Solomenikov, 2006). Various types of straddle carriers replaced the small forklift truck as the backbone of shore operations.

5. Logistics and Supply Chain Approach towards Port Management

After two decades of massive technological change, port managements might have hoped for a period of stability to absorb the changes and gain some revenue from their investments. In the 1980s, and particularly in the later part of the decade, international freight transport embarked on a new cycle of innovations (Ircha, 2001). This new phase of development is characterized by the alteration of the organizational, logistical and regulatory structure of the transport industry (Ircha, 2001; Magableh, 2007). The new trend emphasizes the greater integration and coordination of various components of the transport system and supply chain (Copacino, 1997). Supply Chain Management can be defined as the integration of business processes from end user through original suppliers that provide products, services, and information that add value for customers (Stock & Lambert, 2001). Because of the important role ports are playing as a member of supply chains, they are now considered as part of a cluster of organizations in which different logistics and transport operators are involved in bringing value to the final consumers (O'Leary-Kelly & Flores, 2002; Song & Panayides, 2008). Thus, at present, ports expand themselves as logistics platforms rather than being a mere link between maritime and inland transport (Bichou & Gray, 2004). This requires supply chain members to consider ports as a cluster of organizations in which different logistics and transport operators are involved in bringing value to the final consumers (Bichou & Gray, 2004; Robinson, 2006).The aim is to make the supply chain function so that the right merchandise of the right quality is produced and distributed in the right quantities, to the right locations at the right time in a way that minimizes system wide costs yet meet services level requirements (Tiffin & Kissling, 2007). Ports play an important role in fulfilling this aim as most of these merchandise pass through them.

6. Ports in the Context of Developed and Developing Countries

Recent literature has emphasized the importance of transport costs and infrastructure in explaining trade, access to markets, and increases in per capita income (UNESCAP, 2002). For most developing countries, transport costs are a greater barrier to world markets than import tariffs (UNCTAD, 2001). Port efficiency is one of the most important determinants of shipping costs (UNCTAD, 2002). Improving port efficiency reduces shipping costs (UNESCAP, 2005). In developing countries most of the port infrastructure is underdeveloped006). (World Bank, 2001); and lack of comprehensive planning leads inefficiency in shipping industry (UNESCAP, 2005). Bad ports are equivalent to being 60% farther away from markets for the average country (UNCTAD, 2002). Inefficient ports also increase handling costs, which are one of the components of shipping costs (UNESCAP, 2005). According to World Bank (2001) factors explaining variations in port efficiency in developing countries and developed countries include excessive regulation, the prevalence of organized crime, and the general condition of the country's infrastructure.

7. Operation of Container Ports

Container port operations can be considered as one of the most complex tasks in the transport industry (Clark, Dollar, & Micco, 2004; Mennis, Platis, Lagoudis, & Nikitakos, 2008). This complexity arises due to the nature of interactions, both physical and informational, among different agents involved in container import and export (Clark et al., 2004; Mennis et al., 2008). Sanchez et al. (2003) believe that compounded operational interactions which take place among different service processes at port terminals also make container port operations one of the most difficult in the transport industry. According to Vacca, Bierlaire, & Salani (2007) container port operations can be generally divided into two main operations; (1) quay transfer operations along the berth, (2) storage system in container yards. Quay transfer operation along berth primarily defines the efficiency of a port, and is important to its competitive position (J. Liu, Wan, & Wang, 2005; Ng, 2005). The quayside consists of berths for ships and quay cranes for moving containers (Imai, Chen, Nishimura, & Papadimitriou, 2007). The storage system in container yards act as a buffer between sea and inland transportation or transhipment - storage area for loading, unloading, and transhipping of containers (L. H. Lee, Chew, Tan, & Han, 2006). Storage is normally inevitable as the sizes of ships are often thousands of times the size of land vehicle that carry cargo to and from the port (Moglia & Sanguineri, 2003). Most containers in the terminal have different properties and destinations, and are carried by different vessels (Junior, Beresford, & Pettit, 2003). The container yard is normally separated into different blocks, and each of these blocks is served by yard crane(s) (Yun & Choi, 1999). According to Vecca et al. (2007) the efficiency of a container yard utilization depends on the operation of equipment used in the yard. The equipment determines the height level for stacking containers (Vacca et al., 2007). To achieve land utilization and increase storage capacity, almost all container yards around the world stack their containers in tiers (Vacca et al., 2007). In concentrated terminals, containers are stacked 6-7 level high with a gap of 40cm between rows, whereas in general terminals stacks are limited to

3 - 4 level high with a gap of 150*cm* between rows (Vacca et al., 2007). The operations and management strategies in the container yard ultimately influence the operational efficiency and operating cost of terminal operation as a whole (L. H. Lee et al., 2006).

8. Containerization

Containerization is a system of intermodal freight transport using intermodal containers (also called shipping containers and ISO containers) made of weathering steel. The containers have standardized dimensions. They can be loaded and unloaded, stacked, transported efficiently over long distances, and transferred from one mode of transport to another - container ships, rail transport flatcars, and semi-trailer trucks - without being opened. The handling system is completely mechanized so that all handling is done with cranes and special forklift trucks. All containers are numbered and tracked using computerized systems.

The system, developed after World War II, dramatically reduced transport costs, supported the post-war boom in international trade, and was a major element in globalization. Containerization did away with the manual sorting of most shipments and the need for warehousing. It displaced many thousands of dock workers who formerly handled break bulk cargo. Containerization also reduced congestion in ports, significantly shortened shipping time and reduced losses from damage and theft

8.1. Before containerization

Before containerization, goods were usually handled manually as break bulk cargo. Typically, goods would be loaded onto a vehicle from the factory and taken to a port warehouse where they would be offloaded and stored awaiting the next vessel. When the vessel arrived, they would be moved to the side of the ship along with other cargo to be lowered or carried into the hold and packed by dock workers. The ship might call at several other ports before off-loading a given consignment of cargo. Each port visit would delay the delivery of other cargo. Delivered cargo might then have been offloaded into another warehouse before being picked up and delivered to its destination. Multiple handling and delays made transport costly, time consuming and unreliable.

8.2. Origins of containerization

Containerization has its origins in early coal mining regions in England beginning in the late 18th century. In 1795, Benjamin Outram opened the Little Eaton Gangway, upon which coal was carried in wagons built at his Butterley Ironwork. The horse-drawn wheeled wagons on the gangway took the form of containers, which, loaded with coal, could be transshipped from canal barges on the Derby Canal, which Outram had also promoted. By the 1830s, railroads on several continents were carrying containers that could be transferred to other modes of transport. The Liverpool and Manchester Railway in the United Kingdom was one of these. ”Simple rectangular timber boxes, four to a wagon, they were used to convey coal from the Lancashire collieries to Liverpool, where they were transferred to horse-drawn carts by crane. Originally used for moving coal on and off barges, ”loose boxes” were used to containerize coal from the late 1780s, at places like the Bridgewater Canal. By the 1840s, iron boxes were in use as well as wooden ones. The early 1900s saw the adoption of closed container boxes designed for movement between road and rail.

In 1933 in Europe under the auspices of the International Chamber of Commerce was established The International Container Bureau (French: Bureau International des conteneurs, BIC). In June 1933, Bureau International des Containers et du Transport Intermodal (B.I.C.) decided about obligatory parameters for containers uses in international traffic. Containers handled by means of lifting gear, such as cranes, overhead conveyors, etc.

In the mid-1930s, the Chicago Great Western Railway and then the New Haven Railroad began ”piggyback” service (transporting highway freight trailers on flatcars) limited to their own railroads. The Chicago Great Western Railway secured a US federal patent in 1938 to secure each trailer to a flatcar using chains and turnbuckles. Other components included wheel chocks and ramps for loading and unloading the trailers from the flatcars By 1953, the CB&Q, the Chicago and Eastern Illinois, and the Southern Pacific railroads had joined the innovation. Most cars were surplus flatcars equipped with new decks. By 1955, an additional 25 railroads had begun some form of piggyback trailer service.

During World War II, the Australian Army used containers to help overcome the various breaks of gauge. These non-stackable containers were about the size of the later 20-foot ISO container and perhaps made mainly of wood. Toward the end of World War II, the US Army used specialized containers to speed the loading and unloading of transport ships. The army used the term ”transporters” , to identify the containers, for shipping household goods of officers in the field. A transporter was a reusable container, 8.5 feet (2.6*m*) long, 6.25 feet (1.91*m*) wide, and 6.83 feet (2.08*m*) high, made of rigid steel and with a carrying capacity of 9,000 pounds. During the Korean War the transporter was evaluated for handling sensitive military equipment and, proving effective, was approved for broader use. Theft of material and damage to wooden crates convinced the army that steel containers were needed.

In 1952 the army began using the term CONEX, short for ”container express”. The first major shipment of CONEXes, containing engineering supplies and spare parts, was made by rail from the Columbus General Depot in Georgia to the Port of San Francisco, then by ship to Yokohama, Japan, and then to Korea, in late 1952; shipment times were almost halved. By the time of the Vietnam War the majority of supplies and materials were shipped by CONEX. After the US Department of Defense standardized an 8-foot by 8-foot cross section container in multiples of 10-foot lengths for military use, it was rapidly adopted for shipping purposes.

In 1955, former trucking company owner Malcom McLean worked with engineer Keith Tantlinger to develop the modern intermodal container. The challenge was to design a shipping container that could efficiently be loaded onto ships and would hold securely on long sea voyages. The result was a 8 feet (2.4m) tall by $8ft$ (2.4m) wide box in $10ft$ (3.0m) -long units constructed from 2.5mm (0.098in) thick corrugated steel. The design incorporated a twist lock mechanism atop each of the four corners, allowing the container to be easily secured and lifted using cranes. After helping McLean make the successful design, Tan linger convinced him to give the patented designs to industry; this began international standardization of shipping containers

8.3. Toward standards

During the first 20 years of containerization, many container sizes and corner fittings were used; there were dozens of incompatible container systems in the United States alone. Among the biggest operators, the Matson Navigation Company had a fleet of 24-foot (7.3m) containers, while Sea-Land Service, Inc used 35-foot (11m) containers. The standard sizes and fitting and reinforcement norms that now exist evolved out of a series of compromises among international shipping companies, European railroads, US railroads, and US trucking companies. Four important ISO (International Organization for Standardization) recommendations standardized containerization globally.

Double-stacked rail transport, where containers are stacked two high on railway cars, was introduced in the United States. The concept was developed by Sea-Land and the Southern Pacific railroad. The first standalone double-stack container car (or single-unit 40-ft COFC well car) was delivered in July 1977. The 5-unit well car, the industry standard, appeared for the first time in 1981. Initially, these double-stack railway cars were deployed in regular train service. Ever since American President Lines initiated in 1984 a dedicated double-stack container train service between Los Angeles and Chicago, transport volumes increased rapidly

8.4. Effects

Containerization greatly reduced the expense of international trade and increased its speed, especially of consumer goods and commodities. It also dramatically changed the character of port cities worldwide. Prior to highly mechanized container transfers, crews of 20 - 22 longshoremen would pack individual cargoes into the hold of a ship. After containerization, large crews of longshoremen were no longer necessary at port facilities, and the profession changed drastically.

Meanwhile, the port facilities needed to support containerization changed. One effect was the decline of some ports and the rise of others. At the Port of San Francisco, the former piers used for loading and unloading were no longer required, but there was little room to build the vast holding lots needed for container transport. As a result, the Port of San Francisco virtually ceased to function as a major commercial port, but the neighboring port of Oakland emerged as the second largest on the US West Coast. A similar fate met the relation between the ports of Manhattan and New Jersey. In the United Kingdom, the Port of London and Port of Liverpool declined in importance. Meanwhile, Britain's Port of Felixstowe and Port of Rotterdam in the Netherlands emerged as major ports. In general, inland ports on waterways incapable of deep-draft ship traffic also declined from containerization in favor of seaports. With intermodal containers, the job of sorting and packing containers could be performed far from the point of embarking.

The effects of containerization rapidly spread beyond the shipping industry. Containers were quickly adopted by trucking and rail transport industries for cargo transport not involving sea transport. Manufacturing also evolved to adapt to take advantage of containers. Companies that once sent small consignments began grouping them into containers. Many cargoes are now designed to fit precisely into containers. The reliability of containers also made just in time manufacturing possible as component suppliers could deliver specific components on regular fixed schedules

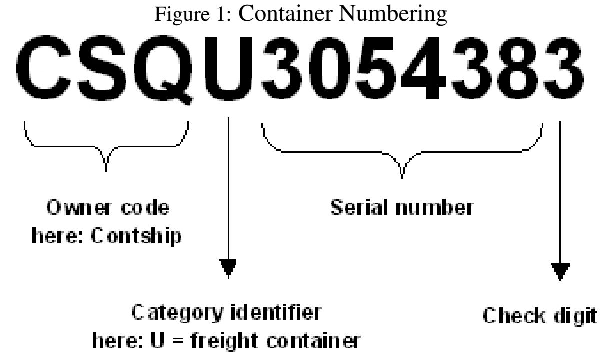
8.5. ISO standard

There are five common standard lengths: $20ft$ (6.10m), $40ft$ (12.19m), $45ft$ (13.72m), $48ft$ (14.63m), and $53ft$ (16.15m). US domestic standard containers are generally $48ft$ (14.63m) and $53ft$ (16.15m) (rail and truck). Container capacity is often expressed in twenty-foot equivalent units (TEU)

Table 1: Container Dimension

20 Foot Container = 1 TEU			
Length:	20ft	=	6,09m
Width:	8ft	=	2,44m
Height:	8ft 6in	=	2,6m
40 Foot Container = 2 TEU			
Length:	40ft	=	12,18m
Width:	8 ft	=	2,44m
Height:	8ft 6in	=	2,6m

Figure 1: Container Numbering



- Owner Code:

  Consists of three capital letters of the Latin alphabet to indicate the owner or principal operator of the container

- Category Identifier

Consists of the following four capital letters of the Latin alphabet

- U for all freight containers

- J for detachable freight container-related equipment

- Z for trailers and chassis

- R for Reefer containers

- Serial Number

  Consists of 6 numeric digits, assigned by the owner or operator, uniquely identifying the container within that owner/operator's fleet

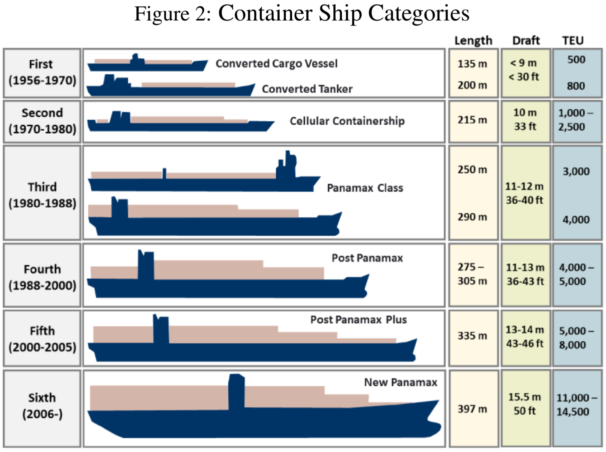
- Check Digit

  Consists of one numeric digit providing a means of validating the recording and transmission accuracies of the owner code and serial number

Container Inspection (CSC)

In general, any container used for international transport must have a valid safety approval plate or ”CSC plate”. CSC is the abbreviation for Container Safety Convention. In order to avoid damage in transit, the container should, however, be properly inspected before and after packing.

Figure 2: Container Ship Categories



8.6. *Container Trade WorldWide*

Table 2: Estimated and Dorecast Growth Rates for Container Trade (1980-2015)

Year	Containers Volumens (million TEU)	Compound Average Growth rate over previous period
1980	13,5	-
1990	28,7	7,8%
2000	68,7	9,1%
2010	138,9	7,3%
2015	177,6	5,0%

Container Handling Equipments

- Quay Crane

Figure 3: Distribution of Container Volumens - 2002

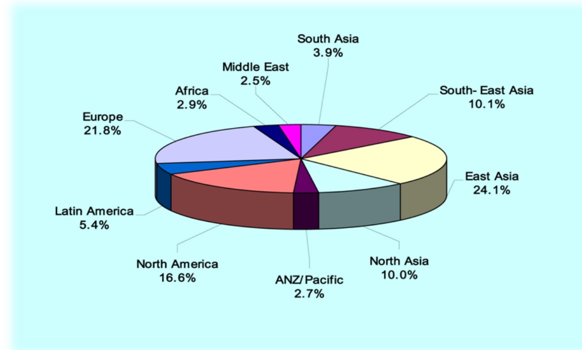
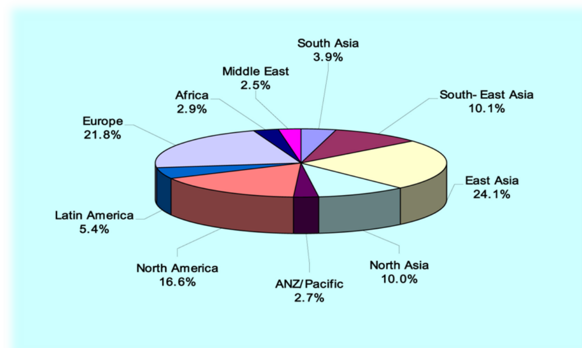


Figure 4: Distribution of Container Volumens - 2015



- Gantry Crane
- Transtainer
- Straddle Carrier
- Rail Mounted Gantry Crane
- Container Truck Loading
- Container Chassis
- M/T Container Loader
- Reach Stacker
- Side Loader
- Mobile Crane
- Top Loader
- Container Runner
- Container Spreader
- Twist Lock
- Corner Casting
- Telescopic Spreader
- Fixed Spreader
- Container Automated Guided Vehicle (AGV)

9. The Problems of Containerization

- Site Constraint

  Large consumption of terminal space; move to urban periphery. Draft issues with larger containerships.

- Infra Cost

Container handling infrastructures (giant cranes, warehousing facilities, inland road, rail access), are important investments.

- Stacking

  Complexity of arrangement of containers, both on the ground and on modes (containerships and double-stack trains).

- Management Logistics Requires management and tracking of every container. Recording, (re)positioning and ordering of containers.

9.1. Hazards

Containers have been used to smuggle contraband. The vast majority of containers are never subjected to scrutiny due to the large number of containers in use. In recent years there have been increased concerns that containers might be used to transport terrorists or terrorist materials into a country undetected. The US government has advanced the Container Security Initiative (CSI), intended to ensure that high-risk cargo is examined or scanned, preferably at the port of departure.

9.2. Empty Containers

Containers are intended to be used constantly, being loaded with new cargo for a new destination soon after having been emptied of previous cargo. This is not always possible, and in some cases, the cost of transporting an empty container to a place where it can be used is considered to be higher than the worth of the used container. Shipping lines and container leasing companies have become expert at repositioning empty containers from areas of low or no demand, such as the US West Coast, to areas of high demand, such as China. Repositioning within the port hinterland has also been the focus of recent logistics optimization work. However, damaged or retired containers may also be recycled in the form of shipping container architecture, or the steel content salvaged. In the summer of 2010, a worldwide shortage of containers developed as shipping increased after the recession, while new container production had largely ceased.

9.3. Loss at Sea

Containers occasionally fall from ships, usually during storms; according to media sources, between 2,000 and 10,000 containers are lost at sea each year. The World Shipping Council states in a survey among freight companies that this claim is grossly excessive and calculated an average of 350 containers to be lost at sea each year, or 675 if including catastrophic events. For instance, on November 30, 2006, a container washed ashore on the Outer Banks of North Carolina, along with thousands of bags of its cargo of Doritos Chips. Containers lost in rough waters are smashed by cargo and waves, and often sink quickly Although not all containers sink, they seldom float very high out of the water, making them a shipping hazard that is difficult to detect. Freight from lost containers has provided oceanographers with unexpected opportunities to track global ocean currents, notably a cargo of Friendly Floatees. In 2007 the International Chamber of Shipping and the World Shipping Council began work on a code of practice for container storage, including crew training on parametric rolling, safer stacking, the marking of containers, and security for above-deck cargo in heavy swell. In 2011, the MV Rena ran aground off the coast of New Zealand. As the ship listed, some containers were lost, while others were held on board at a precarious angle

9.4. Trade Union Challenges

Some of the biggest battles in the container revolution were waged in Washington, D.C. Intermodal shipping got a huge boost in the early 1970s, when carriers won permission to quote combined rail-ocean rates. Later, non-vessel-operating common carriers won a long court battle with a US Supreme Court decision against contracts that attempted to require that union labor be used for stuffing and stripping containers at off-pier locations

9.5. Other uses for containers

Shipping container architecture is the use of containers as the basis for housing and other functional buildings for people, either as temporary or permanent housing, and either as a main building or as a cabin or workshop. Containers can also be used as sheds or storage areas in industry and commerce. Tempo Housing in Amsterdam stacks containers for individual housing units. Containers are also beginning to be used to house computer data centers, although these are normally specialized containers. There is now a high demand for containers to be converted in the domestic market to serve specific purposes. As a result, a number of container-specific accessories have become available for a variety of applications, such as racking for archiving, lining/heating/lighting/power points to create purpose-built secure offices, canteens and drying rooms, condensation control for furniture storage, and ramps for storage of heavier objects. Containers are also converted to provide equipment enclosures, pop-up cafes, exhibition stands, security huts, and more.

10. Simulations

Robinson (2004, p.4) has defined simulation as Experimentation with a simplified imitation (on a computer) of an operations system as it progresses through time, for the purpose of better understanding and/or improving that system. Others (e.g. Banks et al. 2005) offer a relatively similar definition. Robinson (2004) has also compared simulation with other modelling approaches and identified three main differences, which are summarized bellow Modelling variability Many traditional modelling approaches do not contain stochastic elements, which can have a big impact on the results. Restrictive assumptions Simulation does not require restrictive assumptions that do not exist in the real system, but are included in other modeling approaches. Transparency It is easier to get buy-in from a model with an animated display of the real system compared to equations or large spreadsheet models. The simulation process contains many phases. According to Banks et al. (2005), most processes are relatively similar to each other. Some differences may occur due to different simulation approaches, but generally speaking the processes are the same. Figure 10 shows the simulation process as a flowchart.

The simulation process begins by formulating the problem. The policymaker and analyst must agree on a good problem articulation in the very beginning of the project. It is also important to set the overall objectives and create an overall plan before modelling begins (Sterman 2000, Banks et al. 2005, North and Macal 2007). After the formulation of the problem, the model has to be conceptualized. Depending on the chosen simulation approach, there are different methods to accomplish this. In System Dynamics, causal loop, model boundary, and policy structure diagrams are usually formed (Sterman 2000). In Agent-Based Modelling, the potential agents in the model and how they make their decisions need to be considered (North and Macal 2007). In Discrete-Event Simulation, the potential entities in the system, events, activities and delays are considered (Banks et al. 2005). This needs to be conducted before the actual computer simulation model can be created. Data collection occurs during the whole simulation project as the model is refined and modified. The data may already exist in databases, it can be gathered from public sources, or needs to be gathered from the real system. When the conceptual model is ready, it is translated to a computer model. Here the modeler needs to choose the appropriate program and start writing the actual code. (Banks et al. 2005; North and Macal 2007) Stochastic elements, which can have a big impact on the results. Restrictive assumptions Simulation does not require restrictive assumptions that do not exist in the real system, but are included in other modeling approaches.

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10.1. Advantages of Simulation

According to Banks (1998), there are many advantages associated with simulations. According to Robinson (2004), simulations have four advantages. The first advantage is fostering creativity, as simulations allow trying out ideas in a risk-free environment. The second advantage is knowledge creation and understanding. Simulation can work as a catalyst, allowing people to think about a problem in a different way, which helps them to understand the system better. The third advantage is visualization and communication. A visual simulation is a good way to communicate ideas to others. It makes buy-in easier to achieve when the proposed system can be presented in a visual environment. The last advantage is consensus building. Simulations allow parties with differing opinions to share their concerns on an objective platform and to test ideas, which help in creating consensus between the parties.

10.2. The aspects to use simulation

Banks et al. (2005) provide a comprehensive list of the purposes of using simulations:

- Simulation allows studying the interactions of a complex system
- Different changes can be simulated and their effects on the system observed
- Important knowledge is generated during the designing of a simulation model
- Varying inputs can generate information about the most sensitive variables
- can be used as part of teaching to enforce ideas from analytical methods
- Can be used to experiment on new designs or policies
- Can be used to verify analytic solutions
- Can help estimate requirements for a machine
- Can be used as part of training without on-the-job instructions
- Plans can be animated with the help of simulation
- Modern systems are too complex to be analyzed without the help of simulations. Banks et al. (2005) have also summarized some frequent topics in the main Discrete- Event Simulation conference, the annual Winter Simulation Conference. The areas include manufacturing, semiconductor manufacturing, construction engineering and project management, military applications, logistics, supply chain and distribution, transportation modes and traffic, business process simulation, and health care. On the other hand, in the main System Dynamics simulation conference, the annual conference of the System

Dynamics Society, the topics include governance, business application, complexity, conflict and defence, economics, education, energy, strategy, etc. As such, it is clear that simulations can be used in a wide area of applications, and different approaches have advantages in different areas.

10.3. The Aspects Unfit to Use Simulation

Banks and Gibson (1997) have defined 10 rules which indicate when simulation may not be an appropriate tool. These rules are:

- The problem can be solved by using "common sense analysis"
- The problem can be solved analytically (using a closed form)

It is easier to change or perform direct experiments on the real system:

- The cost of the simulation exceeds the possible savings
- There are no proper resources available for the project
- There is not enough time for the model results to be useful
- There is no data - not even estimates
- The model cannot be verified or validated
- Project expectations cannot be met
- The system behavior is too complex or cannot be defined.

The first three rules indicate that an "easier" solution is available by either making direct experiments with the system or by constructing an analytical model of the problem. Rules four to nine can be seen to be project management issues. Simulation modelling usually takes a long time, and requires a lot of data and a high amount of expertise from the modelers. The last rule concerns the human aspect of operations. In an extreme situation people may not work according to normal operational rules and it might be impossible to anticipate every work procedure taking place in these situations.

11. Simulations and Decision Support Systems

Decision-making has always been an important part of organizations. In the beginning of the 1960's, Simon (1960) approached decision-making from the perspective of different types of decisions. Some decisions are programmed, which means that they are repetitive and routine, and a procedure to solve them exists. On the other end of the spectrum are non-programmable problems, which do not have a predefined procedure for dealing with them. Gorry and Scott Morton (1971) expanded Simon's framework with Anthony's (1965) framework of planning and control system, where the focus was on the type of the problem, e.g. whether the problem was an operational control, management

11.1. Transport Chain Simulatiors

The Transport Chain Simulator is designed to simulate the information flows, communication flows, flow of goods and documentation flows, related to the actual transportation of goods. Participants can fulfill various functions in the simulator, which are common in the transport chain, such as forwarder, stevedore, broker, customs or even a bank. Participants acting in the simulation course are placed in a modern office environment and are provided with all equipment, as there are computers, printers, e-mail facilities, telephone and video conferencing. Functions that are not covered by the students can be executed by the simulator. the Transport Chain Simulator makes complete and correct use of Electronic Data Interchange (EDI). The skills needed for making the right choices of (electronic) transport documents as well as filling in these documents are developed during simulations. This option enables (transport) companies to train their administrative personnel.

11.2. STS Crane Simulator

The KraneSIM is an advanced Seaport Cargo Handling Crane Simulator which can be used to simulate a wide variety of dockside cranes, spreaders, terminal vehicles and load types, such as:

- Ship-to-Shore (STS) / Quayside Crane (QC)
- Rubber-Tired-Gantry (RTG)
- Rail Mounted Gantry (RMG)
- Mobile Harbour Crane (MHC)
- Straddle Carriers
- Dock & Ship Pedestals
- Single, Twin and Tandem Spreaders

KraneSIM is designed to meet the training requirements of Ports, Stevedoring & Cargo Companies, Shipping Companies and Training Organisations for general container handling and specific crane operations training related to combined vessel loading and unloading operations.

The simulator can be used to asses participants for their competency in container handling operations. In particular competency can be assessed during the back dock storage and handling areas using the Rubber Tired Gantry or the Straddle Carrier crane training modules as well as handling a wide variety of loose and bulk cargo using the Mobile Harbour Crane module.Also can KraneSIM be used to train crane operators, checkers and other personnel in equipment operations and advanced load handling as well as more advanced aspects such as troubleshooting the various crane controls and safety systems including the Emergency Shutdown Systems and where applicable safe load indicators.

11.3. Simulation Approaches

Many different types of simulations can be created, as it is possible to code the whole source code for the required model. However, modellers usually use platforms, which provide a versatile way to conduct simulations. On the other hand, most programs only allow for one type of simulation, and all approaches have their own advantages. Jahangirian et al. (2010) have analyzed in a recent survey the use of simulations in manufacturing and business. The most widely used approaches are Discrete-Event Simulation (DES), System Dynamics (SD), Hybrid models (combining two or more approaches in one model), and Agent-Based Modelling (ABM). Three simulation approaches (SD, DES, and ABM) are presented in this section.

11.4. System Dynamics

The field of SD originates from the late 1950s when Jay W. Forrester work on the bullwhip effect of supply chains (Forrester 1958). SD tries to understand dynamic complexity, whereas in optimization the interest is in detailed complexity (Sterman 2000). In detailed complexity, the complexity arises from the number of potential combinations existing in the solution space. According to Sterman (2000), dynamic complexity has many different sources, SD uses stock-and-flow diagrams to create the actual simulation models. As the name of the diagram indicates, the main elements used in SD are stocks and flows. Stocks represent accumulations in the model and provide important information to various parts of the model. Flows, on the other hand, shift the entities between stocks and the boundary of the model. The boundaries of models are sources and sinks, which are basically stocks with infinitive capacity. In addition to these, different auxiliary variables help to store certain information during the simulation. The models themselves are simply a large collection of differential equations. (Sterman 2000)

11.5. Reasons for Dynamic Complexity (Sterman 2000)

Dynamic Everything changes through time Tightly coupled Everything inside a system is connected to other actors and even the natural world Governed by feedback Each action creates changes in the system, which then interact back to the original actor Nonlinear Systems tend to be nonlinear. Production can never be negative, no matter how much inventory exists History-dependent Path-dependence exists in many situations Self-organization Dynamics of systems emerge through interaction in the internal system Adaptive Agent rules in complex systems change over time Counterintuitive Cause and effect are separated in time, which makes learning difficult Policy resistant Systems are too complex to understand, which makes obvious solutions fail Characterized by trade-offs Long-term effects tend to differ from short-term effects, which may make good decisions perform poorly initially As mentioned in Section 3.1.3, SD is currently used in a wide variety of areas. SD began from the analysis of supply chains and it is still a widely used method in analyzing supply chains.

11.6. Discrete-Event Simulation

As the name implies, DES uses discrete events, which are executed during the simulation. The history of DES goes back to the 1950s. According to Nance (1996), the first simulator was the General Simulation Program (GSP). An important concept during the simulation is clock time. Different events occur according to a calendar. Whatever the next event, the system will activate the event as soon as the clock time reaches the next active event in the calendar. White and Ingalls (2009) have provided an overview of DES.

The most important concepts in DES are presented bellow Inputs Actions of environment on the system Outputs Measured quantities State Internal condition of the system Entities Dynamic entities which flow through the structure Attributes Unique characteristics of an entity Activities Processes and logic in the model Events Conditions occurring during the simulation, causing a change in the state of the system Resources Anything which has a constrained capacity Global variables Variables containing information about the system.

Random number generator Generates randomized values to be used during the simulation Statistics collector Collects statistics on the conditions Usually DES uses queues and servers (Banks et al. 2005). The entities enter the model hrough a source and go into a queue. As soon as a server is available, the entity gets processed after a delay. After a delay the entity can go into another server and may end up in a queue. According to Jenkins and Rice (2009), resource models can be categorized according to the complexity of the servers and clients.

The more intelligence is included in the model, the more features it needs to have. Servers and clients are still important issues in DESs, but the more computational power there exists, the easier it is to have more intelligence inside the models. Like SD, DES is a widely used approach to analyze supply chains. The yearly conference, Winter Simulation Conference, attracts over 500 participants each year and the main area of interest is in DES. Since 1998, one of the tracks has been logistics, and it still gathers a good number of papers.

11.7. Agent-Based Modelling

ABM is a relatively new approach in simulations. The roots can be seen to go back to von Neumann machines, but ABM started to gather more interest in the 1990s when the computers became more powerful (Macal and North 2005). Cellular automata also played a role on the development of ABM.

One of the earliest applications was Schelling's segregation model (Schelling 1969; 1971). In the model the environment consists of a grid, and each square represents one potential location for a household. Each household will check the number of neighbors who have the same condition as they have (this can be race, income level, education, etc.). The model then contains a threshold value, which indicates whether a household will move to a new location, if too many neighbors do not share the same characteristics. The dynamics of the whole system then emerges from each actorÂ´s decisions. The emergent behavior drives the model towards segregated environments, where only one characteristic is dominant. Similar approaches have later been presented by Conway in the Game of Life (first appeared in Scientific American, Gardner 1970) and Epstein and Axtell (1996) in their Sugars cape model. According to Macal and North (2006), there are four reasons behind the growing interest in ABM. The first reason is that observed systems are becoming more complex in terms of interdependence. Different parts of the system are even more connected. The second reason is that some systems have been too complex to model with other approaches. The third reason is the organization of data at finer levels of granuility in databases, and the fourth reason is the increase in computational power. However, most of the work is still on a conceptual level and few empirical models exist (Davidsson et al. 2005; Hilletofth et al. 2010; Chen & Cheng 2010).

There are some basic principles in ABM. As the name implies, agents are the main area of interest. The agents belong to one or more environment. Each agent will gather information from its local environment and will then make its autonomous decisions. The decisions lead to interaction with other agents and the environment. Each agent also has some sort of goal which it tries to achieve. (Wooldridge and Jennings 1995) Many different ways to classify agents have been presented. There are many ways to classify agents, and Schieritz and Milling (2003) conclude that there is no agreement about the issue on the subject. Schieritz and Milling have provided a good overview of the different classifications of ABM. Wooldridge and Jennings (1995) Computer science Macal and North (2006) Practical modeling Nwana (1996) Software perspective Shehory (1998) Software architecture Haeyes-Roth (1995) Artificial intelligence As ABM is the newest approach of the simulation, there are not many studies containing an empirical case that has been simulated. A vast majority of research is still on the conceptual level.

12. Conclusions

There is no doubt that the use of simulation in the multi-terminal operations beginning of trading operations and stowage and then inland transport process to temporary storage or final places have many pros effect, positively contribute to design the most appropriate in terms of the work of homogeneous groups of assets available scenario container terminal so as to yield the highest possible return at the lowest cost available, an economist important principle to be followed so that we can material and human resources available to the development of the container terminal as simulators operations contribute to reducing trading costs of the container and then positively reflected on the added value of the container terminal as simulators operations contribute to the identification human resources and training levels that are commensurate with the output of container operations as simulations contribute in determining what is known as reduction the cost of training and already Reflections application simulations more positively on the incomes of the terminal

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