Analytics for Decision Making at Ports

Mrinal Kumar Dasgupta*

Abstract

Ports serve as an important link in global supply chain. Worldwide more than 75 percent of cargo move by sea. Over the years, the Indian Union has endeavoured to invest on major ports of the country to meet up to the global standards. Yet the share of major ports under the government of India has decrease from 90 to 70 percentage of total sea borne cargo in the country. The major ports lost its share to the minor ports under the state governments. Two reasons could be hypothesized for the said problem. One, the investments are not made in the right direction and other that the efficiency needs to be improved in functioning of the ports. In this paper an attempt has been made to identify the dimensions of port performance and the causality between the dimensions. It chooses to take average turn round time (ATRT) as an indicator of port performance. The paper proposes an analytical framework to identify the causality that would aid the decision makers. The causal approach has been based on identifying the dimensions (factors) using multi-variate data analysis, establishing the linear causal association between the ATRT and the factors, analyzing the relationship so obtained to propose an System Dynamics model for policy simulation by the decision makers.

Keywords: Port Performance Indicators, Average Turn Round Time, Causality, Analytical Framework, Multi-Variate Data Analysis, System Dynamics

Introduction

Ports serve as an important link in global supply chain. 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

* Research Officer, Indian Maritime University – Kolkata Campus, Email : mrinalsa@rediffmail.com

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 seventy 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, and 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 through 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.

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 these 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 alliances 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.

The literature survey reveals that different discrete analytical tools have been used by the researchers to draw conclusion on factors and dimensions affecting port performance and their relationships. It is felt that a well-defined analytical framework is required to define the causality amongst the factors and their variables. The causal model will enable the port managers to take the right decision.

In this paper an analytical framework has been described to arrive at a causal model for decision making by port managers.

Factor Analysis

Factor Analysis is a multi-variate technique which is used to uncover the latent structure (dimension) of a set of variables (Gorsuch, 1983, Rummel, 1970). It reduces attribute space from a larger number of variables to a smaller number of factors and as such is a ‘non-dependent’ procedure. Factor analysis could be used for any of the following purposes (Hair et al,1998) :

- To reduce a large number of variables to a smaller number of factors for modeling purposes, where the large number of variables precludes modeling all the measures individually.
- To select a subset of variables from a larger set based on which original variables have the highest correlations with the principal component factors.
- To create a set of factors to be treated as uncorrelated variables as one approach to handling multicollinearity in such procedures as multiple regression.
- To validate a scale or index by demonstrating that its constituent items load on the same factor, and to drop proposed scale items which cross-load on more than one factor.
- To establish that multiple tests measure the same factor, thereby giving justification for administering fewer tests.
- To identify clusters of cases and/or outliers.
- To determine network groups by determining which sets of people cluster together (using Q-mode factor analysis).

Factor Analysis is an interdependence technique, whose primary purpose is to define the underlying structure among variables in the analysis (Hair et al 2007). While using multivariate analysis, the number of variables increases. Univariate techniques are limited to a single variable, but multivariate techniques can have tens, hundreds or even thousands of variables. If we have few variables, they may all be distinct and different. When we add more and more variables, more and more overlaps i.e., correlation is likely among the variables. As the variables become correlated, the problem becomes how to manage these variables – grouping highly correlated variables together, labeling or naming the groups, and perhaps even creating a new composite measure that can represent each group of variables. Factor analysis provides the tools for analyzing the structure of the interrelationships among a large number of variables by defining sets of variables that are highly interrelated, known as factors. These groups of variables (factors), that are by definition highly inter-correlated, are assumed to represent dimensions within data. If one is only concerned with reducing the number of variables, then dimensions can guide in creating new composite measures. On the other hand, if one has a conceptual basis for understanding the relationships among variables, then the dimensions may actually have meaning for what they collectively represent. In the latter case, these dimensions may correspond to concepts that cannot be adequately described by a single measure. Factor analysis presents several ways of representing these groups of variables for use in other multivariate techniques.

Factor analysis can be either exploratory factor analysis (EFA) or confirmatory factor analysis (CFA). The purpose of exploratory factor analysis is to identify the factor structure or model for a set of variables. This often involves determining how many factors exist, as well as the pattern of the factor loadings. EFA is generally considered to be more of theory generating than a theory testing procedure. In contrast, CFA is based on strong theoretical and/or empirical foundation that allows the researchers to specify an exact factor model in advance. This model usually specifies which variables will load on which factors as well as such things as which factors are correlated. It is more a theory testing procedure than EFA. The factors are the latent (unobserved), hypothetical, underlying concepts deduced from the correlations between the measured variables of the instrument or test.

Systems Dynamics

System Dynamics, developed by Forrester (1961, 1968) identifies cause-effect relationships and structures them in a feedback control framework to understand the dynamic behavior of the systems. The approach professes causality doctrine associated with determinism. System Dynamics is a methodology that has ability to capture and model dynamic complexity of complex systems. Dynamic complexity refers to state where cause and effect are subtle and where effects over time interventions are not obvious (Senge, 1990).

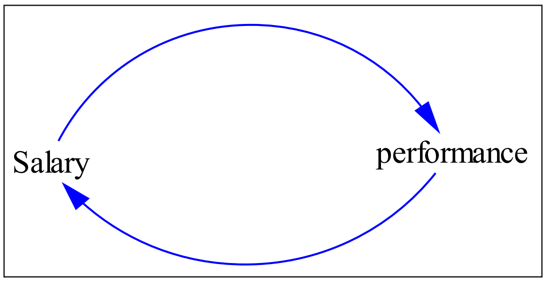
Causal thinking is the key to organizing ideas in a system dynamics study. Instead of ‘cause’, ‘affect’ or ‘influence’ can be used to describe the related components in the system. Some influences can be logically deduced such as food intake increases weight or say if there is smoke there is fire or say use of seatbelts reduces highway fatalities. However unidirectional linear causality is not enough to describe the dynamics of a system. It requires identifying feedback loops that govern the dynamics of a system. A feedback can be said “that an initial cause ripples through a chain of causation ultimately to re-affect itself”. Thus one key element of System Dynamics is to identify closed, causal feedback loops. The most important causal influences will be exactly those that are enclosed within feedback loop.

Causal loop diagrams represent the feedback structure of systems. It captures the causes of dynamics. For example, we know the better salary leads better performance while better performance also results in higher salary. That is, in "Salary vs Performance" dynamics it can be represented as:

- Salary → Performance
- Performance → Salary

The causal loop diagram can be shown as given in figure 1a below.

Figure 1a: Salary – Performance Loop

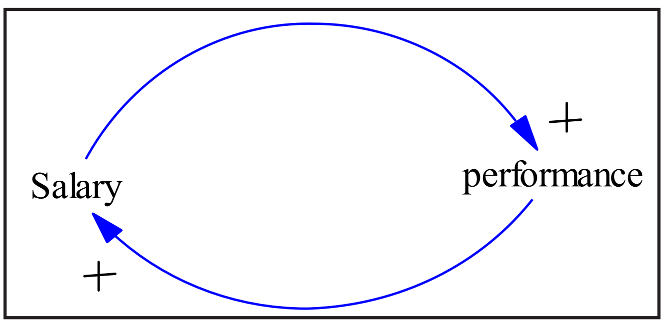


Adding a '+' or a '–' sign at each arrowhead conveys more information. For example;

- A '+' sign is used *if the cause increase, the effect increases* and *if the cause decrease, the effect decreases*
- A '-' sign is used *if the cause increases, the effect decreases* and *if the cause decreases, the effect increases*

Since it is established that salary leads to better performance and better performance leads to higher salary, the above diagram can be shown as (Figure 1b).

Figure 1b: Salary – Performance Loop with signs



The signs establish the polarity of the loop. The polarity results in positive or negative feedback loop. Positive feedback loops have the following characteristics:

- Have an even number of '–' signs
- Some quantity increase, a "snowball" effect takes over, and that quantity continues to increase
- The "snowball" effect can also work in reverse
- Generate behaviors of growth, amplify, deviation, and reinforce

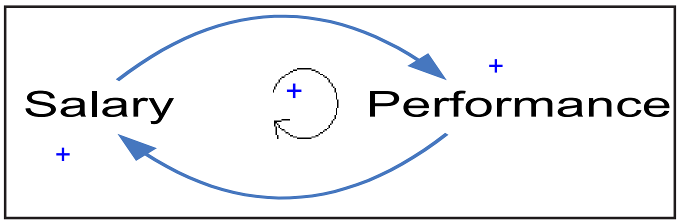
The notation used is to place symbol in the center of the loop

Negative feedback loops have the following characteristics:

- Have an odd number of "–" signs
- Tend to produce "stable", "balance", "equilibrium" and "goal-seeking" behavior over time
- Notation: place symbol in the center of the loop

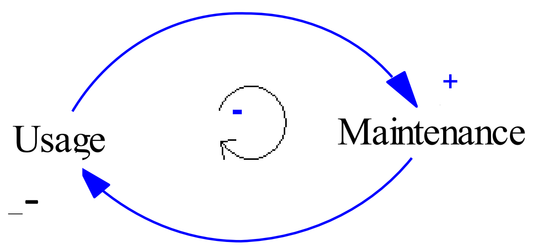
Thus the causal loop diagram for salary – performance dynamics would be as shown in figure 1c below:

Figure 1c: Salary – Performance Positive Loop



There are systems which have more than one feedback loop within them. A particular loop in a system of more than one loop is most responsible for the overall behavior of that system. The dominating loop might shift over time. When a feedback loop is within another, one loop must dominate. A stable condition will exist when negative loops dominate positive loops. An example of negative loop is the example of "usage versus maintenance". More we use a machine more is the maintenance required for that machine. More we maintain the machine less it is available for usage. Figure 1d shows the negative loop arising out of the nature of dynamics between usage of a machine and its maintenance.

Figure 1d: **Usage – Maintenance Negative Loop**



The Analytical Framework

i. Identify the factors and variables associated with each factor through literature review
ii. Use Factor Analysis on data related to port performance
iii. Identify the causality between factors using multiple regressions
iv. Define the Causal Model using Systems Dynamics Approach.

Factors and Variables Affecting Port Performance – Findings from Literature Review

The review of literature reveal that 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. The important findings may be drawn on comparable terminals and indicators. These are summarized below.

i. The operational s 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).

   The performance parameter that indicates this aspect is the turn round time (TRT).

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

   The performance parameter that manifests congestion is the pre berthing delay (PBD).

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

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

   The average output per ship berth day (AOPSBD) is the parameter that reflects the impact of crane and moves per crane on vessel turnaround time.

v. 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.

   The pre berthing delay and post operation time prior to departure or the non-working time reflect the delay owing to regulations and other factors. These time durations are reflected in TRT.

vi. Larger ports produced higher efficiencies (Martinez-Budria et al. 1999).

   Port's size is reflected in terms of number of berths and/or cargo throughput per annum of the port.

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

   Cargo throughput and vessels handled reflect scale of production for ports.

Dynamics of a Port System

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 as follows.

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.

$$T_c = f(S_c) \quad (1)$$

$$S_c = P_c + S_{tc} \quad (2)$$

$$P_c = P_d + P_p + P_b \quad (3)$$

$$P_b = g(I_f, O_e)$$

Where,

T_c = Maritime Transport Cost

S_c = Ship's cost at port

P_c = Actual Port Cost

S_{tc} = Cost of ship's time at port

P_d = Port dues

P_p = Pilotage charges

P_b = Berth hire charges

I_f = Infrastructural facilities

O_e = Operational Efficiency level)

Infrastructural facilities (I_f) constitutes loading, unloading and shore clearing equipment. The stay at berth (that results in berth hire charges) is dependent on number of right equipment and its operational efficiency level (O_e). Operational efficiency level (O_e) determines the output per ship per day. Berth hire charges also depends on the parcel load (total cargo carried by the ship) of the ship. As the tonnage increases, stay at berth increases.

Cost of ship's time at port (S_{tc}) includes opportunity cost (P_{oc}) due to non-working time at port. A ship may have to wait due to non-availability of berths or any other resources such as tugs, or may be owing to stoppage of work, delay in clearance of documents or any other managerial issues. In whole the "Cost of ship's time at port" is function of "Turn Round Time". The Turn Round Time (TRT) is defined as the time duration from the time ship reports to the reporting point of the port and till she leaves this point. Thus, Ship's cost at port (S_c) can be defined as sum total of one-time cost payable to the port per voyage (P_{ot}) and the variable component (P_{vt}) that is proportional to ship's time at port (TRT). P_{ot} includes Port dues (P_d) and Pilotage charges (P_p). Hence we redefine equation (2) as:

$$S_c = P_{ot} + P_{vt} \quad (4)$$

Where,

$$P_{vt} = P_b + P_{oc} \quad (5)$$

Thus, we can conclude that the "Turn Round Time" is a function of parcel load, infrastructural facilities, and Operational efficiency level)

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 a 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.

Case of Port Sector in India

The study has been done based on the data collected on containerized cargo handled by 12 major ports of India, a brief description of which is given below.

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 tonnes in the year 1950-51 to 849.88 million tonnes in 2009-10 at a 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.

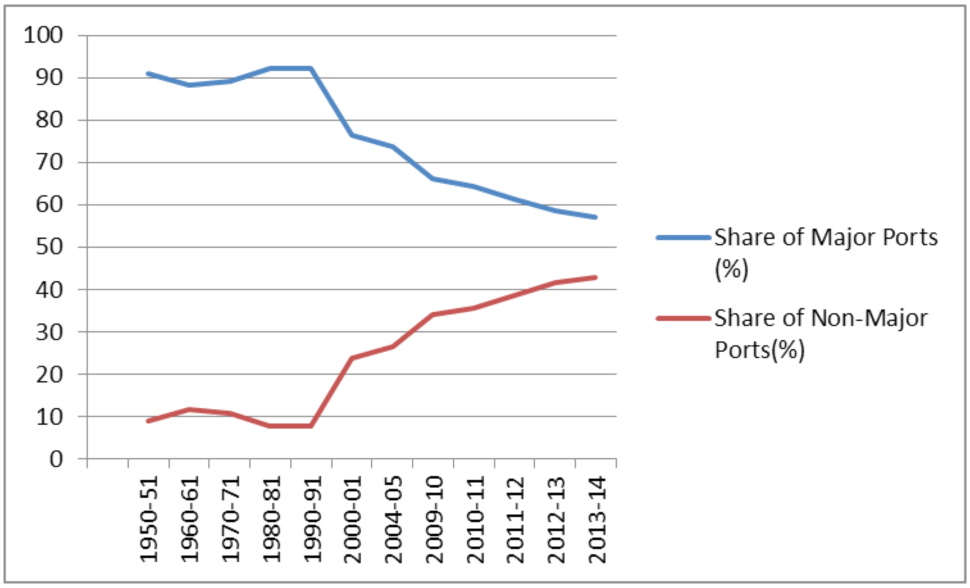
Figure 2 below shows the drop in share of major ports from around ninety percent in the year 1950-51 to less than sixty percent in the year 2013-14. This drop is

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
2010-11	570.03	314.85	884.88	64.42	35.58
2011-12	560.14	353.19	913.33	61.33	38.67
2012-13	545.79	387.87	933.66	58.46	41.54
2013-14	555.49	417.12	972.61	57.11	42.89

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

Figure 2: Share of Major Ports Vis-A-Vis non-Major Ports of India



inspite the fact that the liberisation process started in early nineties in India.

Figure 3 shows the rise in cargo handling by ports of India. It shows an increasing trend and India also poised to be one of the significant economies is the world.

The earning from international trade contributing to the GDP (gross domestic product) of the country is greatly dependent on the port performance.

Table 3 shows the comparison of compounded annual growth rate of cargo handled by major Indian ports pre and post liberalization period. The growth has not been significant in the post liberalization with respect to the pre-liberalization period.

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

Figure 3: Trend of Cargo handled by the Indian Ports since 1950-51

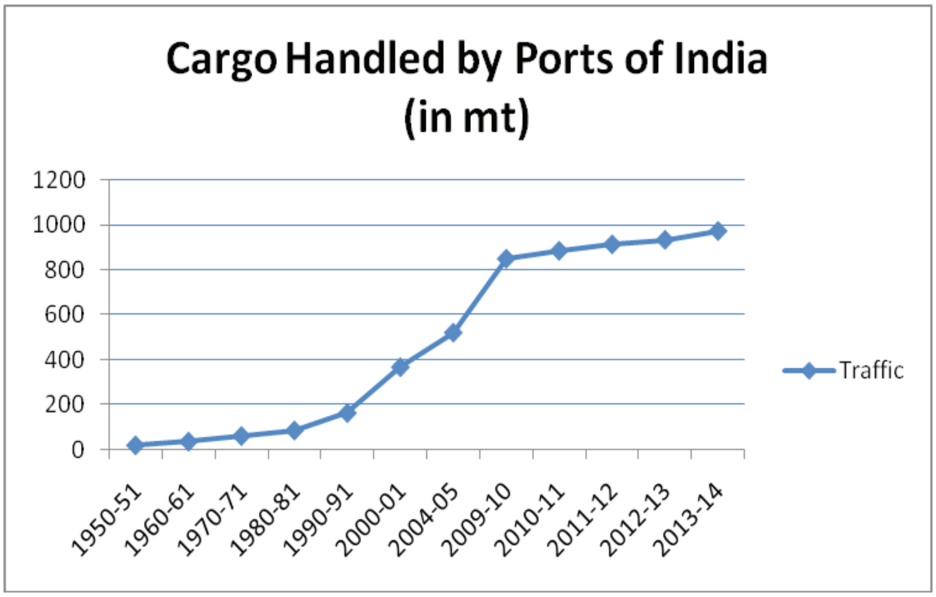


Table 3 : Compound Annual Growth Rate of Cargo handled by Indian Ports

Year	*Major Ports*	*Non Major Ports*	*All Ports*
Pre liberalization Era			
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
Post Liberalization Era			
1990-91 to 2000-01	6.35	21.82	8.40
2000-01 to 2010-11	7.32	13.69	9.16
20001-02 to 2013-14	5.38	12.79	7.75
Overall			
1950-51 to 2013-14	5.47	8.92	6.25

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

from Table 4 and Table 5. Table 4 shows port-wise container traffic in various major ports of India for the year 2012-13 whereas Table 5 shows container handled by top 10 container handling ports of the world in the year 2012. As it is seen, the total container handled by all major ports of India (7.704 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 (2012-13)

Port	*Container Traffic (In ,000 TEUs)*
Kolkata Dock System	463
Haldia Dock Complex	137
Paradip Port Trust	13
Visakhapatnam Port Trust	247
Chennai Port Trust	1540
Tuticorin Port Trust	476
Cochin Port Trust	335
New Mangalore Port Trust	48
Mormagao Port Trust	20

Port	*Container Traffic (In ,000 TEUs)*
Mumbai Port Trust	48
Jawaharlal Nehru Port Trust	4259
Kandla Port Trust	118
TOTAL	7704

Source : Major Ports of India – A Profile: 2012-2013, IPA

Table 5 : Top 10 Container Handling Ports of the World 2012

(In million TEUs)

Rank	*Port*	*2011*	*2012*
1	Shanghai	31.74	32.53
2	Singapore	29.94	31.65
3	Hong Kong	24.38	23.10
4	Shenzhen	22.57	22.94
5	Busan	16.18	17.04
6	Ningbo-Zhoushan	14.72	16.83
7	Guangzhou	14.42	14.74
8	Qingdao	13.02	14.50
9	Dubai	13.00	13.30
10	Tianjin	11.59	12.30

Source : Containerization International, 2012

Identifying Dimensions of Port Performance using Factor Analysis

Secondary Data for the study was collected, collated and compiled for the purpose of identifying the factors and the association, relationship and causation, if any, among the variables. At this stage data analysis was carried out by taking data from all individual major ports for the period 1990-91 to 2009-10. The data were collected and compiled from the publication of port data (titled Major Ports of India : A Profile) by Indian Ports Association, an apex body of all major ports of India; and the data by the major ports in their Annual Administration Reports.

In this study 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 are 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. At the next stage the system dynamics models have been built up.

Variables considered are listed below.

1. Container Traffic measured in '000 TEUs Terminal wise container traffic for the year 2012-13, 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. CRANES : Number of cranes handling containers (including both Quay and Yard cranes)
10. BERTHS : Number of Berths handling containers
11. CAPACITY :Container handling capacity of the terminal

RESULTS

7.1.1 The data set Factor Analysis carried out through Rotated factor matrix (varimax rotation) indicates 2 (two) factors with eigenvalue more than one (table 6). Factor 1 is loaded with Traffic, Vessel Traffic, Average Parcel Size (APS), Average Output per Ship Berthday (AOPSBD) and No. of Cranes , No. of Berths and Capacity whereas Factor 2 is loaded with Average Pre Berthing Time (APBT), Draft(negative), and Percentage of non-working time to total time of ship at Port (PNWTSP). As discussed with the experts the first factor is taken as a measure of the Capacity Dimension (CD) whereas the second factor is taken as a measure of the operational Inefficiency Level (IL) of the port/ terminal. KMO and Bartlett's Test of Sphericity are measures of sampling adequacy. The KMO obtained in this analysis is .814, i.e. over the acceptable value of 0.6. Bartlett's Test of Sphericity relates to the significance of the study and indicating the validity and suitability of the data collected to the problem being addressed through the study. The value of Bartlett's Test

Table 6: Rotated Component Matrix[a]

	Component	
	1	2
TRAFFIC	.967	.028
CAPACITY	.933	-.063
CRANE	.903	-.066
VTRAFFIC	.839	.139
AOPSBD	.822	-.343
APS	.645	-.110
BERTH	.600	.483
APBT	.223	.684
DRAFT	.231	-.571
PNWTSP	-.470	.492

Author's calculation

Extraction Method : Principal Component Analysis

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

Table 7: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.814
Bartlett's Test of Sphericity	Approx. Chi-Square	1691.547
	Df	45
	Sig.	.000

of Sphericity is 0, that is, less than acceptable value of 0.05. The table 7 shows the results of the analysis.

Linear causality between ATRT and Factors

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

The result (Table 8) shows that there is no significant relationship between the Capacity Dimension and ATRT.

However, there is a strong positive relationship between the Inefficiency Level and ATRT is given by

$$ATRT = 2.626 + 1.311\ IL \quad (1)$$

The IL dimension constitutes variables such as pre-berthing time (or in other words waiting time) and non-working time at berth. The increase in these values will lead to increase in ATRT of the vessel. In addition to this

Table 8: Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.626	.067		39.294	.000
	REGR factor score 1 (CD or Capacity Dimension) for analysis 7	.120	.067	.073	1.791	.075
	REGR factor score 2 (IL or Inefficiency Level) for analysis 7	1.311	.067	.796	19.574	.000

a. Dependent Variable: ATRT

the navigable draft is negatively loaded with IL dimension meaning reduction in draft will lead to increase in ATRT. Ports with lower draft have lower scale of operation as the parcel load per vessel tends to be smaller and hence tend to be relatively inefficient compared to hub or larger ports. This corroborates with findings vi and vii enumerated in section 4 above.

The above relation confirms the basic premise that the efficiency level of the logistics chain is dependent on the efficiency level of the port. The increase in efficiency is expected to result in reduction in stay time of ships at the port, that is, decrease in ATRT.

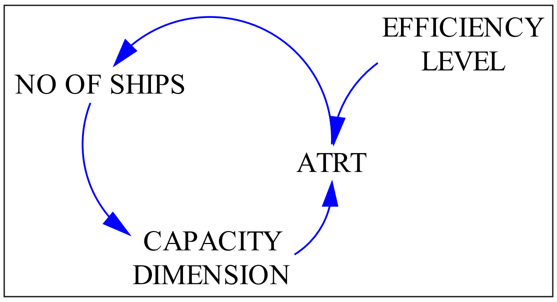
The above relationship is confined to the data set of the Indian major ports. For a different data set the Capacity Dimension and the Inefficiency Level may both or either effect ATRT. Hence, the decision maker would know the dimensions that needs attention improve the performance of the port.

Multi-dimensional Causality

The results of multi-variate analysis show a linear relationship with no circular relation. For example ATRT increases with ineffciency level or in other word it decreases with Efficiency Level. Decrease in ATRT in turn may result in increasing the attractiveness of the port causing more ships to call at the port. This sort of causility can be achieve by defining the causal model using System Dynamics as described above.

Figure 4 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 4: Loop Diagram Showing Causality between the Two Dimensions with ATRT and No. of Ships Calling at Port

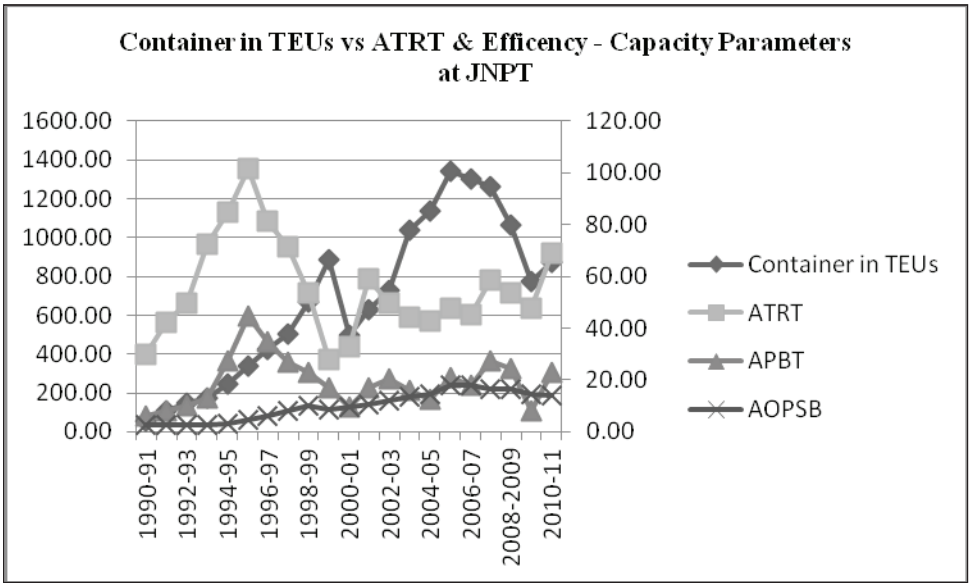


It demonstrates that influence of capacity and efficiency dimensions on ATRT in turn affects the number of ships calling at port. The behaviour of the system is governed by the negative loop. This implies that when the ATRT increases reflecting poor performance of the port, the carriers are expected 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 inefficiency dimension has more weightage than capacity dimension, meaning that the Indian major ports need to streamline their business processes and take other measures such as efficient pilotage system to achieve better performance. These efforts should bring down the pre-berthing time and non-working time at ports, that is, reduction in values of the variables that constitutes the inefficiency level (IL) for the major Indian ports. Inaddition ports under study should endeavour create deep drafted operational points. 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 impact 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.

Figure 5: Container in TEUs vs ATRT & Efficiency - Capacity Parameters at JNPT



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.

Conclusion

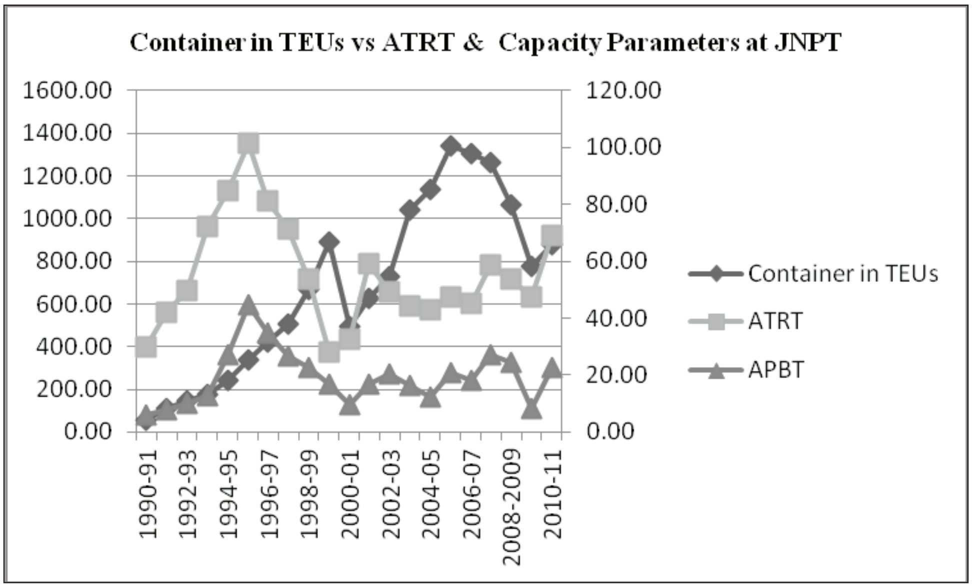
This study lays down the analytical framework for decision makers at ports enabling them to identify the dimensions, their associations, extent of influence on performance of ports and causality between them. The use of factor analysis identifies the dimensions while the beta coefficients of the dimensions, obtained from regressional analysis indicate their association with port performance indicator. The System dynamics model establishes the causality aiding in identification of effect of policies by the port decision makers.

The application of above study on major Indian ports reveal that Average Turn Round Time (ATRT) of a container vessel is dependent on one specific dimension, namely, inefficiency level (IL) of the Port. A decrease in the Inefficiency Level can significantly reduce the ATRT of a vessel and thus can help to reduce the overall transport costs in the Supply Chain. The reduction in pre-berthing time and non-working time can be effected through business process re-engineering and other soft measures. However, as the impact on efficiency caused by any action taken to reduce the ATRT is not static, a dynamic model based on causality must be used before any decision to achieve corporate goal.

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 effect of efficiency parameters such as Average Output per Ship Berth-Day (AOPSB) and Average Pre-Berthing Time (ABPT) on ATRT which in turn effects the cargo flow through the ports can be observed from the figure 4 drawn on data for the period 1990-91 to 2010-2011 for container traffic (in TEUs) at JNPT (Jawaharlal Nehru Port Trust).

The ATRT in the above case decreases with increase in AOPSB and increases with increase in APBT (or the waiting time). Thus 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 5 shows that as container traffic grow the APBT increases meaning that increase in traffic causes the capacity to reach its upper limits resulting in waiting of ships.

Figure 6: Container in TEUs vs. ATRT & Efficiency - Capacity Parameters at JNPT



Further Scope of Research

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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