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Analyzing Port Performances and Logistics Costs: A Multidimensional Causal Approach

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Analyzing Port Performances and Logistics Costs: A Multidimensional Causal Approach

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Abstract

In this paper an attempt has been made to identify the dimensions of port performance and their causality to develop a multidimensional causal model so as to enable the port planners to decide on enhancing the port performance. The study identifies two major dimensions namely capacity dimension and the efficiency dimension that affect the port performance. It defines the relationship between the port performance measured through the metric termed average turn round time (ATRT) and the dimensions. ATRT guides the number of ships calling a port.

The study further describes the causal model for the purpose experimenting on policies of the port. It identifies a stabilizing feedback loop that governs the dynamics of ships flow to a port assuming that there exists adequate demand for import and/or export cargo. The model not only explains the causality but also identifies the limits to growth.

JEL Classification: R-4

Keywords: Port Performance Indicators, Average Turn Round Time, logistics costs, system dynamics

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1 Introduction

Logistics and supply chain are concerned with physical and information flows and storage from raw materials through to the final distribution of the finished products. Logistics concerns the efficient transfer of goods from the source of supply through the place of manufacture to the point of consumption in a cost-effective way whilst providing an acceptable service to the customer. The key areas representing the major components of distribution and logistics include transport, warehousing, inventory, packaging and information. Logistics is an important activity making extensive use of the human and material resources that affect a national economy. Amstrong and Associates (2007) found that for the main European and North American economies, logistics represents between about 8 percent and 11 percent of the gross domestic product of each country. For developing countries this range is higher at around 12 percent to 21 percent – with India at about 17 percent and China at 21 percent. The substantial costs involved in logistics signifies the importance of understanding the nature of logistics costs and identifying means of keeping these costs to a minimum.

The breakdown of the costs of the different elements within logistics has also been addressed in various surveys. One survey of US logistics costs undertaken by Establish/ Herbert Davis (2008) indicated that transport was the most important element at 50 percent, followed by inventory carrying costs (20 percent), storage/ warehousing (20 percent), customer service/ order entry (7 percent) and administration (3 percent). The survey also produced a pan-European cost breakdown which placed transport at about 40 percent, warehousing at about 32 percent, inventory carrying cost at about 18 percent, customer service/ order entry at about 5 percent and administration at about 5 percent. In both studies the transport cost element of distribution was the major constituent part.

In a global context, more products are moved far greater distance because of the concentration of production facilities in low-cost manufacturing locations and because companies have developed concepts such as focus factories, some with a single global manufacturing point for certain products. Long-distance modes of transport have thus become much more important to the development of efficient logistics operations that have global perspective. The broad approach for selecting the suitable mode of transport is split into four stages covering operational factors, transport mode characteristics, consignment factors and cost and service requirements. A modal choice matrix for international logistics as observed by Rushton et al (2010) is given below.

Table 1 : Modal Choice Matrix

Size of order/ load	Short	Medium	Long	Very Long
100T	Road	Road/Rail	Rail/Sea	Sea
20T	Road	Road	Road/Rail	Rail/Sea
Pallet	Road	Road	Road/Rail	Air/Sea
Parcel	Post/Road	Post/Road/Air	Post/road/air	Post/Air

Source : The Handbook of Logistics & Distribution Management (2010)

For goods traded globally maritime transport plays an important role as ninety percent of goods traded globally by volume are transported using sea routes. Access to a global network of reliable, efficient and cost-effective maritime transport services thus often becomes a necessary condition in today's highly competitive global scenario. A well connected maritime transport sector ensures an efficient and cost effective supply chain and implies vast positive spillovers in terms of increased trade.

Ports are essentially points at which sea-borne cargo is transferred from one mode of transport to another. Ports play a vital part in inter-modal transport networks (sea, road, rail). In order to make whole transport operation smooth, both the inward transport to the port and outward transport from the port must be speedy and efficient. In addition, the handling of cargo i.e., discharge from ship to wharf, movement from wharf to stack yard and from stack yard to lorry or railway wagon, in case of imports, and discharge from lorry/railway wagon, movement to stack yard and loading to the ship, in case of exports, must be efficient and cost effective. In this paper literature survey has been carried out to identify different port performance indicators. The selected indicators have been subjected to factor analysis for identifying the dimensions of port performance. The relationship between the port performance measured through dimensions so obtained (from the factor analysis) and the average turn round time (ATRT) of vessels , the dependant variable, has been established though multiple regression. The analysis has been done using SPSS. A causal model has been developed based on System-Dynamics approach, to study the impact of change in port performances on number of vessels and total cargo throughput.

2 Literature Review

In the 1976's United Nations Conference on Trade and Development (UNCTAD) published a document about the port performance indicators and since then it is seen by the researchers in this area as a reference (UNCTAD, 1976). In this document there are several types of indicators to evaluate the operational and financial performance.

Kek Choo Chung (1993) indicates that the operational performance of a port is generally measured in terms of the speed with which a vessel is dispatched, the rate at which cargo is handled and the duration that cargo stays in port prior to shipment or post discharge. According to Chung a more progressive approach would also like to know how extensively and intensively the port's assets are being utilized as well as how well the operations perform financially. Indicators to measure these performances are determined generally in relation to the tonnage of ships calling at the port and of the volume of cargo handled since port services in the main are rendered to ships and cargo.

The evolution of the concept of logistics, in which the operators are classified according to its level of intervention in the supply chains and designated as Transport Service Providers (TSP) allows us to understand that the measurement of the efficiency level of this entities is not confined to quantitative aspects and proves that qualitative indicators are necessary (Antão et al., 2005).

Thai (**2007),** opined that if security measures and initiatives are not carefully designed and effectively implemented, they can negatively impact the whole maritime transport chain. Security improvements resulting from maritime security requirements may also bring about some benefits to the business performance for the organization. Bryan et al. **(2006)** concluded that port infrastructure plays an important role in supporting other welsh businesses. Farrel **(2009)** describes how container terminal efficiency declines as the terminal becomes more congested.

Yan and Liu (**2010)** indicated that the number of berths and the capital deployed are the most sensitive measures impacting performance of most container ports. The analysis also reveals that container ports located in different continents behave differently. The results show that vessel turnaround time is highly correlated with crane allocation as well as the number of containers loaded and discharged. The benefits of such model include giving port operators opportunity to determine optimum crane allocation to achieve the desired turnaround time given the quantity of containers to be processed (Mokhtar & Shah , 2006).

Most of the recent studies used the methodology of data envelopment analysis (DEA) to measure port efficiencies. Martinez-Budria et al. (1999) analyzed 26 Spanish ports using DEA-BCC model and concluded that larger ports produced higher efficiencies. Tongzon (2001) analysed the efficiency of four Australian and twelve other ports using the DEA – Additive and DEA – CCR model and argued that container handling operation is the most important component of the service offered by port authorities. Tongzon (2008) pointed out that operational efficiency does not solely depend on a port's size and function. The study by Wang and Cullinane (2006) included European container terminals with annual throughput of over 10,000 TEUs from 29 countries. They concluded that most of the terminals under study showed inefficiency and that large-scale production tended to be associated with higher efficiency. Yongrok Choi (2011) used DEA and its variant models for 13 major sea ports in North East Asia including the seven largest container ports and concluded that investment in infrastructure does not improve efficiency, rather self created logistics demand and strategic allowances do improve the efficiency. Chudasama (2009) identifies the efficient and inefficient major ports of India and discovers the sources of inefficiency for the inefficient ports on the basis of DEA. Lee et al. proposed a new procedure based on DEA (Data Envelopment Analysis) called RDEA (Recursive Data Envelopment Analysis) and applied it to rank 16 international container ports in Asia Pacific region in terms of operational efficiency.

Bhatt and Gaur (2011) , concluded that after privatisation of the container terminals the performance of the terminals was relatively closely matched. The competition of securing the cargo had led to matching efficiencies on quay side where ships turnaround times and client satisfaction are closely related. However, they found that yard side efficiencies in evacuation of cargo were suffering major differences.

Blonigen and Wilson (2006) developed and applied a straightforward approach to estimate port efficiency by using detailed data on U.S. imports and associated import costs, yielding estimates across ports, products, and time. These measures are then incorporated into a gravity trade model where they estimated that improved port efficiency significantly increases trade volumes. The study provides new measures of ocean port efficiencies through simple statistical tools using U.S. data on import flows from 1991 through 2003.

Stochastic frontier model was used by Coto, Banos and Rodriguez in 2000 to measure efficiency of Spanish Ports. Their analysis resulted in a conclusion that efficiency and size are not related and that autonomous ports are less efficient than the rest.

A similar study and methodology used by Notteboom, Coeck and Van den Broeck in 2000 to measure efficiency of 36 European container terminals which concluded that hub ports are more efficient than feeder ports and that efficiency and size relationship is a function of type of port. They observed no relationship between type of ownership of port or terminal and the efficiency level.

This observation on relationship of ownership and efficiency is further contradicted by Jose Tongzon and Wu heng (NUS, Singapore) in 2005 when they conclude that private participation in ports is useful to improving efficiency however complete privatization is not the answer to improve efficiency of a port and that the relationship is an inverted bell shape curve.

Factors affecting Port efficiency emerging through these studies are Size, Competition – Intra and Inter port, Technology adopted and Management/Institutional structure. These factors are again interdependent and region specific and thus important conclusions may be drawn on comparable terminals and indicators.

The conclusions drawn from the above literature review are stated below.

Conclusion 1: The operational performance of a port is generally measured in terms of the speed with which a vessel is dispatched, the rate at which cargo is handled and the duration that cargo stays in port prior to shipment or post discharge (Kek Choo Chung, 1993).

Conclusion 2: Container terminal efficiency declines as the terminal becomes more congested (Farrel, **2009)**.

Conclusion 3: The number of berths and the capital deployed are the most sensitive measures impacting performance of most container ports (Yan and Liu, **2010)**.

Conclusion 4: Vessel turnaround time is highly correlated with crane allocation as well as the number of containers loaded and discharged (Yan and Liu, **2010)**.

Conclusion 5: Variations in port efficiency are linked to excessive regulation, the prevalence of organized crime, and the general condition of the country's infrastructure (Clark et al, 2004).

They found that besides distance and containerization, the efficiency of ports is also important in determining maritime transport costs.

Conclusion 6: Larger ports produced higher efficiencies (Martinez-Budria et al. 1999).

Conclusion 7: Operational efficiency does not solely depend on a port's size and function (Tongzon 2008).

Conclusion 8: Large-scale production tended to be associated with higher efficiency (Wang and Cullinane 2006).

Conclusion 9: Investment in infrastructure does not improve efficiency, rather self created logistics demand and strategic allowances do improve the efficiency (Yongrok Choi 2011).

Conclusion 10: After privatisation of the container terminals the performance of the terminals was relatively closely matched (Bhatt and Gaur, 2011). The competition of securing the cargo had led to matching efficiencies on quay side where ships turnaround times and client satisfaction are closely related.

3 Port Sector in India

India accounts for 7517 km of coastal line spread over 13 states and Union Territories. There are 12 major ports and about 200 non-major ports. Among the non-major ports only 60 per cent are functioning actively. The thirteen major ports are Kolkata Port Trust, Paradeep Port Trust, Visakhapatnam Port Trust, Ennore, Chennai Port Trust, Tutucorin Port Trust, Cochin Port Trust, New Mangalore Port Trust, Mormugao Port Trust, Jawaharlal Nehru Port Trust, Mumbai Port Trust, and Kandla Port Trust. In India, about 95 % of cargo by volume and 70 % in terms of value are transported by sea. Cargo handled by Indian Ports increased from 21.30 million tones in the year 1950-51 to 849.88 million tonnes in 2009-10 at an compound annual growth rate of 6.45% . During the last 9 years (2000-01 to 2009-10) it has registered a compound annual growth rate of 9.75%. Table 2 shows below the trend of cargo traffic handled by the Indian ports with a breakup of its share among Major ports of India (controlled by Central Government) and non-major ports comprising ports controlled by State Maritime Boards which also include private ports. Table 3 shows the compound annual growth rates of the Major and non-major ports for various time periods. It is evident from the Tables that both the growth rate and the share of the non-major ports increased drastically after 1990-91 i.e., after the liberalization process started.

Table 2 : Cargo handled by Major and Non-Major Ports in India

Year	Major Ports (mt)	Non-Major Ports (mt)	Total (mt)	Share of Major Ports (%)	Share of Non-Major Ports (%)
1950-51	19.38	1.92	21.30	90.99	9.01
1960-61	33.12	4.41	37.53	88.25	11.75
1970-71	55.58	6.69	62.27	89.26	10.74
1980-81	80.27	6.73	87.00	92.26	7.74
1990-91	151.67	12.78	164.45	92.23	7.77
2000-01	281.13	87.25	368.38	76.32	23.68
2004-05	383.62	137.83	521.45	73.57	26.43
2009-10	561.09	288.79	849.88	66.02	33.98

Source : Various issues of Major Port of India : A Profile, IPA

Table 3 : Compound Annual Growth Rate of Cargo handled by Indian Ports

Year	Major Ports	Non-Major Ports	All Ports
1950-51 to 1960-61	5.51	8.67	5.83
1960-61 to 1970-71	5.31	4.26	5.19
1970-71 to 1980-81	3.74	0.06	3.40
1980-81 to 1990-91	6.57	6.62	6.57
1990-91 to 2000-01	6.35	21.18	8.40

2000-01 to 2009-10	7.98	14.22	9.75
1950-51 to 2009-10	5.87	8.87	6.45

Source : Various issues of Major Port of India : A Profile, IPA

Although the traffic through Indian Ports has registered a significant growth, that cannot be said for the efficiency level of most of the Indian ports. The reform process adopted by the port sector of India started more than a decade ago, without having much effect on the status of the Indian ports in the world map of ports. There is no sign of Indian ports being closer to the regional ports of Singapore or Colombo or Hong Kong or Port of Shanghai, in terms of cargo handling and efficiency. This is evident from Table 4 and Table 5. Table 4 shows port-wise container traffic in various major ports of India for the year 2009-10 whereas Table 5 shows container handled by top 10 container handling ports of the world in the year 2009 and 2008. As it is seen, the total container handled by all major ports of India (6.89 million tonnes) is far less than the container handled by the port positioned at number 10 in the world. As a consequence, most of the Indian ports are still being visited mostly by the feeder vessels. This involves a longer time for the entire supply chain and in turn has its effect on overall transportation costs and trade cost for the shippers.

Table 4 : Major Ports of India - Port Wise Container Traffic (2009-10)

Port	Container Traffic (In ,000 TEUs)
Kolkata Dock System	378
Haldia Dock Complex	124
Paradip Port Trust	4
Visakhapatnam Port Trust	97
Chennai Port Trust	1216
Tuticorin Port Trust	440
Cochin Port Trust	290
New Mangalore Port Trust	32

Mormagao Port Trust	13
Mumbai Port Trust	58
Jawaharlal Nehru Port Trust	4092
Kandla Port Trust	147
TOTAL	6891

Source : Major Ports of India – A Profile: 2009-2010, IPA

Table 5 : Top 10 Container Handling Ports of the World 2009

(In million TEUs)

Rank (2008)	Port	2009	2008
1 (1)	Singapore	25.87	29.92
2 (2)	Shanghai	25.00	27.98
3 (3)	Hong Kong	20.98	24.49
4 (4)	Shenzhen	18.25	21.41
5 (5)	Busan	11.95	13.43
6 (8)	Guangzhou	11.19	11.00
7 (6)	Dubai	11.12	11.83
8 (7)	Ningbo-Zhoushan	10.50	11.23
9 (10)	Qingdao	10.26	10.32
10 (9)	Rotterdam	9.74	10.80

Source : Containerization International, 2009

4 Causal Analysis

The dynamics of a port system as a part of the logistics chain, arising out of interaction of different variables that describes the system, may be explained with a system dynamics model. System dynamics focuses on the structure and behavior of the systems. The structure composed of interacting feedback loops explains the behavior of the system. Causal loop diagramming is an important tool, which helps the modeler to conceptualize the real world system in terms of feedback loops. Causal loop diagram consists of of variables and causal relations among them.

Ship's costs at ports constitute a significant part of the maritime transport costs and thus can significantly influence the logistics costs and hence the final price of a product. The total costs incurred in port are found by adding together (1) actual port costs and (2) the cost of ship's time in port.

Maritime Transport Cost = f(Ship's cost at port)

Ship's cost at port = Actual Port Cost + Cost of ship's time at port

Actual port cost = h(Infrastructural facilities, Operational Efficiency level)

Port costs are made up of two parts:

(i) A fixed component which is independent of tonnage throughput (includes the capital costs of quays, sheds, cranes etc.).

(ii) A variable component which depends on tonnage throughput (includes labour costs, fuel, maintenance costs etc.).

As the tonnage handled at a berth increases, the fixed component, when expressed as a cost per tonne, decreases. The variable component, when expressed as a cost per tonne, will probably remain fairly stable until the berth comes under pressure to achieve high tonnage throughputs, at which point the variable cost per tonne will tend to rise owing to use of more costly methods of cargo handling. These costs are realized by the ports through various port charges and dues.

Cost of ship's time at port = g(Average Turn Round Time)

Average Turn Round Time = k (Traffic Volume, Nature of cargo, Infrastructural Facilities, Operational Efficiency level, Capacity)

Ship's time in port is made up of two parts :

(a) The time the ship spends at the berth;

(b) The time the ship spends waiting for a berth to become vacant.

As traffic increases, the time ships waiting to obtain a berth increases. At high berth occupancies, this increase in ship waiting time may be quite dramatic. The time ship spends at the Berth depends on the nature of cargo, infrastructural facilities at the port and operational efficiency of the port.

Average charges calculated on the basis of shipping rates provided by the Maersk Sealand for the year 2006 for import of a container vessel in India reveals that almost 25% of the total freight charges are collected by the terminal or port operators (of which around 13% at destination i.e at Indian ports) for various port related activities. Thus, an increase in the efficiency level of the ports may have an significant effect on the logistics costs. Besides, an increase in the efficiency level of the ports may also increase the overall efficiency level of the supply chain.

4.1 Port's Operational Efficiency and Ship's Cost Dynamics

A change in the operational efficiency of a port results in a change in the cargo handling rate, idle time at port, waiting time of ships, time for ship's stay at berth, time for cargo receipt and delivery. An increase in the operational efficiency increases the cargo handling rate, reduces total operational time and thus results in a faster delivery of cargo at both ends of operation (ship and shore). This reduces the time for ship's stay at port or average turn round time. As ship's cost at port is a function of ship's time at port as explained above, this in turn reduces ship's total cost at port. A decrease in the ship's total cost reduces the maritime transport cost along the logistics chain. As a result, the port's competitiveness compare to other neighboring ports increases and the port is likely to experience increase in number of ship calls. The ships immediately cannot perceive the decrease or increase in its total costs. They may take some time to assess it. The perception delays by the carriers of the average turn round time may play as a compensatory feedback loop, prompting wrong signal to the port management if not interpreted correctly.

Based on the above the above theoretical background and the conclusions drawn from the research findings by various authors, an integrated causal loop diagram representing causality among variables can be constructed as given in section 4.2.

4.2 Integrated Causal Diagram: The Theoretical Construct

The study of literature followed by the conclusions drawn and the understanding of port dynamics can be used for developing the following causal diagram.

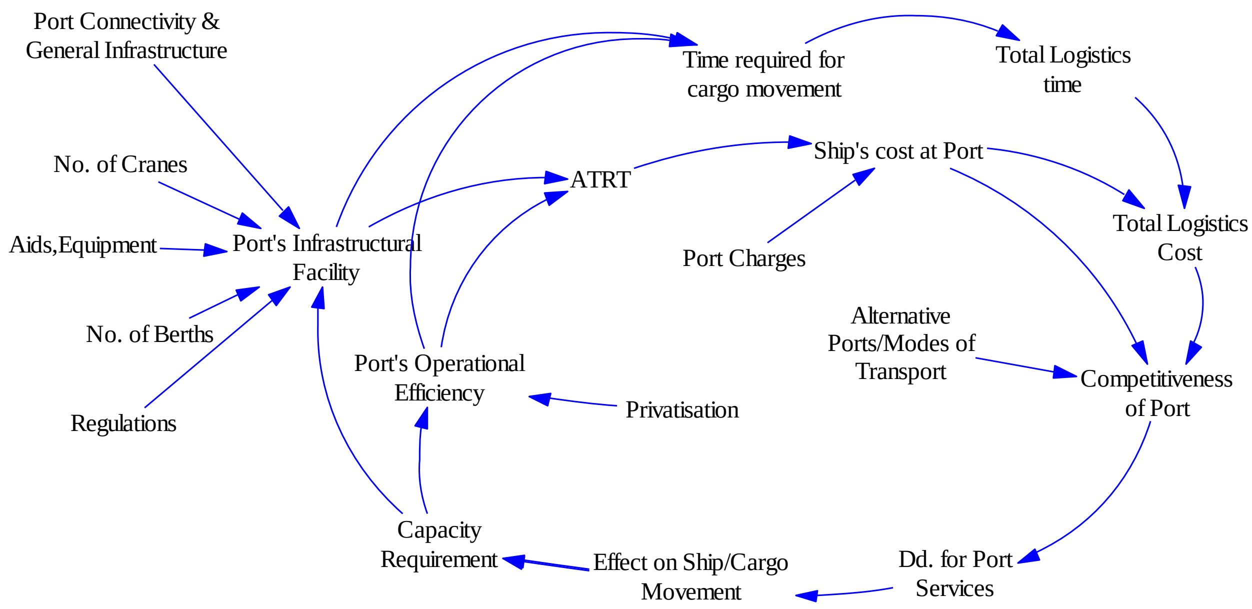

Figure 1: Causal diagram of variables affecting port performance

The above causal model explains the structure that governs the relationship between the performance of the port system and the logistics costs. It gives the causal linkage between the important variables. The port's infrastructural facilities and the port's operational efficiency both influence the average turn round time of the ship. Better infrastructural facilities and better operational efficiency reduce the dwelling time of a ship at a port and thus reduce the cost of ship's time at port. If the corresponding increase in actual port costs for providing improved infrastructural support for better services remains less than the reduction in the costs for ship's time at port, this will result in a reduction in the total logistics costs. This in turn, increases the competitiveness of the port and thus increases the demand for port services resulting in increased s movement of cargo and/or ships. An increase in cargo and vessel traffic increases the capacity requirement at the port and thus puts pressure on the infrastructural facility and efficiency level of the port.

The port's infrastructural facilities and the port's operational efficiency both also influence the total time required for cargo movement through a port. Better infrastructural facilities and better operational efficiency reduce the cargo movement time at a port and thus reduce the total logistics time and costs. This in turn, increases the competitiveness of the port and thus increases the demand for port services which results in movement of more cargo and ships. An increase in cargo and vessel traffic increases the capacity requirement at the port which will in turn has its effect on Port's infrastructural facility and efficiency level.

5 Empirical Evidence

The empirical evidence to the above construct has been done for Port's Operational Efficiency - Ship's Cost Dynamics and Port Capacity - Ship Cost Dynamics. The study has been done based on the data, during the year 2008-09, collected on containerized cargo handled by 12 major ports of India, a brief description of which is given below. . Sources used are

(1) Major Ports of India : A Profile 2008-09, 2007-08,

(2) Annual Administration Reports of all Major ports, 2008-09.

The analysis has been done in two parts. First all the operational indicators of performance of container handling (ship side) activities (except ATRT) of Major Ports of India were taken for factor analysis. Then a multiple regression has been done taking Average Turn Round Time of Vessels as the dependant variable and the Factors obtained from the factor analysis as the independent variables. All the analysis has been carried out using SPSS.

Variables considered were as listed below.

1. Container Traffic measured in '000 TEUs Terminal wise container traffic for the year 2008-09, unit ,000 TEUs. (where available private terminal data were separately treated).
2. VTRAFFIC : Container Vessel Traffic in number
3. ATRT : Average Turn Round Time (ATRT) unit in days. It includes total time needed by a ship for entry pilotage, Pre berthing waiting time, stay at berth and exit time.
4. APBT :Average Pre Berthing Time in hours
5. APS : Average Parcel Size in tonnes
6. AOPSBD : Average Output per Ship Berth Day in tones
7. PNWTSP : Percentage of Non Working Time to Total time at Port

8. Draft : Refers to the available depth of water in the port. It determines the size of the ship that can visit the port. Measuring unit metre.
9. Private Ownership of terminal (Pvto). This is represented by a dummy variable where pvt. Ownership = 1 and otherwise = 0.
10. CRANES : Number of cranes handling containers (including both Quay and Yard cranes)
11. BERTHS : Number of Berths handling containers
12. CAPACITY :Container handling capacity of the terminal

5.1 Results

5.1.1 Factor Analysis

Rotated factor matrix (varimax rotation) indicates 2 (two) factors are with eigen value more than one. Factor 1 is loaded with Traffic, Vessel Traffic, Average Parcel Size (APS), Average Output per Ship Berthday (AOPSBD) and Private Ownership of terminal (Pvto), No. of Cranes , No. of Berths and Capacity whereas Factor 2 is loaded with Average Pre Berthing Time (APBT), Draft, and Percentage of non-working time to total time of ship at Port (PNWTSP). All the variables in the Factor 1 are mainly associated with capacity of the container terminal and hence may be labeled as **Capacity Dimension** (CD) whereas the variables in the Factor 2 are associated with the operational efficiency of the container terminal and hence may be labeled as **Operational Efficiency Level (EL).**

5.1.2 Multiple Regressions

Multiple Regression has been done taking ATRT (Average Turn Round Time) as the dependant variable and CD (Capacity Dimension) and EL (Efficiency Level) as independent variables.

Levene test has been done and it has been found that the dependent variable ATRT is homoscedastic (p value >.05). The relationship has been taken as linear as initially indicated by the scatter diagrams. However, a small value of R^2 (=.48) indicates the influence of nonlinearity.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.061E-18	.211		.000	1.000
	REGR factor score 1 for analysis 1	.019	.219	.019	.089	.931
	REGR factor score 2 for analysis 1	-.689	.219	-.689	-3.153	.009

a. Dependent Variable: ATRT

Equation 1 gives the relationship between dependant variable i.e., ATRT and the dimensions i.e., CD and EL

ATRT = .019 CD - .689 EL ------- (1)

The above relation confirms the basic premise that the efficiency level of the logistics chain is dependant on the capacity dimension as well as the efficiency level of the port. The ATRT increases with capacity of the port as larger ships with higher parcel load are expected to call at the port causing the average turn round time (ATRT) to increase while the increase in efficiency is expected to result in reduction in stay time of ships at the port, that is, decrease in ATRT.

5.2 Multi-dimensional Causality

The causality between ports performance and its dimensions have been evidenced from the above analysis**.** However, there is a evidence of non-linearity and hence multiple regression is not sufficient to describe the causality. The System Dynamics model is capable of capturing non-linearity and enables policy experimentation based on the mental model of the decision maker.

The causal diagram in Figure 2 shows the causality between the two dimensions of port performance, namely, capacity and efficiency level with ATRT (average turn round time) and NO OF SHIPS (number of ships) calling at port

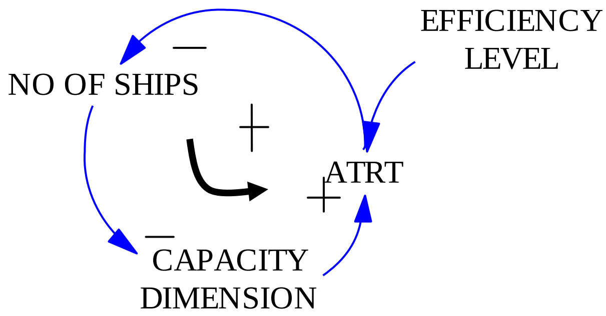

Figure 2: Loop diagram showing causality between the two dimensions with ATRT and No. of Ships calling at port

It demonstrates that influence of capacity and efficiency dimensions on ATRT in turn affects the number of ships calling at port. The behaviour of the system is governed by the negative loop. This implies that when the ATRT increases reflecting poor performance of the port, the carriers are expected to avoid that particular port. As such number of ships calling at port decreases while the reverse is expected to be observed when ATRT decreases. At the same time the number of ships calling at port would impact the capacity dimension, as its increase will tend to demand for more berths and or equipment, meaning that the number of ships calling at port causes reduction in capacity of the port, in turn affecting ATRT.

The policy implication of above model is that the decision maker has two different options to enhance its performance. One way would be to increase its capacity through increase in average ship day output (AOPSBD) (may be through modernizing or replacing the equipment,and/or training of manpower), and/or management restructuring (may be through privatisation). The other option would be enhance efficiency, may be through enhancing “soft measures” relating to cargo handling processes viz, documentation, ICT and statutary inspections, and/or increase in draft (may be through dredging, better disposal), and / or improved supervison resulting in reduction in non-working time of ships at the port.

The data analysis reveal that the efficiency dimension has more weightage than capacity dimension, meaning that the Indian major ports need to streamline their business processes to achieve better performance. However, the impact of effeciency level due to actions taken to improve the ATRT is not static, as improvement of ATRT is likely to increase number of ships causing capacity to fall, meaning a low performance measured through ATRT. Hence, the imapact of the changed decisions has to be simulated and results monitored to achieve the corporate goal. The above model can, therefore, be described as a dynamic model based on principles of causality.

An improvement in ATRT is likely to attract more ships which cause the capacity to act as constraint, resulting in increase in ATRT unless the efficiency level increases to improve the productivity and hence stretch the capacity further. However, there is limit to enhancement of efficiency level, and subsequently may call for increase in capacity through investments.

6 Validation

The effect of efficiency parameters such as Average Output per Ship Berth-Day (AOPSB) and capacity parameter such as Average Pre-Berthing Time (ABPT) on ATRT which in turn effects the cargo flow through the ports can be observed from the figure 3 drawn on data for the period 1990-91 to 2010-2011 for container traffic (in TEUs) at JNPT (Jawaharlal Nehru Port Trust).

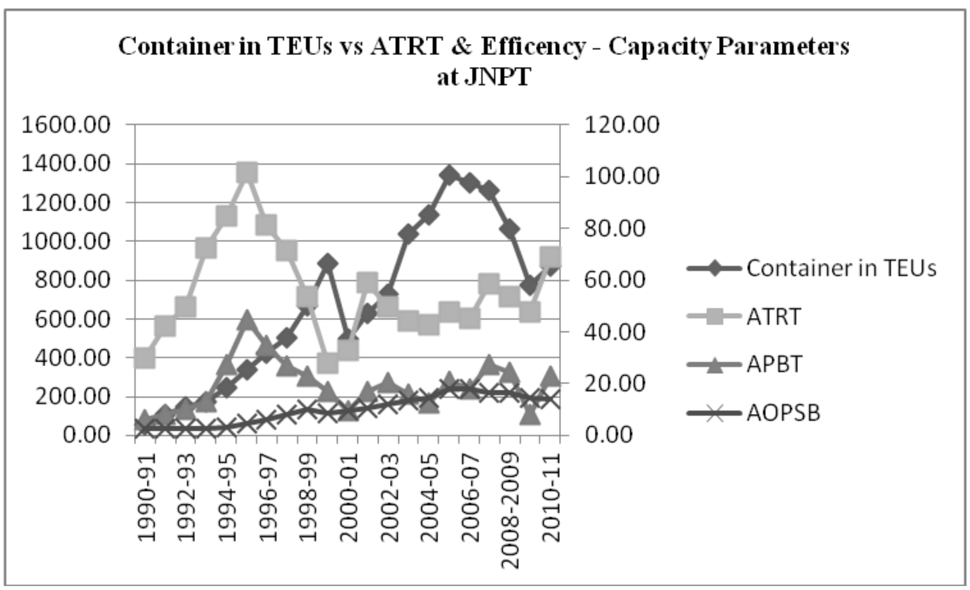

Figure 3: Container in TEUs vs ATRT & Efficiency - Capacity Parameters at JNPT

The ATRT in the above case decreases with increase in AOPSB and decreases with increase in APBT (or the waiting time)

The model not only explains the causality but also identifies the limits to growth. An improvement in ATRT is likely to attract more ships which cause the capacity to act as constraint, resulting in increase in ATRT unless the efficiency level increases to improve the productivity and hence stretch the capacity further. However, there is limit to enhancement of efficiency level, and subsequently may call for increase in capacity through investments. Figure 3 also shows that as container traffic grows the ABPT increases meaning that increase in traffic causes the capacity to reach its upper limits resulting in waiting of ships.

7 Conclusions

The literature on the subject matter that reveal the different relationships amongst the variables and factors have been considered to lay down the conclusions on port dynamics. The same has been used to develop the theoretical construct. The empirical evidence to this construct reveal that Average Turn Round Time (ATRT) of a container vessel is dependant on two specific dimensions namely Capacity Dimensions (level of operation) and Efficiency Level of the Port. The study concluded that an increase in the cargo handling level without any change in the efficiency level will lead to increase in ATRT in the form of increase in Pre Berthing Delay and higher Percentage of non-working time. Similarly an increase in the Efficiency Level can significantly reduce the ATRT of a vessel and thus can help to reduce the overall transport costs in the Supply Chain. However, the efficiency level cannot be increased beyond a certain level and hence the port needs to enhance its capacity with additional investments. The model so described in this paper enables the policy maker to find the impact of efficiency level and capacity on the ATRT. The causal model identifies a stabilizing feedback loop that governs the dynamics of ships flow to a port assuming that there exists adequate demand for import and/or export cargo. The model has been validated using data for the period 1990-91 to 2010-2011 for container traffic (in TEUs) at JNPT (Jawaharlal Nehru Port Trust). It demonstrates the effect of efficiency parameters such as Average Output per Ship

Berth-Day (AOPSB) and capacity parameter such as Average Pre-Berthing Time (ABPT) on ATRT which in turn effect the cargo flow through the ports.

The model proposed in the paper can be simulated using system dynamics software such as STELLA or VENSIM to see the impact of change on capacity and efficiency on ATRT affecting the number of ships calling at the port. The model can also be extended by including variables affecting the dimensions. This will aid the decision maker to carry out policy experimentation on varying internal variables and observe the behavior of the port system on being exposed to shock through variation of the exogenous variables.

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Annexures

Annexure1

Performance Indicators for Container Handling

– Major Ports of India 2008-09

Terminal	Traffic	V Traffic	ATRT	APBT	APS	AOPSBD	PNWTSP	Draft	Pvto	Crane	Berth	Capacity
	In ,000 tonnes	In tonnes	In Days	In Hours	In tonnes	In Tonnes	%	meter	Dummy	No.	No.	Lakh TEUs
KDS	302	526	3.86	9.81	9848	4620	17.59	8.7	0	4	4	4.58
HDC	127	512	2.47	21.57	4639	3523	62.16	6.70	0	1	2	3.33
PPT	2	9	1.63	10.30	3489	3045	23.03	12.50	0	0	1	0.00
VPT	88	251	0.73	3.45	5395	10402	27.68	14.50	1	0	1	1.45
ChPT	1144	710	2.00	13.63	28987	20687	0.00	13.40	1	35	7	28.00
TPT	439	451	1.20	10.67	12155	16887	2.86	10.70	1	11	1	4.17
CoPT	261	335	1.34	21.25	9719	7878	5.47	12.50	1	6	3	3.59
NMPT	29	69	1.64	1.83	5841	3901	20.00	14.00	0	0	1	0.00
MgPT	14	36	1.68	1.41	4080	2675	5.65	13.00	0	0	1	0.00
MbPT	92	12	2.59	12.25	6149	3255	38.34	9.14	0	5	2	1.58

JNPT	1064	752	2.23	24.43	18188	16435	3.14	13.50	0	29	4	15.00
NSICT	1427	747	1.59	3.36	25068	29691	3.14	13.50	1	40	2	15.00
GTIPL	1462	979	1.42	11.28	18256	27102	3.14	13.50	1	40	2	26.40
KPT	147	221	1.75	13.68	9662	9875	67.00	12.50	0	0	1	6.00

Source : Major Ports of India – A Profile: 2008-2009, IPA

Annexure 2

Factor Analysis Results

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.662
Bartlett's Test of Sphericity	Approx. Chi-Square	173.973
	df	55
	Sig.	.000

Rotated Component Matrix[a]

	Component	
	1	2
TRAFFIC	.955	.177
CRANE	.948	.220
CAPACITY	.947	.045
APS	.945	.134
VTRAFFIC	.921	-.089
AOPSBD	.870	.367
BERTH	.691	-.358

PVTO	.575	.482
APBT	.322	-.785
DRAFT	.231	.782
PNWTSP	-.523	-.524

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 3 iterations.

Factor Scores – 2008-09

TERMINAL	Factor 1	Factor 2
KDS	-.11382	-.97902
HDC	-.37286	-2.18439
PPT	-.99896	.17472
VPT	-.69479	1.25353
ChPT	1.82233	-.19037
TPT	.01885	.46662
CoPT	.01322	-.23804
NMPT	-1.05283	.93538
MgPT	-1.08783	.93953
MbPT	-.73243	-.78851
JNPT	1.10866	-.81391
NSICT	1.19968	1.28381
GTIPL	1.48284	.64371
KPT	-.59205	-.50308

Annexure 3

Result of Regression Analysis

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.061E-18	.211		.000	1.000
	REGR factor score 1 for analysis 1	.019	.219	.019	.089	.931
	REGR factor score 2 for analysis 1	-.689	.219	-.689	-3.153	.009

a. Dependent Variable: ATRT

Value of R Square

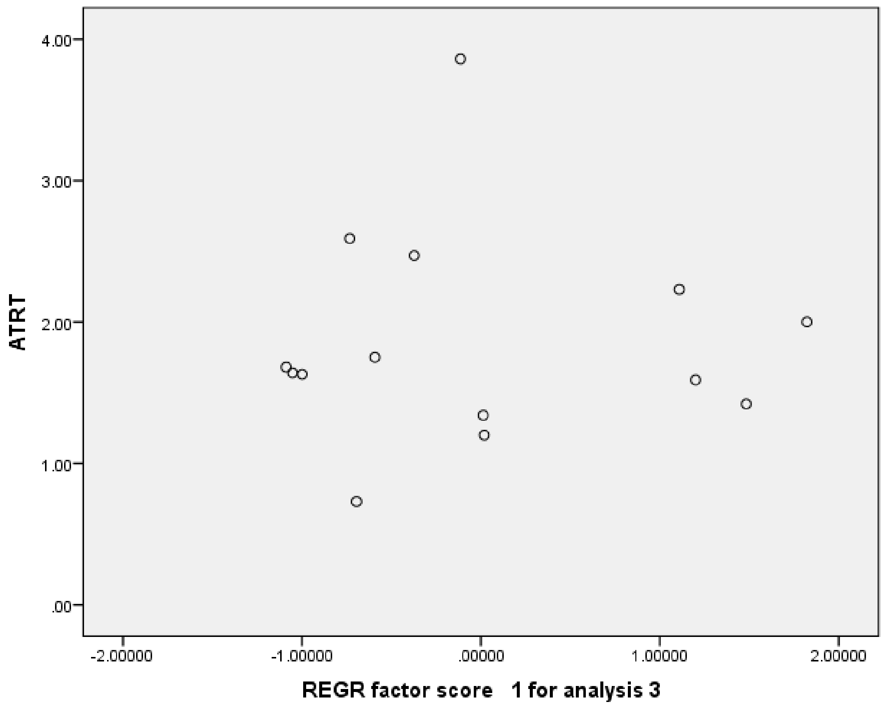
Model Summary[b]

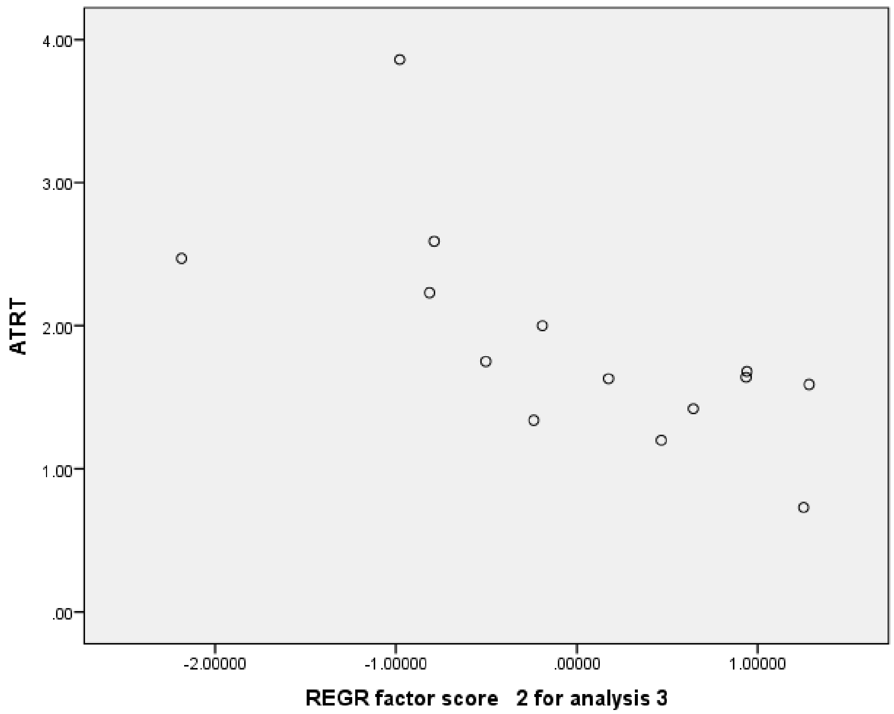
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.689[a]	.475	.380	.59643	1.623

a. Predictors: (Constant), REGR factor score 2 , REGR factor score 1

b. Dependent Variable: ATRT

Scatter Diagrams


4.00
3.00
2.00
1.00
.00
ATRT
-2.00000
-1.00000
.00000
1.00000
2.00000
REGR factor score 1 for analysis 3


4.00
3.00
2.00
1.00
.00
ATRT
-2.00000
-1.00000
.00000
1.00000
REGR factor score 2 for analysis 3