



# The importance of information technology in port terminal operations

Port terminal  
operations

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**Keywords** *Information technology, Ports, Supply-chain management, Logistics*

**Abstract** *Information technology has become an essential part of the rapid and accurate transfer and processing of enormous volumes of data processed in international transport firms and port organisations. The proper management of systems, which process this information and communicate it to those who manage port operations, is vital for efficient transport. This explains why container-tracking systems are given high priority among operational computer applications in ports. Investigates the importance of information technology and its role in improving the operational systems in cargo handling. A computer simulation model is developed to compare two different operational systems – a container terminal equipped with electronic devices versus a terminal without such devices. The importance of information technology in supply-chain management is also discussed.*

## Introduction

Owing to the monopoly of only two major terminal operators in Australia, the necessary conditions for inter-port competition are not generally present. In the last three years, the introduction of the third operator was the basis of several debates (*Lloyd Australian Weekly*, 1999). The operators believe that the existing terminals can absorb the trade growth of 6 to 8 per cent up to the year 2020 (Bascombe, 1998). In contrast, the port authorities in Australia (the responsible body for providing port facilities) believe that the current capacity of container terminals will not meet the demands by 2006-2007 and should be expanded. It is not the intention of this paper to justify the above claims/counterclaims, but to investigate the operational inefficiencies caused by the lack of information technology in terminal operations leading to port congestion.

Since the introduction of containers in the 1960s, determination of the optimum capacity of container terminals has been a major issue for port authorities around the world. This is primarily due to the requirement of a huge capital investment for the expansion of a port. For example, the construction cost of a two-berth container terminal would be around \$150 million (£98 million) excluding dredging and navigation channel modifications (1999 price). When the capacity of stacking area does not meet the demand (through-put), the operators have two options:

- (1) the extra containers must be taken away from the terminal to the designated inland depots near the port for distribution; or
- (2) the terminal must be expanded.

The former applies to most congested ports (e.g. port of Sydney in Australia) that experience congestion particularly prior to the arrival and shortly after the departure of ships (Kia, 1997). This raises the question of when a terminal reaches its maximum capacity since the stay time of containers varies from one port terminal to another. For example, the maximum stay time of containers in tranship ports (i.e. Singapore) is eight hours, whereas, Australian ports offer 72 hours' stay (free of charge) to the exporters and importers. Container stay-time is affected by other factors that cause congestion within the terminal and longer ship's time at berth (Kia, 1999):

- inadequacy in container handling from ship-to-shore and within terminal;
- container through-put (total TEU/year/area of the terminal);
- height of stacked containers;
- the high ratio of imported containers against exported ones; and
- ratio of empty/full containers.

### **The importance of information technology in supply-chain management**

Supply-chain management can be defined as:

all processes concerned with the enhancement of movement and handling of goods from point of production (supply) to point of consumption (demand).

Supply-chain management is a process responsible for development and management of the total supply system of a firm, both the internal and the external components (Burt, 1996). During the past two decades, the maritime industry has witnessed the evolution of one of the most important trends in the history of port community – the increasingly sophisticated use of computers. Although these devices and electronic commerce have found applications in port/transport industry, the business sector is a major beneficiary (Burt, 1996).

Electronic commerce (EC) may be defined as the use of technology to facilitate the exchange of information in commercial transactions among enterprises and individuals, enhancing growth and profitability across the supply chain (Heffernan, 1998). Based on the estimates produced by the US Government, the global free market of information technology and telecommunications via Internet is doubling every 100 days by individuals and businesses (Phillips, 1999). As a transaction payment method and delivery medium, the cost-effectiveness of the Internet and EC is now disputable. In Australia, approximately 1.5 million organisations and individuals have access to the Internet; of those, approximately 250,000 are business related. The worldwide volume of EC conducted over the Internet and its derivatives is expected to reach US\$300 billion a year by the early part of the next decade. It is in the business-to-business application of EC that the Internet is beginning to transform the global supply chains of international trade. In international transportation and logistics services, the already vigorous growth in the

volume of global trade is likely to be further accelerated as EC facilitates new connections of buyers and suppliers. In the Australian maritime industry, terminal operators and port/transport industry intend to develop a longer-term approach to EC to improve the efficiency of operations, aiming to enhance the competence of their existing operational system (Cox, 1999).

Given the complexity of the supply chain, with multiple participants, there is ample opportunity to increase efficiency and reduce costs by EC, which enables integration of the increasingly tighter links in the supply chain. The efficient usage of EC in shipping and cargo distribution could provide:

- transportation management, including optimising the choice of carriers based on service requirements and freight rates;
- logistics management, including the tracking of containers from the port of origin to the port of unloading in Australia, on the rail track and between origin and the final destination and flexible routeing, storage and distribution as necessary;
- trade and transportation documentation, including the electronic development and transfer of shipping documents, customs clearance and other regulatory requirements;
- international trade finance; and
- insurance.

Although this paper, as a small part of a larger study, does not cover application of the Internet in port operations, the authors acknowledge that as an inevitable future trend of this business which will further simplify the suggestions made in their current studies.

### **Data transmission in the port terminal**

To shorten time spent by vessels in the terminal requires that special emphasis be placed on receiving details of containers (e.g. shipment, physical location) prior to the arrival of the vessel to reduce the US\$45,000/day (£30,000) stay of a third generation of containership or US\$65,000 (£42,000) of a large vessel at port. Hence, the development of containerisation is accompanied by the application of computerised tele-transmission of manifest and stowage plan details from the port of loading to the port of discharge. Transmitted data are used to plan discharging operations, as well as to print required report documentation. For a container terminal equipped, for example, with ship-to-rail technique, accurate and current information on all container operations is vital. A properly-designed, computerised container control system increases the operating efficiency of the terminal. However, the main benefits provided by such a system are the following:

- faster discharging and loading of containers;
- increased productivity through faster turnaround of containers;

- better monitoring of the storage of containers (leading to increases in stacking area's capacity);
- high level of accuracy of information; and
- high level of consistency of the information given to various parties in the chain of transport.

Depending on the number of containers handled, three types of data processing systems are also required in port terminals: off-line central system, online multi-point system and online multipoint system with direct telecommunication to yard mobile equipment.

The first type records the container movements centrally, usually in the operation centre of the terminal, i.e. the point of loading on train, the length of transportation and the terminal that the containers are to be unloaded. Basically, the information is recorded in the computer system rather than using the old methods of board or card file system. One of the advantages of such a system over a manual one is that data can be automatically validated during data entry.

The second type consists of a multipoint system giving direct access to the computer from the points where movements of containers take place (e.g. port-to-inland depots). This system provides updated information on the status of the train/truck such as travelling time, departure time and the time of arrival at destination. This is the area that provides necessary information to the freight forwarders.

The third type offers the possibility for communication of yard operations via computer, particularly between the operator of the crane and container management personnel. The cabin of the crane operator is equipped with visual display units (VDU) and simplified keyboards. The driver receives on the VDU an order to move a container. Confirmation of the execution of the order on the keyboard causes automatic updating of the container layout. This solution makes it possible to follow container movements very closely and also facilitates execution of loading or discharging operations.

The above data process systems are currently in place in several US (e.g. Long Beach), European (e.g. Rotterdam) and Asian (e.g. Singapore) ports.

### **Electronic devices in container terminals**

Providing reliable service to the interacting elements of the transportation chain is a major objective of any container terminal. Within a port community, the effective flow of information is considered to be an important variable. For example, in an eight-berth terminal where eight ships are berthed for loading/unloading some 6,000 containers simultaneously, a highly sophisticated information technology is required to provide reliable and timely information for hundreds of people within the port/transport community. Among them are freight forwarders, transport companies, rail operators, crane operators and container carriers in terminals.

To carry out an effective data management, appropriate electronic devices must be used. However, despite the fact that several devices are available in the market, they are not employed in every container terminal. Whilst they can operate as individual devices in ports and outside terminals (e.g. rail track), they should be integrated to the port and transport network communications via a computer system. Only a few international ports have taken maximum advantages of the existing devices to improve their operational efficiency, minimise terminal congestion and establish a fully integrated system (*World Cargo News*, 1997). A brief description of the following devices aims to explain their importance in container tracking, recording, movements and segregation of imported/exported containers.

#### *Microwave technology*

Automated container identification procedures are in the stage of research and development, conducted collaboratively by the shipping operators (*World Cargo News*, 1997). At present, material handling systems are generally manually operated. One of the few US terminals (e.g. Long Beach, Los Angeles) have gone beyond the experimental stage of advancing the state of practice of material handling. Some have employed computer process control to minimise crane travel time from ship's hull to the quay. Microwave technology is simply employed to track the placing and pick-up of containers by recording relevant data on tags installed on the containers. In ship-to-rail direct loading at the terminal, for example, this method would reduce the crane's waiting time when the spreader is in the ship's hull. This is the area in which significant ship's time including human resources can be saved or wasted and the performance of port terminals is appraised.

The system is called "prime mover tracking system" (PMTS) which enables the terminal supervisor to track the unloaded containers at any time while containers are in the terminal. The PMTS enables the operator to track the containers and feed back the location of the containers to the central information system where data can be checked. Any difference between the commanded and the actual slot can be readily spotted when the operator activates the twist lock (four connecting points on the four corners of the container and the spreader of the crane).

As the container comes off the ship, its identification number is read and stored in a computer, PC. When the container is loaded on to the terminal trailer, the ID number is written into a re-writable tag that is then mounted on the terminal tractor. In the absence of totally reliable, automatic PMTS, it is assumed that the ID data are input manually to the PC by a checker. The container ID data are transmitted by wire to a tag-writer installed on the leg of the container crane and then transmitted to the tag. In this system, no fibre optical or other links between the PC and the tag-writer are required. The tag also contains fixed information identifying the tag itself. When the container carrier arrives at the stacking area, the tag is read by a tag-reader installed on

the leg of the yard crane, connected to a computer on the cabin of the crane. The actuation of the spreader twist-locks signals the on-board computer to interrogate the tag reader.

The trolley of the yard crane is then driven to the desired slot. The position of the trolley can be obtained from the PMTS that is accurate to less than one metre. The on-board computer uses its stored image of the stacking area to identify where the container has been placed. The data are transmitted via a radio data link to the central information system and stored in a database. In principle, the tag could also be mounted on the equipment such as straddle carriers, forklifts, stackers and intermodal rail wagons. This system facilitates the identification of containers on the train. The PMTS workstation is connected to the reference station with an integrated data transceiver. The workstation is a Pentium PC that interrogates the position data from the container carriers, stores the data, together with heading and speed and provides indications of status and errors. As stated above, the PMTS is a new innovation in facilitating the container handling particularly where the large number of containers should be stacked in terminal. The maximum advantages of the system can be realised where the container handling is carried out by RTG (rubber-tyred gantry) capable of stacking up to eight containers high and nine containers wide.

#### *Tagging technology in transportation of cargo by rail*

Recent advances in microwave technology include a tag that allows data read or write. The tag can contain up to 4,000 characters of data that can be updated by radio signals broadcaster installed in the terminal or alongside of the train track (e.g. automated wagonload operations on the New Zealand railway system). The tags can be read while the train is moving at up to 110km/hr. This system must be modified when the fast freight trains (160km/hr operate in Japan and Germany) are used for freight transportation.

The antenna used in this system creates an inductive radio frequency field to activate and receive data from tags. It contains a transmit-coil with associated tuning and matching components, and a receive-coil. When a consignment is loaded on the train, the computer will be able to provide relevant information on content of containers loaded on the train, wagons and destinations. Information is then passed to the yard staff. Based on this information, a work order is passed to the crew of the train. As the train leaves the yard, an automated vehicle identification (AVI) reader reads the tags on each wagon and sends a message to the central computer to compare the manifest with information in the central computer. At the same time, the wagons are weighted to check for load discrepancies. Both sets of data are then sent ahead of the train to the next stop so that the freight forwarders can be advised of arrival.

#### *Barcode scanner*

A barcode scanner would help the customs decide whether physical inspection of containers is required particularly when several vessels unload thousands of

containers simultaneously. Barcode and optical character recognition are basically two automatic identification systems. They are environmentally sensitive and application restrictive. The scanner is easy to use where the ambient light environment in the container terminal is high. A barcode is ideal, especially for shipping manifests and outer packing cases or other exposed surfaces. This system is capable of providing prompt information required by customs when vessels are at berth. It operates most effectively in a controlled environment particularly when relatively small amounts of data need to be captured. A barcode scanner is a wireless scanning technology that communicates with the host computer. In the rough environment of a port terminal where the visibility of the straddle carrier operator is minimal (due to the size of the carrier and the position of the driver-approximately 6m above the ground), this wireless system provides effective services to most terminal operators and operational systems.

#### *Radio frequency microcircuit system (RF)*

The system was developed to identify the containers when traffic at terminals reaches the peak. It is not easy to check and control the traffic at a terminal where thousands of containers are stacked and hundreds of containers are on the move. Container carriers deliver the stacked imported containers to the quay area and the newly unloaded containers occupy their slots. The system is ideally suited for operation in a harsh and outdoor environment. Non-conductive materials such as grime, snow and rain that intrude between the interrogator and transponder do not appear to affect operation of the system.

The system consists of the reader or antenna (that is buried in the pavement of the terminal to keep it free from vandalism, accident and weather) transponders (tags), an interrogator and computer interface tag. RF system offers high-speed and remote electronic identification of equipment. The heart of the system is the tag, powered either by a battery or by an RF beam from the antenna. Each tag can have a unique code that is related to the object to which the transponder is attached. The electronic components of the transponders are enclosed in rugged packages that may be as small as a credit card. One application for RF systems is in monitoring the movement of containers and their status in the terminal. This is the area that assists the terminal operator to produce prompt reports for importers/exporters and other relevant agencies. The system can also track containers entering and leaving the terminal through the gate or as they pass the scanning points in the yard.

#### *Voice recognition technology*

Voice recognition technology (VRT) provides communications between the crane operator and the ground personnel. This system could be used stand-alone or it can be integrated with other technologies in communications between the crane operator and on quay personnel during loading and unloading of a vessel.

Voice systems use pattern recognition similar to that in barcode systems. Instead of an image, the computer recognises words in a pre-programmed vocabulary. When it is activated, crane operators speak into a microphone, the machine recognises words or phrases and then converts them into electronic impulses for the micro- or host computer. The high-performance units operate at an accuracy rate of 99.5 per cent. One of the advantages of the system is message recording. This would assist the terminal operator in providing the final report on the position of containers loaded on to the ship. When properly integrated, the system can assist in the automatic capture and processing of marine terminal data.

Figure 1 loosely illustrates the links between the above devices and port components where the central computer integrates the entire system. In the following section, we will simulate the effect of utilising some of these devices by comparing two port operational systems, a traditional system versus alternative case where devices are employed.

### Simulation of port terminal operations

Most complex, real-world systems with stochastic elements cannot be accurately described by a mathematical model which can be evaluated analytically. Thus, a simulation is often the only type of investigation possible (Law, 1982). Simulation can be used to check the validity of assumptions needed and a particular model. On the other hand, an analytic model can suggest reasonable alternatives to investigate in a simulation. Central to any simulation study is the idea of a system (Graybeal, 1980). A system can be defined more broadly than a collection of physical objects and their interactions. In our case, a container port terminal is considered to be a system and its operations and interactions as the collection of objects.

One of the advantages of simulating the performance of a system, e.g. the container terminal, is to evaluate the alternatives capable of satisfying the design specifications before they are implemented. It also estimates the operational costs of such design configurations, which can be compared with the alternative modification costs. Proposed operational improvements and port developments can be incrementally introduced into the simulation model

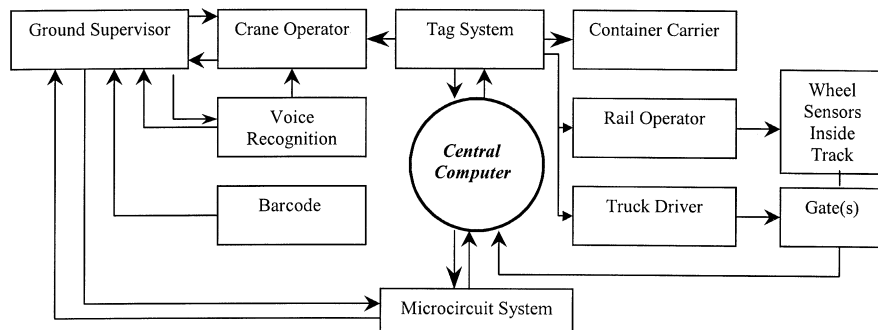


Figure 1.  
Electronic devices in  
port terminals



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to test local terminal performance whilst maintaining the global perspective (Seeley and Griffiths, 1992). It also provides a means of ensuring that the most productive endeavour is being undertaken at any point in time.

The arrival pattern of ships usually takes a random pattern described by some type of statistical distribution. A negative exponential distribution of inter-arrival times (and hence a Poisson arrival rate), is the most frequently used approximation. Ship turn-around time involves the arrival of ships and the duration of occupancy of a berth (service time). The ports or, more precisely, the ship-to-berth links are considered as queuing systems with vessel arrivals, single or multiple service(s) and unlimited queues at an anchorage (Radmilovich, 1992).

The models developed for comparison in this paper deal only with the operational improvements. They cover activities within the terminal, predominantly ship-to-shore operations and the movement of containers from ship-to-stacking area. The models do not cover activities beyond the terminal gates (e.g. land transport). To have a clear understanding of the systems and the sequences, a brief description of the two terminals is provided.

#### *Terminal model without electronic devices*

When a ship arrives at the port, it is placed in the queue and remains there (outside the port facilities) until a berth becomes available. Once a berth is vacant, the pilots and tugboats escort the ship to the assigned berth. Shortly afterwards the assumed 2,000 containers are unloaded from the vessels by the two gantry cranes. The containers are carried away by 16 straddle carriers from the quay area to the designated slots (the allocated area for containers) in the stacking area. Containers normally stay in the terminal between three to six days for customs inspections. After the completion of the inspections, containers are loaded on to trucks/trains and taken away from the terminal. In this operation, cranes frequently stay idle due to:

- (1) the quay area being occupied by other containers; and
- (2) the crane spreader stay-time in the hull being long due to the discrepancy of the ship loading plan (the position of containers in the hull).

Straddle carriers also must wait until the isles (the rows allocated for stacking of containers) are accessible. This normally happens when other carriers use the isles. Terminal congestion also causes further complications in terms of container segregation prior to the departure of containers from the terminal since tens of containers often should be re-shuffled (double handled) to pick up the right container for delivery.

Lack of timely information is the main cause of the quay occupancy, crane waiting time and waiting time for straddle carriers. Two-way radio is normally used to provide communications between the crane operators and the ground/vessel supervisors. Communications between the straddle carrier operators and the ground supervisor also take place by two-way radio.

*Terminal model equipped with electronic devices*

The essence and nature of operations are the same as the terminal model without electronic devices. However, application of electronic devices positively affect, reduce or eliminate the waiting time of cranes and straddle carriers because:

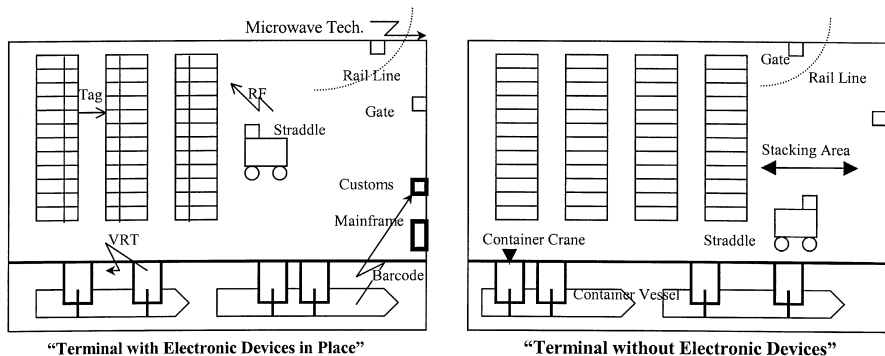
- The crane operator is able to ascertain availability of the quay area, through a monitor installed in the cabin of the crane, including the exact pick-up time of container(s) by straddle carrier(s). Communication between the operators of straddle carriers and the ground supervisor also takes place through the electronic devices, which provide timely information on the space availability for the next container.
- Terminal isles and the movement of straddle carriers throughout the terminal can be regularly checked by the straddle operators through a computer installed in the cabin. When a container is picked up by a straddle carrier, the relevant information of its slot and isle is immediately displayed on the monitor. This would assist the elimination of the search time of the straddle carrier.

*Elements and parameters used for the simulation models*

To construct the models, the parameters taken from study of the real-time operation of four cranes and 32 straddle carriers in two container terminals (West Coast of the USA and Melbourne, Australia) are used. It is assumed that in each terminal a ship unloads 2,000 containers to be stacked in the same sized yard (280m × 350m) with the same capacity of stacking area (4,500 containers). The presence of the electronic devices and their approximate positions in the container terminal under investigation are illustrated in a base-plan in Figure 2.

Further information was required to satisfy the model parameters. This is briefly described as follows:

- (1) Crane service time. Erlang distribution, derived from the real-time data, is 48.7 ( $k = 3$ ) for the USA port, and 53.2 ( $k = 4$ ) for the Melbourne port.



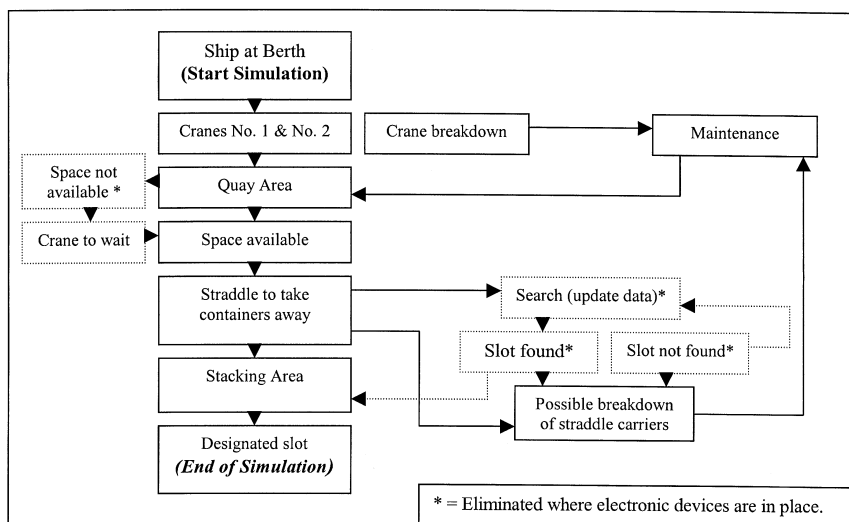
**Figure 2.**  
Port terminal with/  
without electronic  
devices in place

- (2) Movement of containers by straddle carriers. Normal distribution is 25.90, 13.6 for the USA, and 36.50, 23.5 for Melbourne.
- (3) Occupancy of the staking area. Normal distribution is 178.37, 79.55 for the USA and 185.33, 86.43 for Melbourne. The inclusion of this element in the model would provide the percentage of the space utilisation in the terminal.
- (4) Movement of containers between the stacking area and the exit gate.
- (5) Transportation of containers from terminal by trucks or trains. No allowances are made to cover the activities beyond this point.
- (6) The conditions of the cranes (two cranes/ship) and straddle carriers (16 straddles/terminal) are presumed to be the same including breakdown (downtime) for equipment and machinery in the model.
- (7) Taylor II for Windows[1] was used to implement the simulation model.

The major activities of the simulation model are illustrated in Figure 3. Where electronic devices are used is shown with dotted lines. These boxes are removed in the respective model.

### Simulation results

The results of the simulation model provided the answers for the system in question, that is, the positive impact of the electronic devices on the operational system of a container terminal. As stated in the introduction to this paper, it is not intended to derive the optimum capacity of the terminal, but to identify the bottlenecks of the operational system that cause terminal congestion and increase ships' time at port. Results derived from the model include ships' time at berth, service time of cranes and straddle carriers and congestion caused by

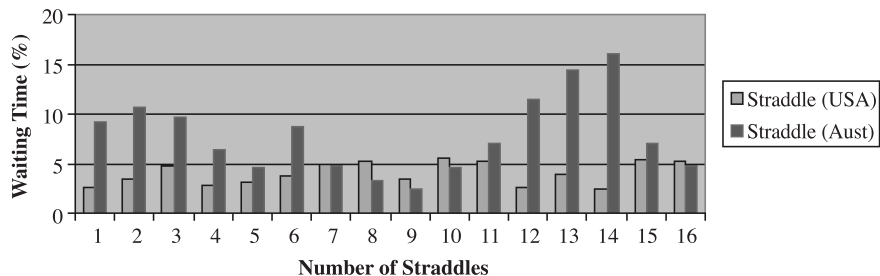


**Figure 3.**  
Logical model of  
simulation

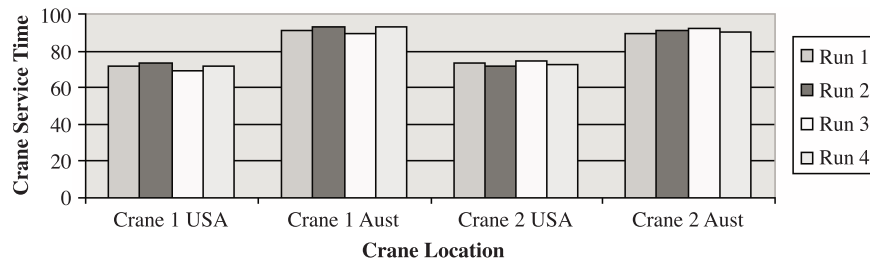
container movers in the stacking area. Figures 4 and 5 illustrate the differences between the service time of cranes and straddles in two terminals under investigation.

As shown in Figure 4, the presence of electronic devices has reduced the waiting time of straddle carriers significantly. This is predominantly due to the elimination of search time (shown in Figure 3) for the right slots, which sometimes are occupied by other containers in the container terminal where electronic devices are in place. The other advantage of the electronic devices in handling containers is that they do not use the same isles simultaneously since the movements of other straddles in the isles are shown on the monitors installed in the cabin of the operators. This is also applied to the quay area where several straddles arrive concurrently to pick up one unloaded container or the presence of several containers on the quay area (under the hook) caused longer crane waiting time and longer ship time at berth. Figure 5 illustrates the service time of cranes in two terminals (with and without electronic devices in place) where the cranes in the terminal without electronic devices appeared to wait longer. As a consequence, the utilisation of cranes is reduced and the ship time at berth increased. The results shown in Table I are also derived from the simulation models and the positive impact of electronic devices on terminal operations.

The presence of electronic devices in major container ports in Australia could provide approximately US\$180 million (£117 million) savings per year. This figure is based on the total number of vessels which visit those terminals per year. As a result of the lower berth occupancy, more ships can be



**Figure 4.**  
Straddle carrier service time (with vs. without electronic devices)



**Figure 5.**  
Crane service time (with vs. without electronic devices)

Description	Terminal without electronic devices	Terminal with electronic devices	Differences
Crane service time (2 no.)	182.50 hours	144.74 hours	-26.08 per cent
Ship time at berth	93.20 hours	74.37 hours	-25.31 per cent
Ship cost at port	US\$174,000 (£113,000)	US\$139,000 (£91,000)	-US\$35,000 (-£22,000)
Straddle service time (16 no.)	1,518 hours	1,214 hours	-25.04 per cent
Savings time in human resources	1,972 hours	1,580 hours	-24.81 per cent
Occupancy of stacking area <sup>a</sup>	63 per cent	44 per cent	-43.18 per cent

**Note:** <sup>a</sup> Actual occupancy derived from the real-time data (The terminal equipped with the electronic devices is also equipped with ship-to-rail technique. This technique would reduce the container stay-time in the terminal and increase the capacity of the stacking area)

**Table I.**  
Positive impact of  
electronic devices on  
port terminal

accommodated at berths. This would prevent the expansion of ports caused by the unavailability of berths. It remains to compare the cost of installation of the devices against the gains, by the management authorities.

## Conclusion

The advancement of information technology provides a wide range of options for the container terminal operator to automate its information system. Electronic devices employed in container terminals reduced the manual effort and paper flow, facilitated timely information flow and enhanced control and quality of service and decision made. The use of computer simulation has become a standard approach for evaluating design of complex cargo handling facilities. It enabled us to investigate the behaviour of two different operational systems leading to significant savings derived from the implementation of electronic devices in port terminals. The importance of information technology, including the Internet, in supply-chain management, facilitating the exchange of information in commercial transactions among enterprises and individuals, and enhancing growth and profitability across the supply chain was also discussed.

## Note

1. Taylor II for Windows, Simulation Software, Holland, 1987.

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