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Container terminal productivity at Sydney ports

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Abstract:

The importance of the waterfront as Australia's gateway to international trade is evident from its contribution to the gross domestic product and the fact that the bulk of our imports and exports are transported by sea. Although crane rates are the most extensively used indicator of container terminal productivity there are a number of other indicators that are equally important such as berth availability, land transport times and costs, etc. Studies by Ashar (1997) on productivity indicators, Sachich (1996) on the use of the engineering approach, Tongzon (1995) on the use of principal component analysis and Roll & Hyauth (1993) on the use of data development analysis, shows that there are a number of methods available to measure container terminal productivity. Depending on the desired outcome and availability of data any one or combination of these methods can be used to measure terminal productivity.

Using available data and indicators provided in available publications the container terminal productivity at Sydney ports are compared with other terminals in Australia and abroad. The results indicate current deficiencies: largely due to legacies of the past. The main areas of reform to enhance container terminal productivity at Sydney ports lies in the areas of labour relations, technology, transport integration, terminal infrastructure investment and pricing policies.

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Introduction

The waterfront is of paramount importance in establishing Australia's position in the international market. Its importance as Australia's gateway to international trade is accentuated by its geographical position (as an island continent)

The contribution of the waterfront to international trade is amplified by the fact that nearly 80% of the value of exports and imports is transported by sea (BIE, 1995). Port and shipping service providers, accounts for approximately 0.5% of Australia's gross domestic product. $30 billion of international trade moves through Sydney Ports. If the Australian economy is to prosper, container terminal productivity needs to compare with the best in the world. In the quest to ensure that Sydney's container terminal productivity does compare with the best in the world it is essential that the principles of container terminal productivity and the methodologies employed to measure productivity are clearly understood. Based on available data these methodologies can be employed to determine Sydney's position with relation to other Australian and international terminals. The outcomes of the comparisons would provide an indication as to the necessary reforms required to increase container terminal productivity.

Defining Port Productivity

According to the Collins thesaurus (1989) the word productive means both efficient and profitable. In the context of this paper, therefore, container terminal productivity is defined in terms of both time taken to complete an activity (ie transfer of a container) and the cost associated with that activity.

Container terminal productivity is directly related to both the sea-based and land-based time and cost associated with the movement of a container to and from the terminal. It starts when the ship arrives at the entry buoy and ends when a ship passes the buoy on its way out after finishing loading/unloading its cargo. It also starts and ends with the collection and delivery of a container by truck/rail at the container terminal.

The actual handling of cargo is performed by one or more gangs, each using a shore-base or ship-based crane. The times and activities are generally divided into those relating to the ship (or truck/rail) itself and those related to the gangs or cranes working the ship (or truck/rail).

Port Activities

The ship handling process involves many time-based activities which include the following:

- *Port Time* is the buoy to buoy time ie, the total time that a ship spends within the boundaries of what constitutes the port and includes waiting for a berth, documents, tugs, a pilot, bad weather, right of way, etc.

- *Berth Time* is the time that a ship spends at the berth. Gross Berth Time is the total time a ship spends at a berth, including ship preparations, waiting for documents, gangs, beginning of shifts, end of shifts, availability of cargo, etc. It also includes major delays during work due to equipment breakdowns. The Net Berth Time is the working time of a ship at berth during which gangs load/unload the containers and perform activities such as lashing/unlashing, placing/removing cones, opening/closing hatch overs, etc. The Net Berth Time includes minor during-work interruptions due to unavailability of cargo, equipment breakdown, etc

- *Gang Time* is the time that a gang works a ship. Gross Gang Time is the time that a gang is available to work a ship and for which the gang is paid, including waiting times before and after work ("standby") and interruptions during work. Net Gang Time is the time that a gang is actually working, including handling boxes and performing other, indirect activities, along with during-work minor interruptions. The Net/Net Gang Time is same as net gang time but only including the time the gang is actually handling containers excluding all interruptions and other activities.

Container terminal productivity is usually measured in terms of the latter two activities, namely berth time and gang time. There is no clear correspondence between gross berth time and gross gang time. Gangs can be waiting for ships and ships can be waiting for gangs. However, there is a direct correspondence between net berth time and net gang time where net berth time is equal to net gang time divided by the number of gangs (Ashar, 1997).

While serving a ship, a gang perform a series of direct and indirect activities. The activities are usually quantified by transfers, and include loading and unloading (the transfer of domestic (import and export) and transhipment containers between ship and yard), re-handling (the transfer of transhipment containers between ship and dock for a later transfer from the dock to the same ship), shifting on-board (the transfer of containers between bays/cells without transferring them on dock) and hatch opening/closing (transfer of hatch overs between ship and dock).

Only the first and the second types of moves are usually charged. A transfer is counted every time a container crosses between ship and dock.

The truck/rail transport process is far less involved than that for a ship and includes the following two main activities:

- Processing of clearance documentation
- Loading/unloading of containers

Factors Affecting Productivity

Following discussions on the activities associated with the container transport chain, factors affecting terminal productivity can be identified. These factors can broadly be divided into two categories, namely those that are controllable and those that are uncontrollable.

Controllable factors relate to the proficiency of planning, organising, operating, and maintaining terminal labour, facilities and equipment. Uncontrollable factors can further be divided into those that are ship related, those that are truck related and those that are port related.

Ship related factors include the type of ships (TEU capacity, cellular/non-cellular) calling at a port, number of moves per call and per bay, type and number of hatch overs, dimensions of the ship (especially width and depth which determine the box path) and stowage plan.

Truck/rail related factors are mainly associated with the arrival pattern of trucks (random vs pre-booked slots) and on-truck technology.

Port related factors include the type of facilities and equipment available at the terminal, including the type of cranes employed to handle the ship, whether they are shore-based gantries, shore-based mobile cranes and other factors such as type of weather, time of day, etc.

Measuring Container Terminal Productivity

The activities associated with container terminal operations and the factors influencing terminal productivity, discussed in the previous sections, provides the basis for comparison of container terminal productivity. Despite years of measuring and recording container terminal productivity, there is no uniform methodology to measure productivity. Crane rates are the most common measure used to compare port productivity. While crane rates are a significant indicator of container terminal productivity, it only forms a part of a complex logistical chain of activities that together makes up the total container transport process. Other similarly significant productivity indicators are berth utilisation, yard throughput and storage productivity, labour productivity, land transport times and costs.

The Bureau of Transport and Communications Economics (BTCE) produces its quarterly Waterline report emphasising crane rates (productivity per crane while the ship is worked), elapsed rates (productivity per ship based on the time labour is aboard the ship) and net rates (productivity per ship while the ship is worked) to benchmark Australian ports (BTCE, 1998). Studies by other bodies like the Australian Bureau for Industry Economics (1993), the Australian Transport Advisory Council (1992) and the Australian Business Council (1988) compared port productivity levels on the basis of quantifiable indicators such as berthing time, crane and labour productivity, cargo dwell time, port charges, etc.

The comparison of container terminal productivity is made difficult by the large variety of factors that influence productivity. Variations in publicly available data sources compiled by different organisations (and for different purposes), together with commercial sensitivities, place limits on the comparison of container terminal productivity.

While striving to attain best practice, there is a real danger of making unfair domestic and international comparisons if there is no similarity between the contexts. The task is not made any easier by a range of less tangible differences that also exist between the ports. Efficiency, or at the very least the ease of operation, is affected by the level of throughput, cargo exchange and stow, vessel size and type, technology and the customer focus of management.

Extensive research has been conducted to compare container terminal productivity with the best in the world. Some of the most notable research includes: Ashar's (1997) productivity indicators, Sachish's (1996) engineering approach, Tongzon's (1995) use of component analysis and Roll & Hayuth's (1993) use of data envelopment analysis

Productivity Indicators

Dr Ashar (1997) from the National Ports and Waterways Institute (USA) suggests the use of the following six productivity measures to indicate productivity of ships and gangs:

- Port accessibility (the difference between Port Time and Gross Berth Time) which reflects the distance and navigation conditions of the port access channel, availability of a pilot and tug, availability of agencies responsible for clearing ships, crews and cargo and the availability of berthage.

- Gross Berth Productivity which indicates the number of container transfers between the ship and the dock divided by ship's Gross Berth Time. This measure reflects the shift structure and labour situation

- Net Berth Productivity which is similar to Gross Berth Productivity but uses Net Berth Time. This measure reflects the number of gangs/cranes assigned to the ship.

- Gross Gang Productivity which indicates the number of container transfers divided by Gross Gang Time. This measure reflects labour contract, especially regarding "stand-by" time at the beginning, during and at the end of a shift.

- Net Gang Productivity which is similar to gross gang productivity but uses Net Gang Time. This measure includes non-productive activities such as handling hatch covers, shifting containers on-board and inserting/removing cones.

- Net/Net Gang Productivity which is similar to Net Productivity but uses Net/Net Gang Time. This measure reflects the technical capability of facilities and equipment, along with the proficiency of the labour in operating the equipment and the competence of terminal management in planning and controlling facilities and equipment

The above measures provides a simple methodology to determine container terminal productivity.

Engineering Approach

Arie Sachish (1996) from the Israel Port Authority undertook research with the goal of developing productivity functions that explain the changes in the productivity in Israel ports by means of changes in various explanatory factors. Productivity is measured against engineering standards. He developed partial productivity indices for each factor separately and aggregated them to yield a total productivity index, which is calculated in two ways: one using updated standards as a basis for comparison (giving local productivity) and the second uses comparison standards of a basic period (yielding comparative productivity figures).

The first step in his analysis of the factors affecting productivity was defining various possible characteristics which might influence productivity. He listed the following factors:

- Production Volume, which is the quantity of cargo in total tons handled (port throughput, labour requirement to overcome disruptions, number of gangs employed, etc).
- Number of Workers (ie the number of workers available on average each day)
- Actual Capital, which indicates the level of development and the potential ability to handle cargo. Three types of capital are defined namely: capital stock (the value of capital in the beginning of each year based on the rate of depreciation), capital cost (the sum of both the annual average and the annual interest of the capital stock) and capital cost per capita (the intensity of capital *vis-a-vis* labour).
- Technology Level. The technology level of plant greatly affects the nature of its activity and the possibility of management exploiting inputs. The level of technology is measured according to the proportion of the complement of direct workers to indirect workers. The assumption is that as technology develops, this proportion will decrease.
- Management Quality. All activities are determined by decisions made by management. Management quality is measured in terms of the relationship between agreements on norms (tons per worker) and standard outputs per input from a given mix of products, the ratio of the standard and the actual indirect labour (strictness

in appropriately reducing indirect workers), work accidents, effective time (the average effective work time during an operational shift) and training in the use of effective methods and technology

- External Factors which are defined by two measures: the percentage of overall unemployment and the percentage of work days lost to labour disputes.

Arie Sachish's work was implemented in Israeli ports between 1966 and 1990. This period was characterised by dramatic changes in technology of cargo handling in ports. These changes had a great impact on productivity and on the effect of explanatory factors on changes in productivity.

Principal Component Analysis Method

Tongzon (1995) from the National University of Singapore attempted to improve the current practice of comparing port productivity by introducing a quantitative and systematic approach to identifying similar ports. His approach is based on the principal component analysis

The first step in this approach is the identification of selection criteria. Criteria used includes: total throughput, number of commercial ship visits, vessel size and cargo exchange, the nature and role of the port, port functions and port infrastructure provided. The second step involves using principal component analysis to develop comprehensive performance indexes reflecting the individual measures of context developed and to identify significant indicators underlying the classification of ports

The advantage of principal component analysis over other methods (like cluster analysis) is that it allows us to compare ports using an estimated principal component

Data Envelopment Analysis Method

Roll & Hayuth (1993) from Israel developed the Data Envelopment Analysis (DEA) approach to measure productivity. This approach applies mathematical techniques which enables relative efficiency ratings to be derived within a set of analysed units. The productivity of units is compared with an 'productivity envelope' that contains the most productive units in the group. The DEA productivity ratings have been developed to provide port managers with a tool to gain deeper insight into port productivity. Data inputs into the DEA analysis include manpower, capital and cargo uniformity. Outputs from the DEA analysis include cargo throughput, level of service, users satisfaction and ship calls.

The DEA analysis approach provides relative efficiency ratings within the group analysed It is a easily adaptable approach for obtaining such ratings and can be used as a regular management control activity by container terminal operators.

Application of Methods

The above research efforts clearly indicate the variety of methods that could be used to determine container terminal productivity. The methods discussed can be applied independently or in combination, depending on the availability of data and the desired outcomes. Although there is no uniform methodology, reported indicators provide a broad indication of the relative productivity of many aspects of container terminal productivity.

Sydney Ports Productivity

Sydney Port vs Australian Ports

According to the Australian Bureau of Transport and Communications Economics' publication Waterline overall container terminal productivity at all Australian ports has increased as follows (BTCE 1998):

- Crane Rates (productivity per crane while the ship is worked) increased from approximately 13.4 TEU's per hour in December 1989 to 23.3 TEU's per hour in December 1997. This indicates an increase of 9.9 TEU's per hour or an annual increase of 7.2% per annum.
- The Net Rate (productivity per ship based on the time labour is aboard the ship) increased from approximately 16.1 TEU's per hour in December 1989 to 30.8 TEU's per hour in December 1997. This indicates an increase of 14.7 TEU's per hour or an annual increase of 8.4% per annum
- The Elapsed Rate (productivity per ship while the ship is worked) increased from approximately 13.5 TEU's per hour in December 1989 to 25.8 TEU's per hour in December 1997. This indicates an increase of 12.3 TEU's per hour or an annual increase of 8.4% per annum

Although Sydney ports crane rate is currently marginally under the average for all Australian ports its net rate is still above that for most Australian ports. Port charges can also be used as an indicator of efficiency, and have an obvious impact on profitability. For the period January to June 1997 the total cost per TEU for export from Sydney was $663. Other port productivity indicators like berth availability, pilotage and towage etc. can prove difficult to compare as there is some variation between port sample sizes and ship call patterns. A comparison of the time taken to work 600 boxes by container ports in Australia is shown in Table 1.

Table 1: Time Taken to Work 600 Boxes by Container Port 1994 (source: Martin (1998) from BIE (1995), p55)

Port	Hours								
	5	10	15	20	25	30	35	40	45
Melbourne	*****	*****	*****	*****	*****	*****	****		
Sydney	*****	*****	*****	*****	*****	*****	***		
Brisbane	*****	*****	*****	*****	*****	*****	*		
Adelaide	*****	*****	*****	*****	**				

Sydney Ports vs International Ports

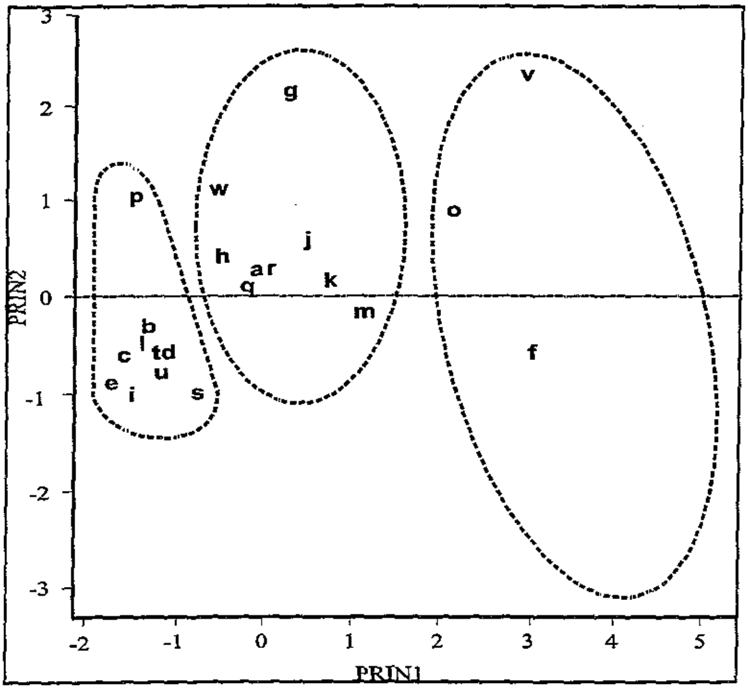
On comparative benchmarks, such as crane and ship rates, Australia has recently joined the performance league of similar sized overseas ports. But there is still a sizeable gap between many Australian ports and better performers in this league. Of course, the performance gap relative to world leaders, like Singapore and Hong Kong, is much more marked. However, these ports have a number of operating advantages over Australian ports in terms of their scale of operations and the nature of ships and cargo exchanges. Another aspect of container operational performance is capacity utilisation. Here, on most measures, Australia is on the lower end of the performance scale. Throughput per crane, per berth metre and per hectare of terminal area are relatively low (Daniels, 1993). A comparison of the time taken to work 600 boxes between Sydney ports and other international container ports are shown in Table 2.

Table 2: Time Taken to Work 600 Boxes by Container Port 1994 (source: Martin (1998) from BIE (1995), p55)

Port	Hours								
	5	10	15	20	25	30	35	40	45
Sydney	*****	*****	*****	*****	*****	*****	***		
Baltimore	*****	*****	*****	*****	***				
Wellington	*****	*****	*****	*****	**				
Antwerp	*****	*****	****						
Barcelona	*****	*****	***						
Zeebrugge	*****	*****	**						

Tongzon (1995) used the principal component analysis technique to compare 23 international ports By plotting the principal component PRIN1, which is an index of overall port performance (number of cranes, TEU's, ship visits, TEU's/ship visits and container berths) versus another principal component PRIN2, which is a contrast between the number of ship visits and all other variables, he derived natural groupings and ratings among ports. The results of the comparison are shown in Figure 1.

Figure 1: Classification of Ports (source: Tongzon (1995), pp 176)



a = Melbourne	h = Zeebrugge	o = Kaohsiung	v = Singapore
b = Sydney	I = Wellington	p = Bombay	w = Bangkok
c = Brisbane	j = Montreal	q = Felixstowe	
d = Fremantle	k = Baltimore	r = Puerto Rico	
e = Adelaide	l = Auckland	s = Jakarta	
f = Rotterdam	m = Le Havre	t = Manila	
g = Tacoma	n = Hong Kong	u = Kalang	

If price is an indicator of container terminal productivity then Sydney ports fall well short of world best practice. A study of international port costs revealed that Australia's five main land ports - Melbourne, Sydney, Brisbane, Adelaide and Fremantle are among the top nine most expensive in the world (Shipping World, 1994).

Reform at Sydney Ports

The disparity between productivity levels at container terminals at Sydney ports, compared to the best in the world, reflects the legacy of past inefficiencies in labour and capital productivity. Although there has been changes on the waterfront since the mid 90's this comes from a very low base and our competitors are improving their productivity at a substantial rate (Martin, 1998). Container terminal productivity at Sydney ports can only be dealt with comprehensively if all the fundamental issues are addressed. Although stevedoring productivity, especially in the area of workplace productivity, usually grabs the headlines, it only forms a small part of total productivity. Integration of all transport modes and the improvement of infrastructure and associated technology are also areas where container port productivity can significantly improve (Ross, 1998). Dealing with container terminal productivity comprehensively would include the involvement of all the key stakeholders in the container transport chain. Table 3 below provides an overview of the key stakeholders and their respective roles in the transport chain.

Table 3: Key Players and Roles in the Container Transport Chain

Key Players	Role
Exporter/Importer	These are the clients who pays for the service either directly or indirectly
Ship	The main bulk transport service in the chain
Ships Agent	Act on behalf of the company in booking space, centralising cargo, and arranging berths, tugs and pilots for ships
Custom Brokers	Act on behalf of importers in arranging clearance of cargo
Freight Forwarders	Act on behalf of exporter in arranging services provided by all parties
Stevedores/terminals	Load/unload ships
Regulatory Agencies	ACS, AQIS
Land Transport Operators	Carriage of goods or containers from depot to wharf
Port Authority	Provision of port infrastructure, traffic management, dredging, provision of state navigation aids within areas of responsibility

It is essential that all of the above key stakeholders combine their efforts to increase productivity of container terminals at Sydney ports to equal those of its international competitors. The main areas of reform would have to take place in the following areas:

- Labour relations
- Technology
- Transport integration
- Infrastructure investment
- Pricing Policy

Labour Relations

Compared to other productivity deficiencies at container terminals, the labour component has the most significant impact (social and media). Go-slows and selective work bans have become a common occurance at container terminals while generous workplace agreements adds to the cost of doing business on the waterfront. Current MUA orchestrated strikes at Sydney ports will again impact significantly on container terminal productivity. The end result being that the cost of waterfront labour is not supported by high productivity (Martin, 1998).

Essentially what is required is a normalisation of labour relations. There is no reason why the waterfront should differ from other sectors of the economy. Terminal management needs to respond to the strikes in a proactive manner and there should also be sufficient support for new entrants into the port market where it is economically feasible to do so. The need to establish a new stevedoring service which challenges the MUA monopoly and the supply of labour on the waterfront is now more important than ever (Martin, 1998)

Technology

Advances in modern technology provides key players with sufficient tools to enhance container terminal productivity significantly. The method of lodgement of manifests until recently been manual. Sydney Ports Corporation is encouraging the lodgement of manifests into their Harbour Management System electronically and has offered a rebate of 2.5% of the manifest wharfage value as an incentive to advance this technology (Ross, 1998). A single integrated system common to all ports in Australia is necessary to enable information to be put into the system once only. This would require Australian Customers Service (ACS), Australian Quarantine Inspection Services (AQIS), port corporation/authorities and shipping lines/agent's support to develop the system successfully (Martin, 1998). The ACS is examining the redesign of their software systems and the opportunity exists for all parties to progress this concept to benefit the industry. Sydney ports has the potential to be a world leader in the development and implementation of port electronic data interchanges.

Sydney Ports Corporation has, over the past two years developed a state-of -the art integrated vessel surveillance system which provides, in conjunction with the CBS, a sophisticated and modern means of managing vessel movement efficiency (Ross, 1998).

Transport Integration

Transport providers (rail/road), container terminals/parks and exporters/importers would need to work more closely together to improve productivity within the total logistics chain. Interface between both the water-based and land-based transport service providers needs to be improved. Land based transport (rail/road) productivity needs to be improved to allow for efficient movement of cargo. The development of hubs, not just intermodal but also ports, will need to be progressed to improve service and reduce costs. The development of technology and electronic data interchanges has contributed significantly in facilitating the integration of transport modes and infrastructure.

According to Chief Executive Officer of SPC, Greg Martin, improved management of rail and road access to Port Botany could successfully accommodate cargo volume increases for many years without the need for major new rail and road infrastructure (Port Focus, 1998).

He further stated that infrastructure developments currently underway, such as the Eastern Distributor and the M5 East extension, will improve access to the port, but major changes to the way freight is managed are now essential. Sydney Ports Corporation developed a four-point plan to achieve greater transport integration which involves:

- Inland rail hubs; and,
- Road freight hubs relying on stack runs to/from terminals (Port Focus, 1998).

Infrastructure Investment

Sydney Ports Corporation has developed the 2020 Master Plan which identifies the importance of retaining existing facilities in Sydney Harbour and areas for future expansion in Botany Bay. The Corporation will be developing the Glebe Island/White Bay precinct providing for improved road and rail facilities which in turn will assist in improving port efficiency through improved traffic management (Ross, 1998).

Pricing Policy

Since the beginning of the waterfront reform process port authorities have generally improved their financial performance, cutting real charges and reducing costs. Arguing that higher productivity will provide for lower handling charges, a meaningful market pricing system should be developed based on "productivity-adjusted" charges. A terminal handling charge should be quoted in terms of a ship-yard move at an average productivity specification of moves/hour. The quotation should also include a premium for a higher productivity and a penalty for a lower productivity (Ashar, 1997). Sydney Ports Corporation has already taken a step in this direction by introducing rebates for stevedores who achieve productivity targets (Ross, 1998).

It is suggested that the industry should develop and adopt a standard stevedoring contract which will include a clear description of times and activities (and delays) involved in the ship handling process, along with a definition of a set of relative productivity measures. To monitor actual productivity, the contract should include a standard ship operations report for recording times and activities according to the contract definitions (Ashar, 1997).

Conclusion

The meaning of productivity has been defined as being synonymous with both efficiency and profitability. Various indices and methodologies used to compare container terminals (ports) in terms of their productivity have been investigated. It has been concluded that although there is currently no uniform methodology by which container terminal productivity are be compared, the methods proposed by Ashar, Sachish, Tongzon and Roll *et al* could be used independently or in combination depending on the availability of data and the desired outcomes. If a uniform methodology is required, the simple method suggested by Ashar could be the first positive step in the this direction.

Employing the current available container terminal productivity indicators it has been determined that Sydney ports are competing on level grounds with other Australian ports. On comparative benchmarks, such as crane and ship rates, Sydney ports have also joined the league of similar sized overseas ports. However, there is still a sizeable gap between Sydney ports and better performers in this league which can mainly be contributed to the legacy of past inefficiencies in labour and capital management.

Based on the identified factors that effect container terminal productivity a number of areas of reform have been identified. Reforms in the areas of labour relations, technology, transport integration, infrastructure investment and pricing policies would improve productivity and enhance Sydney ports negotiation position.

Waterfront reform is important because it impacts on many other areas of the Australian economy. The reform will lead to direct improvements for Australian business with improved services and lower costs for users. Currently, stakeholders are effecting change with varying degrees of success

Furthermore, it should be acknowledged that reform is a process of continual improvement. It often means getting back to basics: understanding productivity, how its measured and compared and how to improve current practices. Numerous tools are available to terminal management and port authorities to ensure that Sydney ports performs well.

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