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**THE PORT OF SINGAPORE AUTHORITY:  
COMPETING IN A DECLINING ASIAN ECONOMY**

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*Eric Lui, Director of Information Technology (IT) and Executive Vice President of the Port of Singapore Authority (PSA) sat in his Alexandra Road office in Singapore, worried about the future success of the port. PSA was feeling the impact of the declining regional economy and had also to manage the heightened competition both now and once the current crisis passed. "We have built one of the most efficient and largest ports in the world, and yet we are subject to economic forces beyond our control," he thought.*

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*The authors prepared this case with assistance from Amy Hazeldine. The case is based on public sources. As the case is not intended to illustrate either effective or ineffective practices or policies, the information presented reflects the authors' interpretation of events and serves merely to provide opportunities for class discussion.*

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## THE CITY-STATE OF SINGAPORE

Singapore is a small country located at the tip of the Malaysian peninsula. It is an island 24 miles long with three million inhabitants. See Figure 1, which is from the Singapore home page, <http://www.sg>.



**Figure 1**

The population is well educated and extremely hard working. The Singapore Web page describes the population:

*Singapore's people are largely descendants of immigrants from the Malay Peninsula, China, the Indian sub-continent and Sri Lanka. They have gradually acquired a distinct identity as Singaporeans while still retaining their traditional practices, customs and festivals.*

*As at June 1997, the resident population, comprising Singapore citizens and permanent residents, is estimated at 3,103,500. This was an increase of 1.9 percent over the previous year. Total population was estimated at 3,736,700 with a 3.5 percent over 1996's. Population density rose from 4,457 people per square kilometre in 1987 to 5,768 people per square kilometre in 1997.*

*Chinese residents numbered 2,394,200 (77.2 percent), Malays 437,900 (14.1 percent), Indians 230,600 (7.4 percent) and persons of other ethnic groups 40,800 (1.3 percent). Resident males numbered 1,559,400 and resident females numbered 1,544,100, giving a sex ratio of 1,010 males per thousand females.*

Since the end of its confederation with Malaysia in 1965, Singapore has been a modern success story. Blessed by an honest government (with some authoritarian tendencies), the country has moved from "developing" to the "developed" status. Various government boards implement social and industrial policies. For example, the Housing Development Board has overseen the construction of around 800,000 flats in a variety of high rises. Individuals own about 86 percent of these flats while the rest are rented. Owners may sell their flats and buy others; they and not the government own the housing. Web pages describe the housing program:

*The Home Ownership for the People Scheme was introduced in 1964. Under this scheme, Central Provident Fund (CPF) savings have been used to pay for flats since 1968. A total of 28,220 HDB flats were sold in 1997. (CPFs Singapore's retirement savings program).*

Singapore's economy is diversified with electronics manufacturing as one important sector. The economy is also heavily trade-based as the following government report demonstrates:

*In 1997, Singapore's total trade grew by 5.7 percent to reach \$382<sup>1</sup> billion. It rose a mere 1.4 percent in the first half of the year and rebounded strongly with a 10 percent in the second half. This was due mainly to the recovery in the global electronic demand, which saw exports in such products expand by 8.1 percent in the later part of the year.*

*Non-oil domestic exports recorded an increase of 5.3 percent in 1997, due mainly to the strong 10.3 percent growth in the second half of the year. Domestic exports of electronics, which comprise 70 percent of non-oil domestic products, rose by 3.4 percent in 1997.*

*This reflected a strong pick-up in domestic exports of integrated circuits, printers and printed circuit board, assembled (PCBA) in the second half of 1997. Exports of disk drives however moderated to 4 percent in the fourth quarter, down from 9.4 percent recorded in the third quarter.*

<sup>1</sup> S\$1 = US\$0.6, 1998 year average

*Personal computers (PCs) were the only top five electronic exports which shrank by 20.6 percent - in the second half. This was due mainly to a fall in demand, arising from sluggish growth in Japan.*

*Domestic exports of non-electronics, which form 30 percent of non-oil. Domestic exports, rose by 9.8 percent in 1997. Chemical exports, a top non-electronic export, grew by 18.2 percent in 1997. This was due mainly to the setting up of new petrochemical companies in Singapore which began operations during the year.*

*Of the top five markets, the European Union chalked up the highest growth rate at 12 percent as buoyant economic conditions fuelled demand for Singapore's exports. The US market did well in the second half of 1997. However, overall it achieved a moderate 4.6 percent growth for 1997.*

## THE PORT

Singapore's most important natural resources include its large, protected harbour, its location on major trade routes, and the skills of its well-educated work force. The location advantage is clear in Figure 2 from the Singapore Web site. Note that Singapore is located where ship traffic between Europe and Southeast Asia and the U.S. West Coast and Southeast Asia must pass; it is a natural entry for products to and from its neighbouring countries.

A port, particularly as shipping has become containerised, requires massive infrastructure development including berths, cranes, trucks, storage and warehousing, anchorages, tugboats, pilot launches, etc. Singapore had opened its economy to foreign investment and as its economy grew, it allocated significant amounts of capital to developing its port. Exhibit A outlines the milestones in the development of the port.

This development can be seen from the panoramic view available at the PSA web site: <http://www.psa.com.sg> and shown in Figure 3.



**Panoramic View from PSA Web Site  
Figure 3**

There is a long history of the port available at this Web site. Recent history since World War II is of the most interest:

*On 1 April 1964, the Port of Singapore Authority (PSA) was formed to take over the functions, assets and liabilities of the Singapore Harbour Board. At that time, its facilities were confined to some five kilometres of wharves and 160,000 square metres of transit sheds and warehouses at Telok Ayer and Keppel Harbour. The main type of cargo then handled was break-bulk general cargo, with small volumes of bulk vegetable oil and latex.*

*"The most significant port development took place on 23 June 1972, when a container berth was opened at Tanjong Pagar (at the East Lagoon). With that, Singapore became the first port in Southeast Asia to accommodate a third generation container vessel, making it an important link in the new chain of global container ports.*

In September 1997, the government-operated Port of Singapore Authority made the transformation into a commercial organisation under the name of PSA Corporation. A news release on the PSA Web site discusses the launch of PSA Corp:

*To enhance its links with customers, PSA Corporation has set up an International Advisory Council (IAC), comprising distinguished leaders of international shipping companies. The Council will advise on global perspectives for the company's strategic directions. PSA Corporation will use the feedback and advice from Council members to improve its service levels and maintain its competitiveness. The IAC is a manifestation of PSA Corporation's commitment to open new channels for customer feedback, and a testimony of respect for its customers' views.*

*The new PSA Corporation seeks to be a world class corporation. Its mission is to excel as the world leader in providing seaport and logistics services of the best value to its customers.*

The 1997 Annual Report reviews the development of the modern port; the portion since developing container facilities is the most significant:

**“Our Operations:  
From Entrepot to a World-class Port**

The Beginning of Containerisation:

PSA boldly proceeded to design and construct a container terminal in the late 1960s. The first 300-metre berth was completed in 1972, and the first container vessel, “m.v. Nihon”, arrived in June that year. Productivity took a quantum leap. With goods packed in metal containers and handled by quay cranes, 53 tonnes of cargo per man-hour were handled, representing a 136-fold increase in productivity when compared to the days before 1972.

Tanjong Pagar Terminal (TPT) ended the landmark year of 1972 by handling 24,515 TEUs, using two quay cranes. For the next ten years, an average of 100,000 TEUs was added to PSA's container volume every year. The additional volume had to be accommodated by building new capacity - berths were progressively added to TPT. By 1981, another milestone was reached, with TPT celebrating the record of its first million TEUs within a year.

**Container Transshipment Hub Port:**

As significant as PSA's achievements in the 1970s were, they were surpassed by the meteoric growth that characterised the 1980s - the result of the pioneering of the hub-and-spoke container-shipping concept in the region. By investing in massive berth facilities and sophisticated equipment and computer systems, PSA began to attract large container ships on global trade routes. From the mega-carriers, large numbers of containers were discharged on each call at PSA, for distribution to the region, while large numbers of containers, which had arrived from regional countries for consolidation at PSA, were also loaded on the same call. PSA had become the container transshipment hub port of the region.

Today, PSA is connected to 740 container ports in 130 countries. On an average day, there are three sailings from Singapore to the United States, four to Japan, five to Europe and 22 to South Asian and Southeast Asian destinations. Manufacturers and shippers have many choices of shipping lines and benefits from a high sailing frequency to all major destinations around the world.

Such a wide network of connections has enhanced PSA's value as a hub port for container transshipment, and has been made possible because of the support of the global ocean carriers and the common-user feeder operators serving the region. The network of feeder services ensures cost-effective, reliable and frequent services for mainline operators, ultimately benefiting the entire logistics chain in the region.

As the 1980s progressed, container volume poured in. From one million TEUs in 1981, [PSA's] volume grew quickly to 4.36 million TEUs by 1989. By then, [PSA'S] value-added per employee had increased 13 percent per annum from \$39,056 in 1980 to \$116,613. (A TEU is a “Twenty-Foot Equivalent” because there are different size containers. A forty-foot container would be 2 TEUs.) PSA once again determined to innovate and improve in order to stay at the forefront of the industry, in the face of greater demands on its container-handling capacity. The conventional wharves at Keppel Terminal were converted into container berths on a large scale. The unprecedented volume also increased the scale and complexity of operations so tremendously that manual terminal operations were no longer possible. PSA adapted to the changing situation by taking another major step: introducing computer systems

linking both terminal and marine operations, based on real-time information, to direct every job by every worker and every piece of equipment. By 1995, PSA achieved more than 10 times the container throughput of 1982.”

## OPERATIONS AT PSA

*PSA is the Number One transshipment port in the world, not simply because of its strategic location but because of its efficiency. Exporters and importers in many countries find it more convenient and cost-effective to transship through Singapore rather than ship direct to their final destination.*

Goh Chok Tong  
Prime Minister, Singapore  
The Straits Times, Singapore,  
September 14, 1998

Port operations have always been a key success factor for PSA. (See **Figure 4.**) Being sited in a strategic geographic location has its advantage but it is not the determining factor for PSA to become the Number One transshipment port in the world. The East-West sea-lanes have many strategically located ports, such as Hong Kong, Port Klang (Malaysia), Colombo (Sri Lanka) and Kaohsiung (Taiwan). However, more than 100 container-shipping lines choose to call at PSA. On an average day, there are three sailings to the United States, four to Japan, five to Europe and twenty-two to South Asia and Southeast Asia ports. PSA is connected to 740 ports in 130 countries. This kind of high volume traffic requires superb port operations.

Key customer requirements in port operations include freight rates, frequency of services, shipping options, turnaround time, port charges (about 20 percent of freight charges), support services (ship maintenance, ship supplies), and feeder operations. The port customers are essentially the shipping lines, however it must be noted that shipping lines often take their cue from manufacturers, exporters, and the big buyers (MNCs) of goods and raw materials.

### (I) PSA Operations in Brief

As Singapore is a transshipment hub for shippers, port operations are very demanding and complex. Arriving containers destined for other port destinations have to be transferred to different ships or stacked for later

shipment, while containers destined for Singapore have to be put onto trailers and taken out of the port. These operations have to be well coordinated to maximize port resources and minimize ship turnaround times.

Before ships arrive in Singapore, shipping companies send messages to PSA through the PortNet system, stating when their ships will be arriving. At the same time, they apply for berthing spaces. Information from PortNet includes how many containers are on board, how they are arranged, their destination and their scheduled delivery. Electronic data submissions are forwarded to the trade development board, customs, and excise and controlling agencies. Information is sent back to the vessels regarding berth location, permit confirmation, and other operational details. Application for port call can be made between one month and 24 hours before the ship arrives. Once PSA receives the application, operations’ planning begins. Planners use the Computer Integrated Terminal Operations System (CITOS) for this purpose. CITOS plans allocation for ship berthing and attempts to optimise the way in which containers are unloaded, transferred or stacked for later shipment. The system also has to deal with import delivery and export receiving for domestic markets.

Pilots and tugs are often required to assist ships into port. An expert system analyses the submitted orders and helps to schedule and deploy the tugs and pilots in the shortest time possible. Pilots, tugs and launch crews receive the instructions and communicate operational information via hand-held terminals. This information is also sent to the central control room.

When a ship arrives, it will be guided to an allocated berth. A specific number of quay cranes are assigned to service the ship based on the number of containers to be unloaded and loaded. Prime movers (special trucks that can carry two containers) move the containers between the ship and the stacking yard.

At the stacking yard, cranes dismount/mount the containers. Containers at the yard are placed in an initial holding area. Internal yard operations restack containers in appropriate place and sequence to await for eventual loading onto another ship or to be sent to domestic destinations by freight forwarders. Containers originating from Singapore exporters are handled by gate operations; they are routed to the stacking yard first before eventual loading onto ships. CITOS determines the stack location.

Transport trucks are easily able to access the designated berth to collect containers directly. The adoption of industry standard barcodes allows PSA to operate in a quick and efficient manner. A system recognises the container numbers when loading and unloading goods and verifies that the correct containers are being moved.

Trucks to receive containers are scheduled ahead of time and given an exact time to arrive at the front gate. A system recognises the truck and a message is sent to the driver to proceed to the designated yard location. Upon exiting, the system recognises the container number of the outgoing container and verifies clearance.

The port operations are shown in **Exhibit B**.

## (II) The Enablers

A number of enablers are important in creating a world-class port, including infrastructure, information technology, workforce and organisation culture.

Singapore's natural deep-water harbour is a strategic asset to PSA. Singapore has the 8th largest merchant fleet in the world, 3,380 ships with 20.77 million gross tonnage (The Business Times, August 21, 1998). Singapore is a major trading nation with total external trade amounting to S\$382 billion in 1997. Singapore is a major oil refinery center as well. PSA is the largest owner of warehouse space in Singapore, managing over 500,000 metre square of space, including the Tanjong Pagar, Alexandra and Pasir Panjang Distriparks. The distriparks cater to a host of distribution operators, manufacturers, traders, and freight forwarders. PSA is attempting to provide value-added services to its traditional port operations. Value-added services include storage of goods and empty containers, labeling, repackaging, tagging, sampling and testing, quality control and billing. The aim is to establish an integrated global logistics network that connects Singapore to major regions and countries such as Asean, Western Europe, China, India, and the US. Such supporting factors will sustain stable long-term revenues for PSA.

Information technology is embedded in every facet of the operations of the port. PSA's strategic drive towards IT-supported port operations started in the early 1980s and it continues today to search for ways to harness IT.

PSA's workforce and organisation environment also help to ensure it as a truly competitive global business. Its workforce is trained and positioned to satisfy customers. It has programs such as the "Key Customer Managers" and "Chat Time." The Key Customer Managers program provides regular dialog sessions with customers, helping PSA staff members to better understand and attend to customer's operational and contractual needs. Chat time allows the organisation to build rapport with customers and keep abreast of the latest developments in the shipping industry. To promote a quality culture in their workforce, PSA has widespread quality circles (QC) and encourages staff suggestions. Joint quality circles involve participation by customers and suppliers.

In 1997, PSA received 13,097 suggestions, which is equivalent to an average of 1.9 suggestions per staff member. Staff suggestions and QC projects have saved PSA about S\$10 million over the last five years.

To maintain the productivity of its port operations, PSA is serious about employee training; spending on training in 1997 was S\$12.12 million, or 3.61 percent of the total wage bill. Average training per year was 5.41 man-days per employee in 1997. PSA has its own in-house training school called PSA Institute. The Institute has conducted 1,707 courses for staff as well as local and overseas maritime personnel.

PSA believes in long-term planning. It anticipated global containerisation in the late 1960s and built the first container port in the region. Second, PSA made early preparations to harness IT on a major scale and used it strategically in its port operations in the 1980s. PSA is expanding its terminal facilities to meet the advent of true globalisation in the next millennium and the anticipated cross-border trade growth that accompanies it.

The most fitting accolade to PSA's prowess in operations is the winning of the 1999 Singapore Quality Award (SQA). This award is given annually to an organisation that has shown consistent business excellence and achieves world-class quality standards in its operations and outputs over a period of several years.

## (III) Statistics on PSA's Operations

Singapore is the busiest port in the world in terms of shipping tonnage. At any one time, there are more than 800 ships in port. In 1997, Singapore

received 130,333 vessels with a shipping tonnage of 808.3 million gross tons. Singapore is Asia's main transshipment hub. PSA is one of the world's largest container terminal operators, handling a throughput of 14.12 million TEUs in its container terminals in 1997. See **Exhibit C** for statistics in graphical representation.

PSA facilities can provide on average 88 container moves per hour. It holds the world's record of 229 container moves per hour in 1995 with the ship "Mette Maersk." PSA Marine, a wholly owned subsidiary, performed 108,048 pilotage jobs and 94,904 tug jobs in 1997. The company provides high standards of service as 99 percent of pilotage jobs were serviced within 30 minutes and 96 percent of tug jobs were serviced within 15 minutes.

As a comparison, ports of China handled 10.77 million TEUs in international container services in 1997. Hong Kong had 14.5 million TEUs in 1997 while South Korea handled about 6 million TEUs in 1996.

Taiwan's main port at Kaoshiung had 7.87 million TEUs in 1996. However, these are all larger countries than Singapore and the containers in the country are handled by more than one port operator.

As a world class leader in port operations, PSA has won several major awards including The Best Seaport (Asia) eleven times, the Best Container Terminal Operator (Asia) 9 times, and the Best Warehouse Operator 9 times.

Also, other awards related to IT innovations include the American Association for Artificial Intelligence Award (Montreal, Canada) in 1995, the Salzberg Concept Memorial Medallion Award by Syracuse University (New York, USA) in 1994 and the National Science and Technology Award (Singapore) in 1993.

#### **(IV) Terminal Facilities**

PSA Corporation currently operates three container terminals: Tanjong Pagar, Keppel and Brani. A fourth terminal is being developed at a cost of S\$7 billion at Pasir Panjang. This development will yield 26 berths with a capacity of over 18 million TEUs. Table 1 presents statistics about the four terminals.

Together, these 4 terminals provide a global container shipment hub that connects Singapore to 740 ports worldwide. See Exhibit D for the major connections.

#### **(V) Future Trends and Strategic Directions for PSA Port Operations**

PSA presently operates a competitive port that focuses on quality service and reliability. Their core competence is an ability to handle a large volume of containers with a short vessel-turnaround time. PSA routinely handles 2,000 containers per vessel and turns vessels around in less than 12 hours.

Future trends in the container-shipping arena include global shipping alliances, the deployment of mega container ships, trading blocks, and the importance of total logistic support for businesses. See **Exhibit E** for information on the four ports in Singapore.

Consolidation of major shipping lines into global shipping consortiums is already ongoing and will intensify. Examples of past consolidation include Maersk-Sealand and more recently, P&O with Nedlloyd, and NOL with APL. Global shipping consortium demand competitive rates and, at the same time, port operators must have the capacity, the expertise, and the facilities to accommodate the large volume of ships coming from these global shippers.

The shipping world is experiencing a growing size in container ships. Current 3,000 TEU to 4,000 TEU ships will be replaced by 6,600 TEU ships and eventually up to 8,000 TEU ships. The implications are that berth facilities must be able to accommodate these giant container ships and port operators must anticipate greater volume per ship. Such development challenges turn around operations for port operators.

Regional quasi-trading blocks such as the European Union, the North American Free Trade Agreement and others cause realignment of shipping routes and the formation of new transshipment hub operations. Port operators must be able to anticipate the pattern of shipping volume that will evolve from the realignment of shipping routes and form alliances with strategically located hubs.

The growing importance of total logistics support for businesses means that terminal operations and shipping operations have to be integrated to provide a seamless logistics chain. This chain will include warehousing services, delivery services, ship supply replenishments, ship maintenance, documentation (importing and exporting) and customs support.

PSA recognises these trends and is positioning itself to meet future challenges. PSA is evolving into a "One-Stop Service Center." It provides comprehensive domestic logistical support in the form of distriparks and warehouses. Singapore is ideal for cargo consolidation and de-consolidation, storage and regional distribution, logistics management, cargo sampling, surveying and re-marking, and container re-packing.

Singapore acts as the distribution center for S-E Asia while coastal cities of China act as centers for N-E Asia. PSA hopes to become a distribution center with its Dalian (China), Aden (Yemen), Tuticorin (India), and Sinport (Genoa, Italy) port operations. PSA has equity interests and operations management rights in these ports. This strategy is, in effect, a globalisation of port operations. By strategically positioning itself in major crossroads of the world, PSA becomes a worldwide distribution center.

Other value-adding maritime services include bunkering reception, pilotage, tugs, water supply, ferries, sea garbage collection and gas free inspection. PSA also provides invoicing services and electronic documentation to support shippers' operations.

However, one emerging factor might pose considerable challenge to PSA. The government in Thailand is considering the proposal to build a canal across southern Thailand. It will be called the Kra canal. The plan for a canal was first suggested way back in the 18th century. The idea was to provide easy passage for the Thai navy to defend the country. However, the massive cost of constructing such a canal has prevented the idea from turning into a reality. However, over the last few years, the canal proposal was again seriously being considered, with a lot of support coming from Japan, whose main concern is to maintain easy access to oil from the Middle East. If the proposal is accepted, it may cost up to S\$35.6 billion (Business Times, 1999, August 25) to complete the canal. The Kra canal will allow ships coming from the Indian Ocean a through passage to the South China Sea without having to pass through the Straits of Malacca.

The ships will make a loop around Singapore to get onto the South China Sea. (See Figure 2.) Likewise, ships sailing from East Asia and going to Europe will not need to pass through Singapore.

## INFORMATION TECHNOLOGY AT PSA

PSA invested heavily in information technology to improve the efficiency and operations of the port. In particular they have used technology to substitute for the lack of physical space. This lack of space reduces the room for storing containers and limits the number of employees who can work at the various port facilities. The need to stack containers nine high creates a tremendous operations and information processing task.

It is important not to find the container of interest at the bottom of a stack. Technology helps to plan loading and unloading, facilitate and choreograph the movement of various actors like crane operators, truck drivers, launches and tugboats. The technology also expedites clearing shipments through the port.

Singapore has long had government policies promoting economic growth and employment. During the late 1970s and early 1980s, a blue-ribbon Committee on National Computerisation recommended ways the country could pursue growth in the information technology field. Part of their plan involved the production of more IT professionals; there were only 850 in the country in 1980. The Committee estimated that there would be a need for 10,000 IT workers by 1990 to accomplish its goals. By 1986, there were nearly 4000 IT professionals in the country (King and Konsynski, 1994).

**TradeNet:** Since trade is vital to Singapore's economy, applying technology to processing trade-related information was a natural choice. In addition, Singapore knew that its main rival as a port, Hong Kong, was developing an EDI system for trade.

Trade involves many entities in Singapore, so the effort to reengineer trade information processing included representatives of the Economic Development Board (EDB), the National Computer Board (NCB), the Trade Development Board (TDB) and various statutory boards involved with trade such as Customs, PSA, and the Civil Aviation Authority.

It was clear that automating present procedures and documents would produce few gains; it was necessary to reduce the 20+ forms involved in trade to a few, or even one form. The design effort resulted in a single, long, formatted computer screen to serve nearly all trade documentation for Singapore. The development effort led to the creation of Singapore Network Services (SNI) to establish the EDI system.

SNI purchased a mainframe EDI “engine” from IBM to serve as the core of the trade system; a local Singapore firm wrote the custom interfaces, monitoring and billing subsystems among others. These added modules constituted about 250,000 of COBOL code. Other subcontractors developed the user interface software for the trading companies that would use TradeNet (King and Konsynski, 1994).

The TradeNet EDI system links the TDB, Customs, shipping agents, the ports, freight forwarders, traders and others together. When implemented in January of 1989, the S\$10 million plus system was a tremendous success. Customer response was much greater than anticipated, and by 1991, the use of TradeNet became mandatory. Several freight forwarders reported savings of 25 percent or more in handling trade documentation. An evaluation of TradeNet showed that the TDB staff handling trade documentation and procedures fell from 144 before the system to 38 afterwards. After the system, turnaround time for documents that took 2 days under manual processing dropped to 15 minutes while documents that used to require 4 days now normally take four hours (Teo, Tan and Wei, 1997).

**At the Port:** TradeNet has greatly facilitated document processing, and it has removed time considerations for most of the parties who use it. Port operations, on the other hand, impose severe, real-time requirements on information processing. The objective of outstanding customer service, which is measured by minimum ship-turnaround time and error-free container handling, imposes significant constraints on information processing and port operations.

PSA, in combination with various partners, developed an integrated set of traditional and expert systems to provide exceptional customer service to shipping lines. It is estimated that there are more than 300 applications used in all facets of the Port’s operations (Tung and Turban, 1996). There are two major systems and many subsystems, which allow the port to provide superb service despite its handicap in land area for storing and moving containers.

### PortNet and MAINS

Two major systems provide information to Port customers and PSA staff. PortNet is a nationwide system connecting PSA to users; it is linked to TradeNet. The Maritime Information System (MAINS) collects data from shipping agents, shippers, truckers and others about a vessel, its contents, schedule,

cargo, etc. MAINS provides a central database of information that other systems access (Tung and Turban, 1996).

Before the arrival of a ship, shippers notify the Port Authority of the containers that will be loaded using PortNet, an online system with about 1,500 subscribers. PSA replies with a window of time for the shipper’s trucks to appear at an entry gate to the Port. Its objective is to have trucks go to the right stack of containers and to have a yard crane available to offload the container on the truck. Such scheduling minimises the need to handle containers.

In 1987, Mr. Eric Lui, currently the Chief Information Officer for PSA, approached what is now Kent Ridge Digital Labs (formerly a part of the NCB). Lui wanted to explore how expert systems might be applied to reduce turn-around times and improve efficiency at the Port. The late 1980s was a time of great enthusiasm for expert systems technology, and Eric thought it was better to outsource than hire a group with ES experience.

### Computer-Integrated Terminal Operations System (CITOS)

The Computer-Integrated Terminal Operations System, or CITOS, supports planning for and managing all operations of the port. The subsystems in CITOS process information for allocating berths to ships, planning the stowage of containers, the allocation of resources in general, and reading container numbers and operating trucking gates. Kent Ridge Digital Labs (KRDL) developed the first version of CITOS in 1988; it was converted to a production system in 1989 and won an Artificial Intelligence Innovation Award shortly thereafter.

There are four subsystems for berth allocation, stowage planning, yard planning and resource allocation. There is also a neural network application for gate automation.

**Berth Planning:** The assignment of ships to berths is complex given the large number of ships handled daily (40 or more), priorities, weather constraints, changes in schedules, and the need to allocate resources like quay cranes. The Expert System relaxes some of the constraints on the problem using different heuristics. The system provides about 80 percent of the solution so planners can use it as a starting point. The planner works with a graphic user interface to drag and drop vessel icons in different berths. The system reduces the planning time by

up to 90 percent and has improved the utilisation of berths (Tung and Turban, 1996). (PSA has not put this system into operation).

**Stowage Planning:** The planner assigns containers to cranes and to bays on a ship; he or she determines the containers to be removed and loaded. Each ship is different and has a unique template showing its holds and the locations of containers. Planners must balance the load on the quay cranes subject to safety and ship balance constraints. (There are 20-30 berths and 10 quay cranes). The KRDL team first built a prototype using TI Explorer; after proof of concept, they developed the system for a Sun system using Objective C and LISP. The team involved 7 to 8 KRDL staff members and 5 to 7 people from PSA.

This problem is complex because ships typically carry cargo for several destinations, and it is important to minimise handling by loading containers in the right sequence. As an example, one of the new large container ships, the 6,600 TEU Sally Maersk, recently made her maiden voyage to Singapore. PSA achieved a rate of 203 container moves per hour for this vessel, exceeding its 1997 average of 88 moves per hour (the fastest in the world). The Port handled 1,700 boxes and turned the ship around in less than 8.5 hours. The ship loaded containers from 44 other vessels and discharged containers to another 38 during her visit.

The IT staff spent a great deal of time at the Port, and stayed there continuously when the system was implemented in case the planners needed help in the middle of the night. The project was successful because the IT staff developed a good rapport with users, and because shipping is so important to Singapore.

**Yard Planning:** Singapore is a small island with limited space. PSA stacks containers up to 9 high, which is much higher than other ports with more land. If a container that is needed is on the bottom of a stack, a lot of handling and time are required to retrieve it. The Yard Planner determines the placement of containers to support the rapid turnaround of ships. Its objectives are to use space efficiently and keep yard activities orderly.

**Resource Allocation:** This system helps deploy operations staff and container handling equipment with the exception of quay cranes. Users work with a graphical tool to deploy resources and produce a deployment plan. Employees use their staff passes, which are smart cards, in a machine that provides them with instructions.

**Gate Automation:** As trucks carrying containers arrive at the entry gate to the port, the Container Number Recognition System reads and interprets the container's number. The system uses a video camera for each letter and number of the 11-character container ID that is painted on each container. A neural net recognises each character and the system checks it against its record of the container that was expected. The gate automation subsystem also records the weight and directs the driver to the container's location within 45 seconds. The system also checks each exiting container in the same manner. This system reduced the number of individuals manually checking IDs from 16, one per lane, to 3.

### **Computer-Integrated Marine Operations System (CIMOS)**

The Computer-Integrated Marine Operations System helps to manage shipping traffic and the activities of the port. It includes a Vessel Traffic Information Subsystem, which watches the Singapore Straits and approaches to the port using five remote radars. Another set of four radars monitors port waters; this subsystem sends information to expert systems that plan the deployment of tugboats, pilots and launches. All of this information is available in a database that shippers access via PortNet to learn the status of vessels in the port.

There are five expert systems used for planning including applications to assign ships to anchorage's, schedule the movement of vessels through channels to terminals, deploy pilots to tugs and launches, route launches, and deploy tugboats.

**Vessel Traffic I & II:** This expert system provides surveillance of the port approaches including the Singapore Straits. It uses a computer-aided radar tracking system with five radars in place. The system relays vessel movement information to a control center where it is displayed on high-resolution, colour graphics terminals. The second Vessel Traffic system has four radars to monitor port waters. The information from this system is used to deploy pilots, tugs and launches, and to assign anchorage space.

**Port Traffic Management:** This system provides a central database integrating all information from other subsystems. It is also linked to PortNet so that customers and others can obtain status information.

**Marine Radio System:** This system is installed on PSA vessels and transmits operational data using wireless technology. The system is installed on tugs and launches and carried by pilots.

**Planning Systems:** There are five expert systems that help plan resource allocations for the port:

1. Anchorage Utilisation assigns anchorage slots to vessels according to the ship's characteristics.
2. Channel Utilisation plans and schedules movements of container vessels calling at terminals (over 45,000 a year).
3. Pilotage Deployment assigns pilots to tugs and launches.
4. Launch Deployment produces routes for the launches that serve vessels and employees.
5. Tug Deployment allocates tugs to meet service demands (Tung and Turban, 1996).

#### THE COMPETITION AND THE ECONOMY

Eric Lui knew that PSA's competition would become even more intense during the Asian economic downturn. Hong Kong had always lagged behind Singapore, but it could be expected to try for a greater portion of the regions shrinking trade, especially now that it is a part of China. The port of Colombo at the tip of South Asia is a growing competitor as ships can usually leave there and time the entrance to the Suez Canal to avoid waiting. Closer to home, Malaysia had instituted taxes on shipments that transit through the country to Singapore in an effort to force shippers to use Port Klang. There have been threats of legislation to stop this flow to Singapore's port.

To diversify and apply skills learned in Singapore, PSA would sell some of its software to other ports and would build and operate port facilities in other countries. For example, PSA was a partner to develop a port in Aden in Yemen.

Eric, however, wondered if all of this was enough given current and expected economic conditions. How could PSA use its operating and IT knowledge to become even more competitive? What changes and investments in new operating and technology systems should have the highest priority? Lastly, if the Kra canal is going to become a reality, what implications would that mean for PSA?

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FIGURE 2



FIGURE 4



Source: <http://www.psa.com.sg>

## EXHIBIT A

### MILESTONES IN THE DEVELOPMENT OF THE PORT

#### 1964

- The Port of Singapore Authority, a Statutory Board, was formed from Singapore Harbour Board on April 1 1964. With Mr. S. T Stewart as its first Chairman, PSA was formed to administer the Port of Singapore, provide port services and facilities, regulate and control navigation in port waters, and promote the use and development of the Port
- Introduction of a two-shift system for cargo handling, a 24-hour pilotage service and an advanced berth allocation scheme

#### 1965

- PSA started three-shift roster systems
- PSA hosted first Inter-Port Sports Meet (subsequently renamed ASEAN Ports Association Sports Meet)

#### 1966

- Tonnage of ships exceeded 100 million net registered tons for the first time

#### 1967

- Opening of shipping enquiry bureau to provide port users with a 24-hour information service
- Introduction of computerised integrated wharf documentation and billing system (below)
- Formation of Port Officers' Union. (The Singapore Port Workers' Union was the first Union to be registered, in 1946)

#### 1970

- Mr. Howe Yoon Chong was appointed Chairman of PSA in January 1970, and he served until February 1979

#### 1971

- Completion of the first container berth at the East Lagoon container terminal, the present Tanjong Pagar Terminal

#### 1972

- On 23 June 1972, the PSA's East Lagoon container terminal was officially inaugurated. The opening coincided with the arrival of the first container vessel, 'm.v Nihon', at this terminal, later renamed as the Tanjong Pagar Terminal. Within six months, PSA handled some 25,000 Twenty-Foot Equivalent Units (TEUs) of containers

**EXHIBIT A  
(CONTINUED)**

**MILESTONES IN THE DEVELOPMENT OF THE PORT**

- PSA purchased its first mainframe computer.

**1977**

- Completion of first phase of Pasir Panjang Wharves

**1978**

- The opening of World Trade Centre, a 13-storey complex, which provides over 61,000 metre square exhibition/conference facilities, and office and retail space
- Appropriate Berth Scheme introduced at Keppel Wharves to maximize the use of facilities. Under this scheme, shipping lines enjoyed priority berthing and volume discounts

**1979**

- Mr Lim Kim San was appointed the Chairman of PSA in February 1979, and he served until August 1994

**1981**

- Godown 407, the longest warehouse in Singapore, was built at Pasir Panjang Wharves
- PSA was the first statutory board in Singapore to form Quality Circles
- PSA achieved its first one million TEUs' record

**1982**

- New Clubhouse providing wide range of sports and recreational facilities for staff was built
- PSA held its first Quality Circle (QC) Convention
- Singapore became world's busiest port in terms of shipping tonnage

**1984**

- World Trade Centre became the market leader in exhibition space and attained its status as the premier exhibition centre in the region

**1991**

- Singapore Cruise Centre, a S\$50 million project, commenced operations with an International Passenger Terminal with three passenger berths, a Regional Ferry Terminal for ferries to the nearby Indonesian islands and Malaysian destinations, and a Domestic Ferry Terminal to southern islands of Singapore
- The first berth at PSA's Brani Terminal, a S\$1.4 billion project, was commissioned in December

**EXHIBIT A  
(CONTINUED)**

**MILESTONES IN THE DEVELOPMENT OF THE PORT**

**1992**

- The terminal handled 784,000 TEUs with three main berths and ten quay cranes.
- From January to September 1997, it has nine container berths, handling 3.05 million TEUs

**1993**

- Phase I reclamation for the new container terminal at Pasir Panjang started in August
- PSA won the Outstanding SHARE (Social Help and Assistance Raised by Employees) Programme Award

**1994**

- In August, Keppel Distripark, a S\$400 million modern container freight station with state-of-the-art technology started operations with 112,000 square metres of warehouse space for multi-country consolidation and re-consolidation of cargo, container freight station operations for import, export and re-export containers, and other related services
- PSA achieved a record of handling 10 million TEUs within a year
- PSA achieved ISO 9001 Certification for quality management of its software development

**1995**

- The S\$28.6 million Tanah Merah Ferry Terminal, a new gateway for regional passengers plying between Singapore and the Malaysian and Indonesian islands, began operations in August with two berths
- PSA achieved a world record of 229 container moves per vessel hour on "Mette Maersk"

**EXHIBIT A  
(CONTINUED)**

**MILESTONES IN THE DEVELOPMENT OF THE PORT**

**1996**

- The signing of PSA's first Virtual Terminal Agreement for a 10-year period with The Global Alliance, a major shipping consortium. This agreement provides customers with reliable customised service, price certainty and cost effectiveness
- Launch of PSA's first overseas project, Dalian Container Terminal costing RMB 4 billion. The project is a joint venture between Singapore partners and Dalian Port Authority (below)
- Completion of the first two berths at Pasir Panjang Terminal
- In the cruise survey carried out by UK's Dream World Cruise Destinations, Singapore won the 1st prize for being the Best Turnaround Port and the Runner-up for the Best Destination and Best Information Provider. Overall, Singapore was rated as one of the three best ports in the world for the cruise business – Singapore and Dover were joint runners-up behind Port Everglades
- QC participation rate hit 100%
- PSA organized its first Staff Conference Day
- Commencement of 'Adventure Learning', a corporate-wide team building programme that emphasises communication and team building among the participants
- Singapore Port Workers' Union celebrated its 50th Anniversary

**1997**

- In June, PSA was awarded an Engineering, Procurement and Construction contract to develop and construct a container terminal at Aden in Yemen, at a sum of US\$187 million
- In July, PSA signed an agreement with Asia Pulp and Paper Company to jointly manage and operate a central distribution centre at Pasir Panjang Wharves for the handling, transhipment and distribution of pulp and paper cargo
- PSA was appointed the manager for Singapore Expo by the Ministry of Trade and Industry. This new mega exhibition complex, a S\$220 million project, is at the eastern part of Singapore. Phase I will offer 60,000 square metres of covered exhibition space and be completed in early 1999. The exhibition capacity can be expanded to 100,000 square metres, the largest in the region
- PSA achieved a record of 14 million TEUs in a year
- PSA became the first Asian port to receive the world's largest container vessel, the 6,600-TEU 'Sovereign Maersk'

**References**

- The Straits Times*, Singapore, 1998, September 14, p. 20.  
*The Business Times*, Singapore, 1998, August 21.  
*The Business Times*, Singapore, 1998, March 24.

EXHIBIT B  
PORT OPERATIONS AT PSA

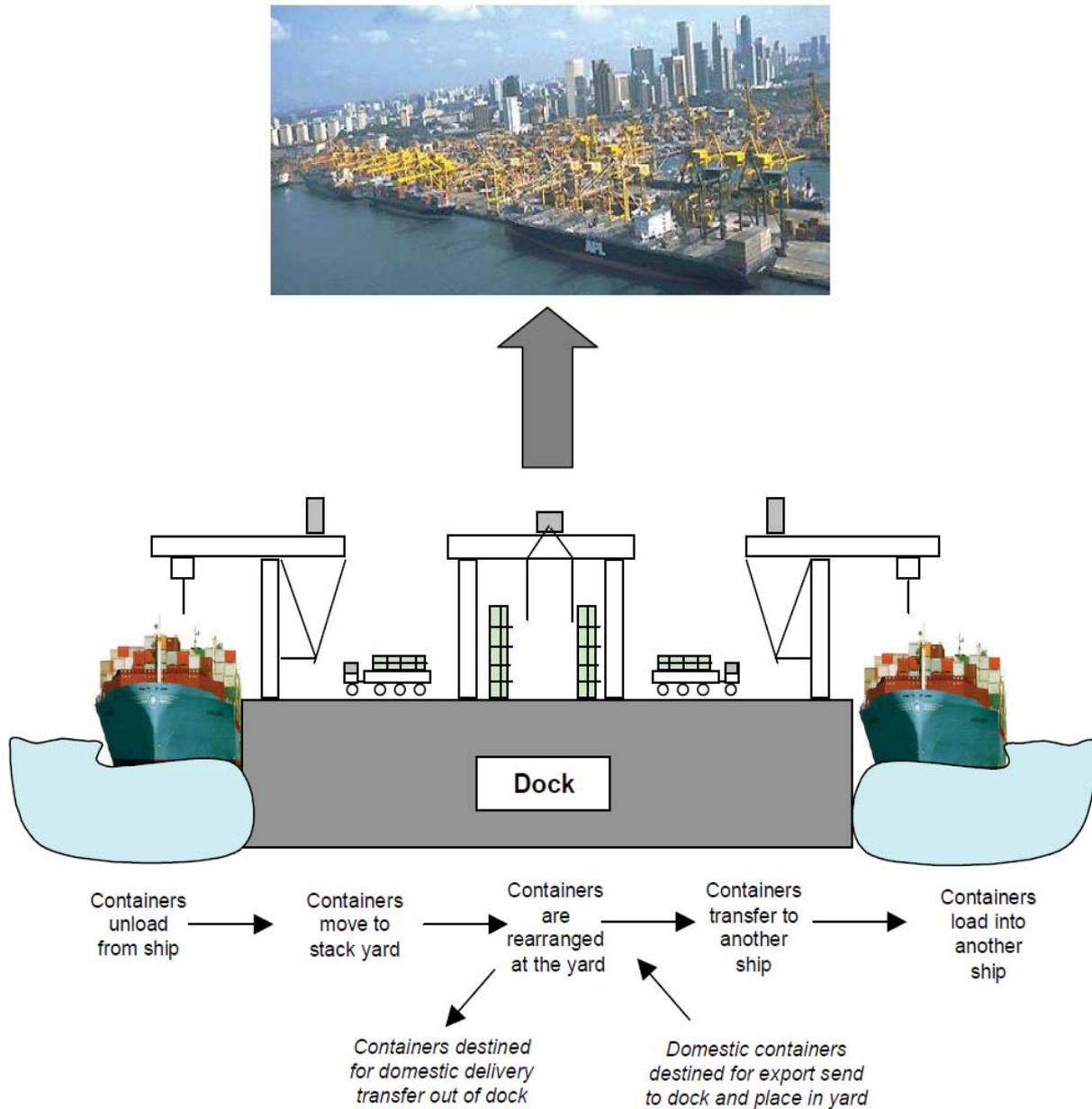


EXHIBIT C

FIGURES 4 THROUGH 7 PRESENT SOME ANNUAL OPERATING STATISTICS ON PSA

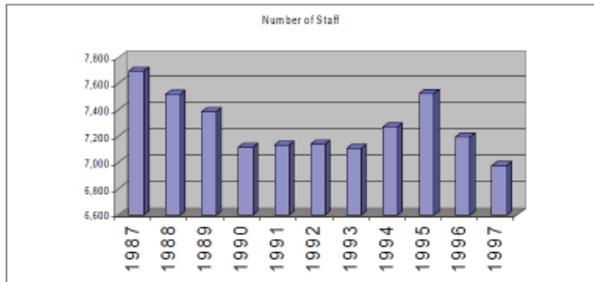


Figure 4

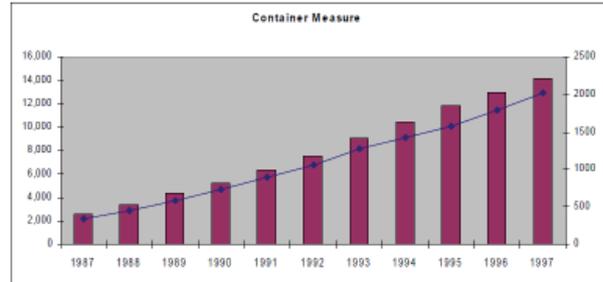


Figure 5

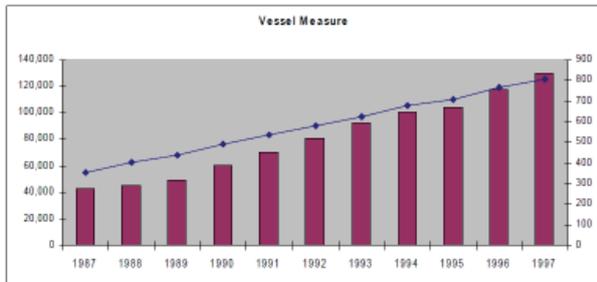


Figure 6

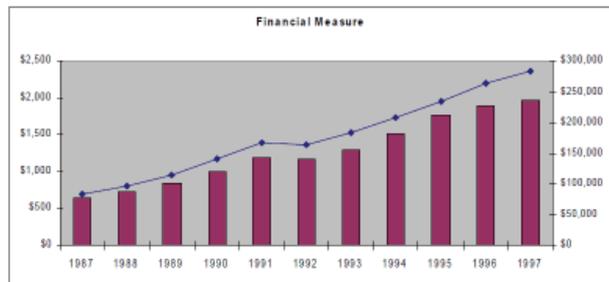


Figure 7

**EXHIBIT D**
**MAJOR CONNECTIONS**

Major Region/ Country	Average Number of Daily Sailings
Europe	5
West Asia	3
South Asia	5
Africa	3
Central & South America	2
Australasia	2
US	3
China	4
Hong Kong	8
Japan	4
Korea	4
Taiwan	6
Indonesia	8
Malaysia	10
Thailand	3
Philippines	1

**EXHIBIT E**
**CONTAINER TERMINALS AT PSA**

	Area (Heactares)	Draft (metres)	Berths (main, feeder)	Wharf Length (metres)	Equipment (quay, yard cranes)	Ground Slots	Throughput (TEUs in 1997)	Started Container Operation
Tanjong Pagar	88	9-14.8	6,2	2,330	29, 102	15,062	4.46M	1972
Keppel	96	9.6-14.6	5,8	3,300	36, 117	18,700	5.26M	1980s
Brani	50	12-15	7,2	2,627	30, 112	15,523	4.22M	1991
Pasir Panjang	65	15	4,0	1,455	12, 26	9,400	2,366	1998

Pasir Panjang (PPT) is a new development, which eventually will become a mega container terminal facility. PSA started operations at PPT with 4 berths; another 2 berths will be ready by 1999. When fully completed, the terminal will have 49 berths and a capacity of 36 million TEUs, compared with the 16 million TEUs for Brani, Keppel and Tanjong Pagar Terminals combined.