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Data Envelopment Analysis of the Resilience of Container security in the Indian Dry Ports

by

Ashish Panda

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Abstract

In the dynamic environment of International trade, the importance of Maritime Supply Chain cannot be underestimated. More specifically the container logistics sector had a very important role to play in facilitating the global trade development. Due to the increasing importance of container logistics, the development of optimal inland logistics has become inevitable. So, the development of dry port has been a very important part of this whole process of providing more efficient and faster logistics facilitation.

In this thesis an attempt has been made to understand and analyze the complexities and problem related to the security of the container transport related to dry port and inland logistics. Legal regimes have been analyzed from theoretical as well as practical point of view. A study about the Gaps in the available legal regime has been done. At the same time the practical issues related to security have been understood. Even if there are laws it is always tougher to implement them especially if they are not economically and practically feasible. Although implementation of security measures is considered to be an extra cost, still the threat to security cannot be ignored especially when quality of service level is considered to be a competitive advantage for the dry port.

Supply Chain Resilience has been gaining significance in recent times as more unpredictable events are expected to occur and subsequently have adverse effect on Supply Chain efficiency. An attempt has been made to quantify dry port resilience and dry port security. The quantification of the dry port resilience takes both capacity and flexibility into account. At the end an attempt has been made to measure the efficiency of a dry port in terms of TEU throughput, dry port security and dry port resilience. The results have been analyzed with respect to the public and private dry port performances.

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Chapter 1 - Introduction

1.1 Introduction

India is not considered to be one of the traditional maritime countries. Most of the initial development of ports and other maritime activities were done by the British who ruled over the sub-continent for a considerable period. The growth in the major coastal port cities such as Bombay, Calcutta and Madras was witnessed in that period. With a wide spread and symmetrical coast line, India always had and still has the potential to become a major Maritime hub. In order to develop an economically feasible maritime infrastructure in form of ports and modern terminals, the Indian economy needed to open up to global international trade. The same goes for developing a strong inland connectivity from ports to the final consumers for imports and from suppliers to ports for exports. The Indian economy started to open up during the period of late 1980s and early 1990s. At the same time containerization started to pick up which was again supported by the development of JNPT – Mumbai. JNPT till date handles half of container trade in India. All this development also prompted the development of Dry Ports to facilitate the distribution process of containers (Haralambides and Gujar, 2011). Dry Port is an integral part of intermodal logistics as it facilitates activities to utilize all the advantages of containerization such as fast and efficient supply chain. The Indian Railways was the most important mode in fulfilling this connectivity logistics. The development of international standard high ways in recent times has also given boost to all the Road logistics activities. The containerization is expected to grow even at a faster rate due to increasing consumer purchasing power and expected high growth rate in GDP per capita. So the role of all the nodes mentioned above would become more important to facilitate efficient container logistics.

One of major issues, in fact the most critical challenge for all the nodes of supply chain is the security of the all these nodes. This challenge is not only limited to India, but it is global issue. The issue related to security is not a frequent or regular problem but any major mishaps related to security have huge implications on the responsiveness as well as efficiency of the supply chain. All the nodes of Supply Chain are huge infrastructural investment. For the same reason it is very difficult to have alternative nodes. The broader or higher we move into the supply chain, the costlier it is to have an alternative. The issue of security is even more pronounced in India and in the sub-continent. This can easily seen by the number of terrorist attacks in recent times. The nature of these terrorist attacks have not only been to have higher casualty level but also had the purpose to disrupt business environment. A small attack can have adverse impact on the local economy leaving already built infrastructure to be useless. At the same time an event like the September 9/11 at the heart of global business center can have long term impact on the global economy. In India the problem of Naxalist who target public and private infrastructure is a huge threat to the whole Supply Chain, which starts from the production center to the retail outlets. It can be said that the security threat to Supply Chain is many folds and its implications are very unpredictable. Due to its unpredictable and dynamic nature, it is very difficult to have an ideal solution to this problem.

In case of containers, this problem is even pronounced, due to nature of the containers. The container logistics is expected to have uninterrupted flow. But due to the closed nature of the container box, it can be used as a very useful tool for the miscreant to cause security threat to all the nodes in the Container Supply Chain. All the nodes such as the Marine terminal, the container stack yard, the connectivity mode of railway and road and the dry ports are vulnerable to this threat. In order to make the Supply Chain cost optimized all the nodes mentioned are designed to optimum capacity. In order to have alternatives, the cost incurred would be huge. Moreover the even tougher challenge to be to determine the bearer of this cost or to find the right proportion to distribute this cost.

Table 1: List of Maritime security mishaps in recent times

Maritime target attacked by Al – Qaeda (October 12, 2000, Yemen)
Maritime target attacked by Liberation Tigers of Tamil Eelam (LTTE) (October 30, 2001, Sri Lanka)
Maritime target attacked by Aden Abyan Islamic Army (AAIA) (October 6, 2002, Yemen)
Maritime target attacked by an undisclosed group (March 15, 2003, Russia)
Maritime target attacked by an undisclosed group (November 30, 2003, Iraq)
Maritime target attacked by Harakat-ul-Mujahidin (HUL) (May 25, 2004, Pakistan)
Maritime target attacked by an undisclosed group (June 23, 2004, Pakistan)
Maritime target attacked by an undisclosed group (July 31, 2004, Pakistan)
Maritime target attacked by an undisclosed group (August 26, 2005, Philippines)
Maritime target attacked by an undisclosed group (May 13, 2006, France)
Maritime target attacked by Liberation Tigers of Tamil Eelam (LTTE) (December 22, 2006, Sri Lanka)
Maritime target attacked by Liberation Tigers of Tamil Eelam (LTTE) (January 21, 2007, Sri Lanka)

Source: Lecture of Mr. Reinout Gunst in Port Economics and Policy at MEL.

The list above shows the growing threat of terrorism on the Maritime sector. The maximum impact of these threats is more evident in the Indian sub-continent.

1.2 Ports in India

The ports are the most important node in Supply Chain since they connect the water side maritime transport to the land side inland logistics. In recent time the importance of ports has been growing with more globalization. There has been very high rate of growth in international trade between nations. Shipping is the most efficient means of cargo transport so the significance of ports has increased. As a result there has been rapid increase in the capacity of the ports. In some cases either existing ports have expanded or in other cases there have been development of new minor ports. Another feature of shipping industry has been the increase in size of the ships in order to achieve economies of scale in maritime transport. This trend has prompted the ports to become more responsive in their operations. So there has been lot of stress in increasing port productivity. There has been an increasing expectation from ports in terms of improvement of quality and quantity of cargo handling. So this has made ports

even a more critical part of the supply chain. As discussed before containerization has been growing, subsequently the maximum growth in case of shipping has been seen in the container sector. There has been a rapid increase in container sector majorly due to the relocation of production centers to the developing countries in order to take advantage of the cheaper labor. China is the country with the highest container throughput which accounts to around 30% of the total container trade in the world (World Bank data, 2010). The majority of the top container ports are now located in China with Shanghai leading the way.

As mentioned before the port sector in India is expected to grow at high rate. This growth has been prompted by consistent economic development in recent years. This growth has been more significant due increase in service sector like Information Technology when compared with manufacturing sector. In recent years, due to high demand of power and steel there also has been significant growth in manufacturing sectors. As mentioned before the higher growth in GDP per capita would prompt more growth in container sector. The ports in India can be divided into major, intermediate and minor ports. They are present in the west coast as well as east coast of India. The container sector is more dominant in the western side and the bulk sector is more prevalent in the eastern part. The Jawaharlal Nehru Port Trust is the largest container port in India and it handles half of the container volume. The other important container ports are Chennai and few ports in Gujarat.

As discussed before the security of all the nodes in the supply chain has become a major concern and ports being one of the major nodes have to be under proper security check. The security threat to the ports could be from foreign elements as well as domestic sources. Any security lapses in the port can affect the Supply Chain responsiveness on both sides. The security related threat to the port can be divided into following points

- The threat can be in the form of cargo. Along with the cargo, weapons or unwanted products can be hidden and transferred to the required destination. The presence of such objects is a threat to the port security as well as the whole supply chain. At the same time people or human being can be smuggled along with the cargo. There is various kind of cargo being transferred through ports. But containerized cargo poses maximum threat. The reason is that, it is inside a closed box and invisible to naked eyes. It is very difficult to detect any unwanted object inside the containers unless and until, it is thoroughly scanned using modern scanners.
- The vessels coming to the port can be used as a weapon to cause damage to the port infrastructure. Ships are moving heavy mass objects carrying cargo as well as bunker used for engine. So the presence of inflammable elements inside the ship makes it suitable to be used as a weapon to destroy infrastructure. Especially the gas carriers and oil tankers can be used even more effectively for this purpose.
- The people visiting or working in the port or in the ship can also be security threat to the port infrastructure.

The map below shows the major and intermediate ports of India.

Map 1: Major and Intermediate Sea ports of India

Source: Compare InfoBase limited

1.3 Port connectivity and Dry ports

The concept of maritime logistics not only includes the ports but also further connectivity from ports to final destination in case of imports and from the point of origin to the ports in case of exports. This connectivity from ports to the final destination can be done with Roadways, Waterways and Railways. It can be a mixture of all three ways or also a mix of two ways. The hinterland connectivity is such an important parameter in terms of port competitiveness that the shippers of today choose their ports based on the

hinterland connectivity facility a port offers. In some cases the cost of the connectivity is important and in other cases shippers need a more responsive connectivity. Typically in case of bulk commodities cost is considered to be more important parameter, but in case of containers responsiveness becomes a more critical factor. In case of containers the door to door delivery concept is also gaining more prevalence and hence the concept of reliable logistics.

The growth of containerization which required better service levels started around 1980s in India. In order to facilitate the growth of containerization in the year 1988, the Jawaharlal Nehru Port trust started its operation in Mumbai. Around the same time the Container Corporation of India (CONCOR) was developed as a separate division in the Indian Railways to facilitate the inland movement of containers. The first Inland Container Depot (ICD) was started in Delhi Tughlakabad (Anon 1).

Initially the ICDs were developed in the north part of India in places such as Delhi, Agra, Ludhiana by CONCOR. These ICDs were connected to the gateway port of JNPT by Railways. These ICDs were an interface between the gateway port and the final destination or origin point with also facilities of storage (Anon 1).

As a result of increasing importance of global Supply Chain, the Dry Ports started to acquire the equal amount of importance like the marine ports and terminals (Harambides and Gujar, 2010). One of the other factors was the shifting of manufacturing units from coastal cities more towards inland. At the same time the cost of land in the ports and marine terminals were increasing. In case of India the containerization started to pick up in late 1990s which demanded for door to door delivery. At this point the need to develop dry ports was felt more severely. A dry port can be defined as an inland cargo handling facility where functions such as consolidation and distribution of cargo, temporary storage of cargo, customs clearance, and connectivity between different modes of transport can be done (Ng and Gujar, 2009). At the same time it allows for agglomeration of public and private institution and also creates facility for interaction between different stake holders in the Supply Chain (Ng and Gujar, 2009). The dry port is connected to one or more Gateway Port through rail, road or barge on one side. On the other side it is connected either to the consumer in case of import or to the producer or supplier in case of exports through rail, road or barge.

The objectives of dry ports are many folds. The urgent need to increase the capacity of the ports and marine terminals in terms of numbers as well as present capacity has been discussed in section before. This is done to handle the increasing international trade and size of ships. This expansion is not easy since there are constrains such as land usage, cost of expansion. In order to prevent congestion at ports and at the same time divert activities from the ports to inland the creation of dry ports has been very significant. Historically, it has been observed the economic development in port cities have been more compared to inland places. The development of dry port in certain region entices investors to promote industrial activities in such areas due to the logistics and transportation facilities provided by these dry ports. It can be said that in reality dry port helps to reduce the economic distance between inland and coastal regions by providing logistics facilities.

The movement of the container from the port to the final customer or from the supplier to the port is also an important part of the Supply Chain. There are alternative modes available and the dry port has a major role to play in this case. The security of all these modes is also very important to have uninterrupted movement in the Supply Chain. The problem here is once the container is out of the port and flows through all these chain, it is very difficult to judge the accountable party who is responsible for any lapses in the Supply Chain. So it is even more difficult to determine any capacity improvement in the supply chain in order to create a buffer in case of any security lapses. All the hinterland nodes in supply chain have their specific tasks cut out so the distribution of responsibility in terms of security becomes a difficult task.

The following map gives the major rail and road connectivity in India. It shows the rail and road network connectivity between the major coastal cities and the inland cities of India. The most important railway route in terms of container transportation is from Mumbai to New-Delhi. This route passes through fully electrified broad gauge electrified line passing through Surat, Vododara, Ratlam, Kota, and Mathura junction. It connects the largest container port of India that is Jawaharlal Nehru port trust located in Mumbai and the largest dry port of India that is Tughlakabad located in New Delhi.

Map 2: Inland Connectivity in India. **Source**: Compare InfoBase limited

1.4 ISPS code

The ISPS code is the most significant measure taken by the IMO in order to counter the security threat to the Maritime sector. This code got its impetus after the 9/11 attack. It was adopted by the IMO in 2002 and became fully effective from July 2004. The major objective of the code is to have a standardized frame-work in Maritime security. The goal is to first evaluate the risk. It empowers the governments to have appropriate security levels and take appropriate measures to counter any security threat. It covers both the aspects of maritime industry which are the ships as well as the ports.

The ISPS code was started by US coast guard and US security agencies. All the ships having tonnage above 500 tons are under the jurisdiction of ISPS code (Anon 2). It covers various aspects of security such as plans to withstand terrorist attack, baggage screening, creation and maintenance of restricted area, installation of surveillance equipment, personal identification documents (Anon 2).

In terms of Indian ports, it will be a challenge to implement ISPS in an effective way. The reason is that India is a developing country and the level of infrastructure available to counter any security threat is limited compared to its western counter parts such as US. Sharing of information is going to be a very key aspect of ISPS code which would depend heavily on the level of ICT implementation done in a port. This development again is huge investments which has been relatively lesser when compared to the other developed ports of the world.

1.5 Supply Chain Resilience

All the global supply chain has the target to be cost effective. But at the same time modern techniques have been formulated to make the supply chain flexible enough to adapt to any change in demand. These supply chain aim to have an optimal amount of capacity. But all these are possible taking into assumption that there are no abrupt operational halt at any stage of the supply chain. The supply chain is expected to be resilient to any such unexpected events which might affect the efficiency as well as the responsiveness of the supply chain (Sheffi, 2005). The supply chain can be affected because of different factors. They can be reasons such as natural disasters like super cyclone, hurricanes. The others can be problems like terrorist attack and labor union problems. Resilience in Supply Chain can be brought by building extra capacity or by making the whole chain more flexible. A simple example of increasing the capacity is by increasing the inventory to face such disruptions (Sheffi, 2005). A decision like increasing inventory not only increases the cost for the company but it also slows down the whole operation. On the other hand increasing flexibility in Supply Chain would lead to better way to built resilience in the system (Sheffi, 2005). This flexible approach not only makes the chain more resilient but it also makes it more capable to face any changes in demand across different markets in global Supply Chain.

In this case also a company has to implement customized Information Technology system in order to develop a flexible Supply Chain. The role of IT is important as it would help to take very fast decision. On the other hand an increase in capacity would demand for more investment on the hardware side in form of fixed capital investment. In terms of investment also a onetime investment on customized IT looks to be a more feasible investment when compared to hardware fixed capital investment.

1.6 Research Question

In a broad sense there is growing concern of the threat on the Supply Chain. Maritime sector is a key player in the global supply chain, hence any security lapses in the maritime sector will have a huge impact on the Supply Chain. The objective of this thesis would be to study the security threat on the hinterland part of the Maritime Logistics more specifically on the container sector and the dry ports. The thesis would employ different tools to study the resilience of the dry ports in order to counter the security threat from the transacting containers. So the main research question of the thesis would be

How can the Dry Port efficiency be measured by combining critical factors such as Dry Port Resilience and Dry Port security with the TEU throughput to achieve balanced results with respect to growing importance of service levels as a measure of competitive parameter?

The sub-questions can be as follows

What are the present security levels, measure and legal regimes available to counter the security threat to the Maritime Logistics sector in India?

What is the practical status of dry port security in India?

What is right methodology to develop the resilience of a dry port?

What are differences between public and private dry ports in terms of throughput efficiency when combined with the dry port resilience and dry port security levels?

1.7 Data and Methodology

As per the research question of the thesis the data required would be more specific to the dry port terminal. A set of dry port have to be selected which are close to each other because dry port of different regions behave in a different way. The different capacity parameters have to be obtained. The three main parameter involved are dry port efficiency, the container security and Resilience. In order to calculate the efficiency of the dry port the throughput of the dry port would be considered. The container security would be calculated based on the primary data. A set of questionnaire would be prepared related to the container security issues. As per the results of the questionnaire the container security would quantified. Another important term used here is resilience

which has to be quantified. The capacity data would be required for calculating the resilience. The required capacity would be the throughput capacity of the dry port as well as the capacity of the connectivity to the dry port to quantify the resilience of the dry port. The connectivity capacity would include the rail or road capacity whichever is applicable in the case of the respective dry port. In order to calculate the capacity of the dry port data related to land and equipment handling capacity would be required.

In order to measure the efficiency of the dry port the throughput has to be calculated. The container security would be quantified based on the results of the questionnaire. The resilience of the Supply Chain would be quantified based on the available literature on the Supply Chain Resilience. The inland transportation of container along with the dry port operation is a major part of the Supply Chain. So an attempt has been made to formulate the resilience the dry port based on the principles of the supply chain resilience as per the available literature.

After the quantification of all the important variables of the analysis Data Envelopment Analysis (DEA) has been used as a methodology to find the answers to research question. DEA method was found to be the most suitable approach to solve the research question as per the literature review and availability of the important data.

1.8 Structure

The thesis has been structured in such a way so that it covers all the important aspect of the research. Chapter 1 is the introduction chapter which gives brief explanation about the important concepts related to the thesis. It also gives a summary of the research question, data, methodology and structure of the thesis. In the second chapter the available and upcoming legal regulations related to port and inland transportation of containers have been discussed. The salient features of the ISPS code and the Rotterdam rules have been explained. It also covers the analysis of available legal regulations for port, dry port and the hinterland connectivity from Indian point of view. In chapter 3 the security of the container in a port/terminal, dry port and in the inland connecting medium has been explained from an Indian prospective. Also some new concepts such as Dedicated Freight Corridor has been explained. Chapter 4 is a literature review of the Resilience of a system and the Supply Chain Resilience. In the next part of the chapter the dry port resilience has been discussed as per the literature review. In chapter 5 the data related to the thesis has been explained. All the important parameters such as the efficiency of the dry port, container security in the dry port and the dry port resilience have been quantified as per the available data, questionnaire result and literature review. Chapter 6 consists of the use of DEA method to find the results of the whole analysis. Initially a literature review of the DEA methodology has been done to provide the justification for the use of DEA in this thesis. Chapter 7 consists of the Conclusion which lays down the results of the entire chapter. At the same time a final conclusion has been pointed based on the analysis in all the chapters.

Chapter 2 – Maritime Security Legal Regulations

2.1 Introduction

The attack on the World Trade Centre on 11th September 2001 was a key turning point in the modern history. The usage of transportation system in form of airline carrier exposed the fragility of the security issues in the transportation industry as a whole. Any such terrorist attack involving the transportation system would have severe adverse affect on the global trade which would not only involve human casualties, but also economic, political and social impacts, notably the breakdown of the global supply chains and potentially global economic recessions (Gujar, per.comm, 2011). The implication of the 9/11 attack was huge as expected and more importantly increased the importance of security awareness in transportation systems.

Ports are one of the most important nodes in the global Supply Chain and International trade. Any disruption in the Port activities would affect the complex global logistics in a very negative way (Ng, 2007).

In this chapter an attempt has been made to understand the various available and upcoming regulations in order to have a tighter control over maritime security which is perhaps the most important part of the Global Supply Chain. The ISPS code in section 2.2 consists of the ship and the port part of the Supply Chain. The focus is more on the ports in this chapter. In section 2.3 and analysis of the different existing and proposed regulations related to the hinterland part of the transport cycle has been discussed.

2.2 ISPS code and its implication

2.2.1 Objectives of ISPS Code

The ISPS code has been described briefly in the introduction chapter. In this chapter a more detail analysis of the ISPS code will done, especially its impact on the port sector. The major objective of the ISPS code is as follows

- It aims to indentify or detect any kind of risks related to security.
- To execute many types of security procedures.
- Assemble and propagate information associated to maritime security.
- Provide a dependable method to evaluate maritime security risk.
- There security level keeps on changing. Proper methods have to be found to upgrade to higher security levels.

- To determine the role of different stake holders involved like the government, port authority and shipping companies.
- Create facilities for training.(Anon 2)

2.2.2 Highlights of the ISPS Code

The ISPS code was basically divided into two parts which are named as Part A and Part B (Anon 3). Part A consists of the compulsory part which is mandatory for the ship or the shipping company. Part B consists of the various recommendations in order to implement the ISPS code. Part A focuses on the compulsory regulations which the stake holders should follow and Part B help the same stake holders to implement these regulations in practice (Anon 3). The following three points are related to the port security

- A three-tier security system should be introduced in all the ports based on the area of the contracting government, level of authority, the nature, the degree of the threat and the repercussion as a result of occurrence of the threat as security lapse.
- A department or body with adequate authority should be appointed by the government in order to take control, administer and regulate proper security measures. The appointed body should work as per the instructions mentioned in the Part A of the ISPS code.
- The contracting government should take care of the fact that a Declaration of Security (DOS) is a required document when the ship and port work together. The ports which are under the contracting government compliance should set up security level as per the standard set by the government port security authority. More over the ports should continuously assess the security situation and upgrade as per the required security levels. The designated port security authority should do periodic monitoring, assessment of the port security level of the complied ports under the authority. All the report of the assessment should be mentioned adequately in the Port Facility Security Assessment (PFSA). If the assessment is being done by some other agency then the designated department of the government has to verify the report appropriately. The Port Facility Security Plan (PFSP) has to be developed by the port as per the guidelines developed by the designated authority and hence it has to take care of the three tier security planning (Anon 2).
- The three levels of security would include measures to avoid the entry of weapon and other dangerous apparatus and chemicals into the port area.
- Based on the sensitivity of location, special areas would be created which would have limited access only to authorized personnel (Anon 2).
- The port consists of many kinds of equipment and more importantly for the smooth continuity of the cargo handling operation of the port the cargo handling equipment has to be kept under proper security.
- In the present age of ICT the information is a very valuable asset for any company. The modern ports of today are generally equipped with huge ICT infrastructure to improve the operational efficiency and speed. All the

confidential data and valuable information has to be properly secured in the internal network.

- A proper procedure has to be laid down with respect to any security practice which has been developed to counter security threat. The instructions should be very clear and depending on the difficulty level of the respective procedure drill and trainings should be conducted for the relevant personnel. Any serious security activity such as evacuation should be conducted in collaboration with the ship if required.
- The PSFP should be reviewed and upgraded if the security environment seems to change.
- Any security incident should be immediately reported to the relevant authorities and should be also updated in the document to maintain a record.
- Detail information about the visitors to the port should be maintained. In this respect the information regarding the ship crew should be also properly maintained as most of the crew would have foreign nationalities.
- A Port Facility Security Officer (PFSO) has to be appointed to be the overall in charge of the security of the port. The other security personnel should be deployed under the PFSO. The other important job of the PFSO is to take care of the fact that the points mentioned in the PFSA and PFSP has to be adequately implemented. At the same time the PFSO also has play the role of a coordinator between the various stakeholders involved in the port security. This stake holder includes the shipping company, the government, the companies and the various agents involved in the port operations. In a way the role of PFSO is most important in terms of successful implementation of the various regulations to maintain and upgrade the port security arrangements.

All the points discussed above are important highlights of the ISPS code in terms of ports. For the ports to comply with the ISPS code there is no certification given to the port. The port has to sign a document of compliance with the relevant government and the IMO has to legitimate the respective contracting government. In case of ships the IMO has to issue a certification but in case of ports the contracting government is more responsible than IMO as the document of compliance is signed between the contracting government and the port authority. So the contracting government has to see to it that the Port Authority is following all the security related regulations as per the compliance. In fact the government has to facilitate the environment in such as way that the Port Authorities comply with the ISPS code. In other words it can be said that the degree to which the Port complies with the regulation of the ISPS code depends on the priority level of the government on security issues and unfortunately in some cases how politically is a government motivated to prioritize the implementation of security related regulations.

2.2.3 ISPS Code in Indian context

In Chapter 1 section 1.2 the ports in India have been briefly discussed. Also the threat to the port in terms of security to the Port has been briefly discussed. In the same chapter in section 1.1 in table 1 major security mishaps in the Maritime sector in the past decade has been discussed. It can been observed that Indian sub-continent has

been one of the most targeted region of the world with Pakistan and Sri-Lanka being the target in many of the occasion. India is by far the largest country in the region and the coast line is also the proportionately the largest. The ports in India also are under all kind of security threat. So a successful implementation of the ISPS code becomes important for India.

India is a developing country and industrialization has been picking up at a rapid pace in recent years. This has also made ports very important in terms of export and import nodes. The importance of dry ports in the economic growth of the country also has been discussed in Chapter 1. Due to the developing nature of the country, the priority given to capital investment in security related project sometimes takes a back seat. In a developing economy the capital investment in economically beneficial projects are generally given high priority for the economic growth of the society and also due to the limited budget available. Although in India security threats are from multiple sources due to the external terrorist threat and also groups evolved due to domestic unrest, still the government has to very judiciously allocate the some part of budget in security related investments. So fully implementing ISPS code in a huge country like India is always going to be a challenge for the government as well as the Port Authorities.

The first and the most important challenge for India in terms of port security would be the sharing information with the ports of neighboring countries. Sharing of information between different entities in the same country is not an easy task. Moreover the sharing of information with ports of other nearby countries is even a more challenging task especially in case of India when the political relationship with some of the neighboring countries is not the most cordial. In fact one of the countries is considered to be a major threat to Indian security. The prioritization of different issues on the national political agenda was very much decided by how a given condition was interpreted, and responses were often subject to social, political and institutional constraints (Jacobs and Hall, 2007) and it was clear that the concept of security was interpreted very differently in Asia and was typified in the Indian subcontinent. So the conflicting national interests are a big barrier to improve the security information sharing between the ports. At the same time the investment done on the ICT development of any project is limited when compared to such projects in the developed world.

The Ports have not been considered a major point of threat by the Indian Government. This is due to the fact that all the terrorist attacks have been on the borders of Pakistan and Bangladesh in the last decade. So land related security infrastructure development has always been given priority over maritime security infrastructure.

But for the same reason as mentioned above due to almost no major security lapses in maritime infrastructure the government must focus on investment in maritime security infrastructure. The security attack off late have not been limited to the traditional targets. The attacks have been very surprising and often have been in new locations. So it can be said that due to the poor history of attack on maritime infrastructure there are high chances that such infrastructure might be attacked in near future. The implication of any such attack would not be just limited to human casualty but it would have highly adverse affect on the effectiveness of the Global Supply Chain and hence International Trade.

2.3 Legal regulations in the hinterland – Rotterdam rules

Any kind of legal issues related to the sea transport by ship is quite clear in terms of international regulations. The carrier is the responsible party for the sea leg of the transport. The other side of the coin is the containers (as the thesis is focused on Container security) transport from the sea port to the dry ports. There are some ambiguities regarding the legal implications in the land side of the container transport. The recent Rotterdam Rules have been made to make the responsibilities and liabilities more clear.

Container security is an issue especially in the land side movement in India. If India ratifies the Rotterdam rules, it would go a long way to help to solve most of the related legal ambiguities (Gujar per.comm, 2011). The dry ports are believed to be the responsible party to take the responsibility of the Container Security (Mr. Mukul Jain per.comm, 2011).

In case of India dry ports are the key players for the smooth running of the inland transportation and door to door logistics (Haralambides and Gujar. 2011). The functions of a dry port at a broader level have already been discussed in section 1.3 of chapter 1.

2.3.1 Present status of legal regulations in the Indian inland transport

The carrier issues the bill of lading for the entire door to door transport to the shipper. As per Carriage of Goods by Sea Act (COGSA) the shipper enters into an agreement with the carrier. This part of the legal regime is quite clear.

In order to regulate the inland part of the chain the Multimodal Transportation of Good (MMTG) act was introduced in the year 1993. In case of India the inland transportation can be divided into road and railway. So the MMTD act was compiled based on the Contract of Carriage of Goods by Road convention in 1956 and International Carriage of Goods by Rail convention in 1980. The MMTG convention was not widely accepted due to the non-inclusion of the actions of the third parties who practically do the work (Haralambides et al., 2011).

The Inland Way Bill (IWB) which is monitored by the Railway Act of 1989 which facilitates for the carrier to enter into a contractual agreement with the Dry Port operator. The dry port operator enters into a separate contractual agreement with the inland operators which are the road truck operators and the rail operators. The problem with this regulation is that the role of the dry port operator is not clearly stated (Haralambides et al., 2011). As per the Indian Railway act the Dry Port authority is the party responsible for the transportation of the container in the inland part of the chain but the same Dry Port cannot be held responsible for any issues such as delay in delivery etc (Mr. Mukul Jain. Per.comm, 2009).

Under the Ministry of Commerce in the year 1992, the Inter-Ministerial Committee (IMC) was set up as a primary governing body to enhance the development of dry ports. The primary goal to the ministry of commerce through the development of dry ports was to

give impetus to development of trade. This was a strategic move by the ministry of commerce to develop dry ports in order reduce trade barriers such as customs delay as well as improve inland logistics. The IMC was the primary governing body which issued licenses for the development of new dry ports. As per the regulation developed by IMC the dry port would be under the jurisdiction of the local custom commissioner. Although the IMC was instrumental in the starting of several dry port, it did not take the responsibility of supervision of the operations of the dry ports. The overall supervision of the dry port was handed over to the local custom commissioner. So the IMC plays the specific role of a licensing authority. Such an arrangement of separate licensing and monitoring authority sometimes misleads the licensing during the future allocation of licensing as the IMC stay away from the operational problems. Nevertheless as per the customs act of 1962 the local customs official has adequate powers to have a control over the custodian. In this case the custodian is the dry port operator. If the local custom official finds any kind of inefficiencies at the operation level of the custodian or the dry port operator in case, the local custom official has the right to take away the custodianship of the dry port operator.

The dry port operator has to act as a custodian in collaboration with the railway operator, road transport operator, customs department and the police or any form of security officials. As a custodian the dry port operator would be responsible for the safety and security of the cargo. In order to maintain the security equipment and personnel facilitating security have to deploy but this has not been seen often in practice (Mr. Mukul Jain, per.comm, 2011). A proper standardized structure or checklist has not been developed which would go a long way to improve the security standards in dry port. Despite legitimate power of the local customs commissioner, a lack of standardized set of regulations reduces the impact or effectiveness of the same. In other words it can be said that the duties to be discharged by the local customs commissioner in order to have a genuine impact on the security and safety levels of the dry port is not clear. As a result of this gap, there is high concern for the security levels in a dry port (Mukherjee, 2009).

The first dry port operator in India was CONCOR which is a government enterprise. Off late there have many other private dry port operators in the market. These operators take care of the inland transport of the cargo. When they receive the cargo for final delivery, they enter into a contract with the carrier. In this case the carrier or the shipping lines acts as a consignee and the dry port operator acts as a carrier as they carry the cargo from the gateway port to the dry port and hence forth the final destination. So the dry port operator enters into a contract with the carrier and issues a Railway Receipt (RR) as per the IWB based on the Railway Act. The shipper holds the carrier responsible for the safety and security of the cargo for the door to door delivery. At the same time another loop is generated when the dry port operator signs a contract with the carrier. There is no direct link between the dry port operator and the shipper as the shipper thinks the responsibility is with the carrier but at the same time the carrier has delegated the responsibility to the dry port operator through another contract. The shipper sets its expectation from the carrier as per the contract with the carrier even for the land side of the transport chain. But carrier signs a separate contract with the dry port operator as per the local regulations which might not be exactly congruent with the contract between the shipper and the carrier for the inland transportation. In case of

such ambiguities if there are legal issues then manipulations becomes easier and hence it does not serve the purpose of fair jurisdiction which is sole purpose any legal system.

2.3.2 Rotterdam Rules and its significance

There have been some ambiguities regarding the regulations governing the carriage of goods by sea. The reason for the existence of these ambiguities has been the presence of three set of rules namely the Hague rules, the Hague-Visby rules and the Hamburg rules. Moreover there were some clarity issues in this rule due to the international nature of the industry and the different mode of transport being used in the complex logistics supply chain in today's age. As a result 'United Nations Convention on Contracts for International Carriage of Goods Wholly or Partly by Sea' was framed. This convention is also commonly called as Rotterdam rules.

An attempt has been made in case of the Rotterdam rules to cover all the points which were missing in the previous regulations. It aims to cover all aspects of the complex logistics chain of today including all the modes of transport. A clear definition of the liability of the different parties involved has been made. Due to the international nature of the regulation there have been unclear rules defined in the previous regulations especially related to the liability of different parties involved in the land leg of the transport. But Rotterdam Rules appear to be more clear and detailed oriented to solve such areas of concern. A clear definition of various rules would give more transparency to the various parties involved in the Maritime trade and hence would be a real impetus to global trade as a whole (Goddard et al., 2010).

In terms of measuring risk especially in case of hazardous cargo, the shippers are considered to be more capable than the carriers, hence the shippers are required to list the hazardous cargo as per the Rotterdam rules.

The following points provides the salient points of the Rotterdam Rules

- There is a concept of the 'Performing Party' introduced in the Rotterdam rules.
- For the rule to be applicable the most important point is that the some part of the international transport should be done through sea. Even if it is an international transport and the journey is only done by road, rail or mix of both, Rotterdam Rules would not be applicable in such a case.
- As per the rules the 'Performing Party' undertakes the responsibility of the carrier in some part of the transport chain. The 'Performing Party' cannot be the carrier himself or it cannot be the shipper or Consignee.
- The 'Performing Party' must be under the direct or indirect supervision of the Carrier. The 'Performing Party' must be carrying out the functions which the carrier was suppose to do as per Carrier's contract with the shipper. So there must be some kind of link or relationship shown between the Carrier and the Performing Party.

- The various task involved during the international movement of cargo such as storage, handling, unloading, loading, safety, security and carriage of the goods are a part of the functions performed by the ‘Performing Party’

In case of the earlier regulations, in case of any legal hassles the shipper was not clear about the liabilities of the different parties involved. The shipper exactly was not sure about whom to sue and hence this leads many legal complexities and also unfair beneficiaries.

If the Rotterdam Rules are ratified by the Indian government then there would be more clarity with respect to the obligations and responsibilities of the dry port operator. The Dry Port operator would also act as ‘Maritime Performing Party’ and hence would be equally responsible as the carrier for any kind of loss or damage to the goods. Since the operational level activities are increasing in Dry Ports when compared with the Gateway ports, the Rotterdam Rules would go a long way to give clarity to the legal ambiguities in the Supply Chain.

As per the Rules the Customs are responsible for the custom clearance and also the security of the container cargo. In India the customs mostly take care of the custom clearance with respect to the revenue it generates. They are not much concerned about the security of the container. So the responsibility for the security falls on the custodian that is the dry port operator in this case. But the security standards to be followed by the customs are not that well defined.

The Rotterdam Rules by clearly defining the obligation of the dry port operator as a ‘Performing Party’ would in way enforce the dry port operator to follow certain security standards. But at the same the dry port operators have an economic objective of increasing the container throughput which makes the security handling task a more difficult one. So the container security is a big issue in the dry ports of India especially considering the recent security lapses in different sector of India.

Chapter 3 – Security at Ports and Dry Ports

3.1 Ports

3.1.1 Functions of a port

As discussed in Chapter 1 ports are one of the most important nodes in the Supply Chain. The major activity of the port is that it acts as an interface between the water side incoming vessel and the land side. The ports are divided as terminals on the basis of the cargo and the type of ships they handle. The functions of the terminal can be broadly divided into three set of activities. They are as follows

- Receiving the cargo from the ship while it is imported through cranes in case of containers or dry bulk and pipelines in case of tankers. The same way loading the required cargo through the same means in case of export.
- Storage of the cargo at the intermediate stage before it moves to the land side or water side depending on whether its export cargo or import cargo. In case of containers there are huge container yards, whereas in case of oil product and crude oil there are huge storage tanks to fulfill the storage job of the ports or the terminals. In case of container yards there are empty container yards where empty containers are stored.
- The third operational function is to receive or dispatch the cargo to the land side from the storage. This is done through various means such as rail, road and barges.

3.1.2 Present day trend in Container terminals in a Global Supply Chain perspective

The thesis is concerned with container security so the focus in ports will be on container terminal. The present day container terminals are one of the most complex material handling terminals. The basic function matches with the three functions mentioned above. The difference lies in the more complex and demanding logistics in case of containers. The major advantage of the containers is the speed at which it is transported due to relatively easier handling of the box. This helps in improving the responsiveness of the supply chain in a huge way. In recent years the cost factor in the Supply Chain has also become an important factor which has led to development of huge container ships up to 18,000 TEU in order to achieve economies of scale in maritime transport. The choice of the specific port of call or a terminal has become foot lose in the Supply Chain (Gujar, Per.comm, 2011). Earlier the ports used have more monopolistic power and liner companies were dependent on them. In recent time's ports mainly does the function of a service provider (Gujar, Per.comm, 2011). This has resulted in high competition among the ports and the terminals. In order to improve the efficiency of the terminals the private sector has had to play a very important role. Most of the advanced ports are no longer government owned enterprises. But the private sectors are playing important role especially in case of container terminals. Big liner

companies like AP Moller have started their own terminal operating companies to keep the reliability factor under their control. The factors mentioned above have increased the pressure on container terminals to provide even higher productivity. This has led to large fixed capital investment in form of equipments and other infrastructural requirement. At the same time the terminals also had to invest heavily on Information Technology for more automation and better data collection and utility. Any kind of rapid industrial development has its own set of externalities. In this case generally the externalities are in the form of environmental problem, congestion issues and increasing security concern. This increasing competition among ports and at the same time increasing externalities has made the port business very complex. The increasing externalities have resulted in formulation of many laws and regulation in order to internalize these externalities. All these regulations are very tough to implement as they incur economic cost, time and try to change practices which have been practiced for a long period. This thesis mostly focuses on the security aspect especially in case of container supply chain.

3.1.3 Security at ports

In chapter 1 some points were mentioned about Indian ports. At the same time the various forms of security threat to a port were mentioned at a broad level. It was quite clear that while the cargo is transacted through any port, the containerized cargo shows maximum threat. Container security is one of the most critical and important issue to be taken care of in order to ensure Supply Chain Security (Benacchio *et al.*, 2000). Since the 9/11 attacks the government of different countries have deliberately tried to increase the security facility and implement new regulations and laws. This kind of advanced security measures and regulations generally become a barrier to free trade among countries. If the case of container scanning is taken into account, it requires heavy capital investment in form of equipment and also there is recurring cost of maintenance and personnel deployment and training. There are two major issues to consider in case of container security schemes. The law and regulations with regard to container security has not been very clearly stated (Haralambides and Gujar, 2011). It means that in case of any security lapses, it is very difficult to point out to a particular party or node of the Supply Chain responsible or accountable for the incident. The second problem is the method in which a container is scanned. 100% container scanning rule initiated by the US required all the containers to be 100% scanned before entering any US port. This kind of rule is not only a very costly in terms of capital investment by the exporting countries to US but also slows the whole Supply Chain. So it is practically almost infeasible to implement this kind of regulation by all the countries. Another rule which came up was 10+2 rule but it is very challenging in terms of data collection. In India after some of the recent terrorist attacks, the issue of container security has started holding very high relevance and as per present trends, its importance is expected to even increase more.

At the same time even if the container security has to be taken care of it would not only involve economic cost but there are chances of substantial increase in the time period. If the security of the container has to be checked properly, a process of scanning would be required at various levels at different stages. There would be a basic increase in

time period due to the time taken to scan the containers or for that matter undertake any other kinds of security check. This basic increase in time period would account for a reduction in the responsiveness of the overall supply chain. In modern day global supply chain and logistics any reduction in responsiveness of the supply chain cannot be ignored or underestimated. At the same time the growing concern about security also cannot be overlooked in order to make the supply chain more responsiveness. So it can be said that a basic time can be allotted to scan the containers in order to address the issue of security, despite the growing importance of the augmented supply chain responsiveness. But the problem related to the time does not draw to a close with respect to the basic time allotted to the scanning process. As it is a well known fact that the number of containers varies a lot as per the market demand. Ideally all material handling system has to be designed to handle the peak load (Saanen, 2011). In this case if scanners have to be installed in order to handle the peak load a huge investment would be involved. On the other hand if a limited number of scanners are installed to satisfy the legal regime then it would make the supply chain highly unresponsive especially during peak periods.

3.2 Dry Ports and Container Security

The Dry Ports are considered to be important node in the supply chain of container transport. As the name suggest the dry port is not connected by sea, but it is connected by road and railway. One of the primary goals of the dry ports was to free the gateway port from heavy traffic. The dry ports also aim at improving the inland logistics by performing the following functions as listed below.

- Aggregate and unitize the cargo (Haralambides and Gujar, 2011)
- Act as a storage yard (Haralambides and Gujar, 2011).
- The dry port also has customs clearance facility in collaboration with the customs department from the respective government (Haralambides and Gujar. 2011).
- Issue the bill of lading .
- Share the load of some function of the sea port to make the gateway port congestion free.

As discussed in the introduction chapter the dry ports in India have a significant role to play in terms of development of the Maritime Logistics. A lot of public sector dry ports have been built to provide impetus to the container trade. But most of these dry ports suffer from overcapacity (Haralambides and Gujar, 2011). The efficiency of the dry ports has become questionable issue due to the huge overcapacity.

As discussed in Chapter 2 there are many legal ambiguities in the hinterland part of the container logistics. The responsibility of the container safety and security is not very well defined. As the law is not enforced in a proper way, the security of the container is an issue of concern. In case of India the dry port operator is responsible for the container once it leaves the sea port. The container is transported either by truck via

road or by train to the dry port. As discussed in chapter 2 the legal document which the shipper signs with the carrier is the bill of lading. The shipper would hold the carrier responsible for any kind of security issue to the container. At the same time here once the container is out of the port and is in the inland mode of transportation the inland modes are responsible for the security of the container. Suppose a truck operator has taken the responsibility to take the container from the port to the dry port, then the responsibility of the container security lies in the hands of the truck operator until it reaches the dry port. Once it reaches the dry port the dry port operator is responsible for the container. There can be a case where the dry port operator is also the truck operator. In such a case the dry port operator has to be in charge of the security of the container for the whole inland leg of the container transport. In the same way a dry port might be connected to the port via rail network rather than road network. In such case, if the train operator and the dry port operator are the same company then dry port operator is in charge of the inland transport of the container. If the train operator and the dry port operator are separate companies then the responsibility will also be divided. In case of India many dry ports are operated by the Container Corporation of India (CONCOR). The CONCOR is also a sub-division of the Indian Railways. In many of the public dry ports, the dry port operator takes the responsibility of the container for the inland part of the container transport. Once the container reaches the dry port it is under the responsibility of the dry operator. As per the description above there can be many parties involved in the inland part of the container transport. So it is very difficult to hold a part liable in case of a mishap since the liabilities are not very clearly defined especially in Indian system.

Any kind of security provision or facilitation is a cost for the company. In case of containers, as it is a moving material, it is not economical for a company to invest in the containers security. The most ideal solution for proper container security would be to scan the containers at various stages. Any dangerous good can be placed inside the container and it would be difficult to track it since the container is an enclosed box. It is practically not possible to open the container and check it thoroughly at various stages. This would cause huge delay and would defy the basic rules of container transport that is fast and efficient logistics. The scanners are a better solution but it would be a huge cost. But as the container passes from one party another, to install scanner at each of the stages is also not an economically viable option. The next question is about who should bear the cost of securing the container. If regulations are laid out in order to improve the security, the companies might have to create facilities to improve the security. The higher cost due to the increase in the security would increase the cost of the overall logistics. This would finally fall on the customers and might have an adverse impact on the trade between countries. But the issue here is with the increasing security issues in many countries due to external threats. In case of India most of the security issues are caused by external security threat mostly due to the terrorist attack. This is facilitated by supply of dangerous weapons from other countries. As containers are imported for foreign land the security of the containers is a issue of concern. Any lapse in container security can cause disruption in the supply chain. Once the container supply chain is affected it can cause all kinds of delay hence affect the business environment as a whole. Moreover many varieties of cargo are shipped through the containers in an enclosed way. Due to the enclosed nature of the box, without any proper security check unwanted products can be shipped across borders. In case of

India the issue is very serious due to the growing frequency the security lapses in different part of the country.

When the container reaches the dry port, it is due for a check. The custom department has a role to play as discussed in chapter 2. The custom depart is concerned with the collection of revenue due to the cargo imported with the container (Haralambides and Gujar, 2011). Here there two different parties, one is the dry port operator and the other is the custom department. There is a conflict of interest about which party should be responsible for the security of the container. It is perceived that the dry port operator should take care of the container security in the inland part of the container transport especially if it is Rail operated and the dry port operator and the inland transport company are the same. Once the custom check is over the container can be taken by the consignee. Once the consignee takes away the cargo, the cargo is in the hands of the consignee. It can be seen that the container security during the inland transportation of the containers is many folds. In the same way for the export container the stuffing of cargo takes place in the dry port. The shipper hands over the cargo to the dry port operator. The dry port operator stuffs the container with the required cargo and customs gives the final approval for export. But the problem here is that the customs is mostly concerned about the revenue collection and the dry port operator does the stuffing of. The shipping lines have signed a contract with the shipper which is not involved in stuffing. The most important point here is that the dry port operator should have adequate supply of equipments and personnel to monitor the stuffing of cargo which is not the case in most of the Indian dry ports (Gujar, 2011). The responsibility of the liabilities is not very clearly stated as per the present regulations. Moreover any security lapses can have huge implications.

3.3 Inland Transportation of Containers and Dedicated Freight Corridors

The inland part of the container transport is mostly handles by either the rail or road. The involvement of inland water navigation is almost non-existent. Most of the transportation from the Port to the Dry Port is done via the Rail. CONCOR is the leading public sector company which does the work of transportation through rail to the dry port. At the same time the Dry Ports are also operated by CONCOR. There are few private companies also which are into the business of inland container transport and dry port operations.

The concept of Dedicated Freight Corridor is quite prevalent in United States of America (USA). Most of the container transport is done with private train operators. This facilitates the container logistics to a great extent due to fast and efficient cargo movement through train. The concept of Dedicated Freight Corridor (DFC) is being encouraged at present. A number of dry ports have been built to prevent the congestion in gate way port. These dry ports have created lot of capacity for container movement in India in terms of storage. But in recent years the problem has been the connectivity of dry ports to the gateway ports. If the cargo carrying trains have to share the railway tracks with the passenger carrying trains, the passenger train always gets the priority to move first. This causes delay for the cargo trains. In India there has been congestion in the railway tracks due to limited capacity. So the idea of introducing DFC was

developed around 2004 in India. It meant that the new DFC would only be for carrying cargo. So container transport between the Port and the Dry Port was an important part of the plan. The container transport would be mostly concentrated on the western part of India. The various dry ports near JNPT and the north part would be connected through the western corridor. The important station would be Baroda, Ahmadabad, Jaipur, Tughlakabad, etc. The eastern part of the country would be also facilitated with DFC. It would mostly consist of mineral ore cargo since eastern part of India is rich in mineral ore. There is scope to export iron ore due to the number of available mines and there is high scope to import due to high requirement of specific minerals by the steel, thermal and other mining industry. The important stations are Saharanpur, Allahabad, Lucknow, Mughalsarai, Tatanagar etc. There would be provision for double stack container trains. These DFC is expected to reduce the time duration required for the transit by almost half the required time presently. This would be a real boost to the inland logistics which is considered to be a hindrance to the International Trade. Moreover it would encourage the transport of container by railways which are faster as well as more environmental friendly. Another important factor to consider here is that most of the dry ports is operated by CONCOR which is a separate business unit within the Indian Railways. So the dry port operator can be considered the responsible party for the container transport.

Chapter 4 – Supply Chain Resilience

4.1 Supply Chain Resilience

A brief introduction about the concept of Supply Chain Resilience has been given in section 1.5 of Chapter 1. In the present era the Supply Chain is very long and also complex. Due to the developing ICT it has made it possible to involve many different parties to make the supply chain very efficient and also responsive. Investment in efficient Logistics or supply chain is not only done to reduce cost but it is being considered an important competitive measurement index among competing companies. Any kind of disruption to this Supply Chain can have huge implications on the whole business environment of today (Sheffi, 2005). The events such as a terrorist attack or a natural disaster which are low probability but high impact incident have an adverse impact on the Supply Chain. The major cause of worry is that it is almost impossible to predict such an event based on any econometric analysis on available historical data (Sheffi, 2005).

Despite the issue discussed above it has been seen that some companies or government are better equipped to face such disastrous events when compared with some other similar parties. Any kind of such unpredictable event will surely affect the supply chain in a negative way and there is no denial about the fact the system collapses for a certain amount of time despite any condition. The important question is how quickly an affected system can bounce back to its original form. In material science a word ‘Resilience’ is used to explain similar phenomena. Whenever a material undergoes any kind of deformation, the ability of the material to come back to its original shape is called as the resilience of the material. In terms of material science, the respective material should have the strength or the capacity to with stand the blow or else it would completely break. Moreover it should have the required elasticity to come back to its original shape. If the same allegory is developed for the word ‘Resilience’ in Supply Chain, it can be said that the strength or the capacity of the material to withstand the blow is similar to the capacity or the extra capacity available in the supply chain to withstand any such event. In the same way the elasticity of the physical material can be compared with the flexibility of the system. The most important point for a supply chain system to be resilient is that it should have the extra capacity to withstand the event. Over that the system should be flexible enough to be capable enough to use the available capacity.

The companies can improve their supply chain resilience in three ways which are increasing redundancy, building flexibility and changing corporate culture (Sheffi, 2005). The growing complexity of Supply Chain in terms of globalization has increase the level of risks in the Supply Chain (Christopher, Peck, 2010). This requires the Supply Chain to be more efficient with the sharing of information being a critical activity (Christopher, Peck, 2010). An increase in Supply Chain resilience increases the competitiveness of the implementing company (Sheffi, 2005).

4.2 Understanding Supply Chain Resilience in practice

In the following section the Supply Chain Resilience has been explained taking practical scenarios into consideration. As explained above in the literature review the requirement of resilience in a company can be many folds. Depending upon the nature of work and type of resources required the resilience of a company has to be developed. The requirement of basic resources such as Land, Capital and Labor will be present in all kinds of company. But the importance of these resources varies as per the kind of product or services a company provides. Taking into consideration the importance of these resources, supply chain resilience should be developed. The following points would provide some kind of explanation

- In case of IT Services Company the availability of skilled human resource is the most important asset for the company. As a result, for such human resource dependent company, in no case there should be a shortage of skilled workers if there is a demand for such skills in the market. The high performing companies generally maintain bench strength of skilled worked who are trained adequately to meet sudden increase in demand. The increase in demand can be due to any external factor. So the extra capacity in form of bench strength makes the company more resilient in case of increase in demand. In the same way some of the IT services companies have a more flexible approach by training their work force in multiple skills to meet the demand whenever required.
- Another example of a container terminal can be taken to understand the importance of resilience from a different prospective. In case of container terminal the significance of the land and capital is more than the labor in terms of investment as well as importance. Moreover, in recent years due to huge investment in ICT infrastructure in form of automation has made container terminal even more capital intensive. The berth capacity, yard storage capacity, equipment handling capacity and the gate capacity should be designed as per the peak load factor ideally. So the system is made capable of handling the peak load that is when the demand is highest. So the resilience is built for peak load in terms of capacity. As per the actual principle of resilience the peak is also not enough. The capacity should be even slightly more than the peak to handle the unexpected surge in demand.
- In case of security set up for any kind of system building resilience is a key aspect. The reason is that if the security system fails, it would have huge impact. So generally a security system has redundant alternatives to counter any kind of failure. If an arrangement fails another arrangement is used to protect the system from external threat.

In all the three cases above it can be seen that any kind of resilience development is a cost for the company. So a company has to very judiciously decide about how much extra capacity to build in order to counter unexpected event because there is a cost factor involved. In most cases companies build extra capacity to handle expected increase in demand. This gives the system some kind of basic resilience. But the question is about the extra capacity to be built over the peak handling capacity or the expected demand capacity in order to counter an unexpected event. Another important aspect of resilience is the time factor. The time factor indicates the amount of time a system takes to come back to normalcy after the unexpected

event. This of course depends on the impact of the unexpected event. If the system has absolutely no resilience, it will completely break down due to a high impact event. If the system has some level of resilience it might take more time but it might come back to normalcy. If the system is highly resilient then it would come back to normal level in lesser time. So for any company or organization the management has to take a decision based on the tradeoff between the cost of maintaining resilience and the time of recovery. If the resilience is high it would take time for the system to recover. In order to take a decision about the degree of resilience the company has to focus on its most key resource and invest capital depending on the possibility of a disruption. In some cases resilience is not just the cost but it also gives companies business advantage over other competing partners. In case of any major disruption, the company with the maximum resilience would have the capacity to fulfill the excess demand in the market while the companies with lesser resilience fail to counter such a disruption.

In case of supply chain resilience both capacity and flexibility play important roles to improve the resilience. The different nodes of the supply chain such as ports, warehouse, and transport vehicles have different kind of requirements in terms of resilience. More capacity in supply chain improves the resilience but at the same time it also increases the cost factor. Flexibility in network helps in a big way to have a more resilient system. If alternative nodes exist in the supply chain then it can be considered to be more resilient. At the same time it can be said that creation of alternative node is also a capacity creation and it also involves cost.

4.3 Measurement of Dry Port Resilience

There are several definitions of Resilience, one of which is the ability of the system to bounce back after a shock and return back to its normal service levels. It could also be defined as capability of the system to provide and maintain an acceptable level of service during disruption. Resilience requires strategies to be in place for managing risks that have not been identified. Supply chains today are global, complex, vulnerable and traditional risk management focuses on addressing source of risk: but the risks themselves are numerous, imprecise and ambiguous. The importance of Resilience Principles is emphasized as they take into consideration vulnerabilities and mitigate probabilities and then focus on failure mode preparations.

High Consequence-Low Probability (HCLP) events are no longer low-frequency with the increased interconnected nature of global supply chains (SC). The frequency is very low for specific disruptions affecting a specific location/firm/time frame; but the frequency of disruptions somewhere affecting global SCs elsewhere is increasingly high. Thus supply chain risk management (SCRM) needs to include not just preventive measures but also Back up Plans (BCP) for predictable outcomes. The outcomes from any disruption can be categorized into one or more of 6 ‘failure modes’ (or core capacity losses) Developing BCP for each of the failure modes will prepare the firm to handle

and respond to disruptions therefore reducing the impact of disruptions on their supply chains. A failure mode focus will help create resilience within the firm.

All disruptions result in one or more of these capacity losses for a period of time:

- Capacity to acquire materials (supply)
- Capacity to ship/transport
- Capacity to communicate
- Capacity to convert (internal operations)
- Availability of human resources (personnel)
- Financial flows (e.g. demand)

It has been noticed several dry port disruptions which have been categorized by failure mode and subsequent impact. The failure mode analysis consists of preparing contingency plans for recovery from failure modes, not on risk source. Such plans entail business continuity planning (BCP) which is nothing but a design to 'fail smartly' – plan to fail with limited impact. It also takes into consideration network *resilience* which is essentially the ability of system to sustain & recreate itself after disruption. Such abilities entail prior investments in infrastructure, excess capabilities prior investments in capital for building capacity that may not be used.

In India today dry ports are vulnerable to threats such as natural disasters, human factors, organizational factors and infrastructure failures. The dry ports are critical nodes in a complex system with a wide range of interdependent stakeholders. The failure of such a system could cascade from delays to a complete closure. As such in a dry port environment it becomes imperative to study and understand interdependencies, associated unbounded risks and how it affects resilience. Hence we have developed a measurement model that takes into consideration risk dependencies across the system and helps assess their impact on system wide resilience

The measurement model developed by us in the next chapter takes into consideration system wide activities/processes with performance measures along with real or hypothetical/single or multiple risks in order to evaluate how a failure of an organization affects others. The model Measures of disruption & recovery along with period of disruption for the overall system and throughput levels during and after threat. The data collection and the methodology would be explained in detail in the next chapter.

Chapter 5 – Data description

5.1 Introduction

In this chapter the data and the quantification part of the thesis has been explained. The thesis deals with three aspect of a dry port. These are the efficiency of the dry port, the security of the dry port and the resilience of the dry port. In future, it is believed that all the above three variables are important in terms of measuring the efficiency of the dry port. The importance of security is growing with time. So the resilience of dry port becomes an important factor. As explained in chapter 4, if there is a failure in the supply chain then how much capable is the system to come back to its original form is the meaning of resilience. The quantification of all the three factors has been explained in the sections below. A set of 10 dry ports from a particular region have been selected for the study. These dry ports have many similar as well as dissimilar characteristics. Out of this around 6 are public sector dry port and 4 are private dry port. Some of them are connected by rail and some of them have only road connectivity.

5.2 Capacity of a Dry Port

The capacity of the dry port is the most important data used in this chapter. As per the literature review the following formula has been used in many of the cases. (Haralambides, Gujar, 2011) have used it in the capacity calculation in the paper related to the public private partnership of dry ports. (Watanabe, 2001) developed the formula for calculating the capacity.

$$C = \frac{L * H * W * K}{D * F}$$

Where

C = Annual Capacity of the terminal in TEU/year.

H = Number of TEU ground slots in TEU.

W = Average stacking height of the container in TEU.

K = Working slots in terms of percentage.

D = Average dwell time of the container in the yard.

F = Peaking Factor.

In the formula above an attempt has been made to calculate the capacity of a dry port. The number of TEU ground slots would depend on the area of land available for the construction of the terminal. It has been noted that a part of the total area will be used for administrative purpose. Also some land would be required for the infrastructure for

the railway and road connectivity. The rest of the area can be used for the storage yard which is normally measured in terms of TEU slots as per industry standards. The average stacking height of the container is an important determinant of the total capacity of the yard. It depends on the type of the yard handling equipment being used in the yard. It also depends on whether the container is empty, full loaded or partially loaded. It also depends on the strength of the material used for construction of the basement of the yard. The material used for the construction of the basement is a determinant of the container stacking height as well as the yard handling equipment being used. The dwell time in a container yard is the average amount of time a container stays in a storage yard. This is generally calculated in days. If there is high dwell time the terminal can become inefficient. The peak factor is taken under consideration to make sure that the capacity of the yard is designed as per the maximum load expected. The capacity of any material handling system is designed as per the peak factor (Saanen, 2011). The peak factor varies from 1 to 1.5.

This capacity data will help in quantifying the resilience of the dry port.

5.3 Quantification of the Resilience of a Dry Port

A literature review and analysis of the resilience of a dry port has been done in Chapter 4. The basic understanding of the resilience indicates that quantification of the resilience has to be done based on the capacity and flexibility of a system. The dry port capacity can be measured with the formula described in the section 5.3 above. Any extra capacity of the dry port gives higher resilience to the dry port. If a dry port is designed to meet the peak demand, it would provide some form of resilience during non-peak periods. The degree of resilience would depend on the difference between peak and the non-peak capacity, assuming that dry port has been designed for peak capacity. The question is about the resilience during the peak period which would require more capacity building to counter any disruption during the peak period. In reality any disruption in the supply chain during peak period would lead to even higher adverse implications when compared to disruptions during non-peak period. The terminal capacity of the dry port is one of the indicators to be considered for calculating the resilience.

Another important aspect of resilience is the flexibility of a system as per the literature review done. It is difficult to measure the flexibility of a system quantitatively in case of a supply chain system. The most important factors for a supply chain system to be flexible are the capacity of a system and the number of options available to connect to the specific node of the supply chain system.

If the example of a dry port is taken the first parameter to consider is the capacity of the dry port. The flexibility of the dry port would depend on the connectivity to the dry port. At the same time the flexibility would also depend on the capacity of the available in the system. The scenarios below have to be understood to formulate and then quantify the flexibility of a dry port.

- The dry port can be either connected only via road, only via rail, both rail as well as road for the connectivity from the port.
- The dry port is connected to its clients and vendors on the land side via a road connection.
- All the connections mentioned above that is through road, rail can be multiple connection meaning that there can be two railway tracks.
- The capacity of the rail is an important parameter. The capacity of the railway depends on many factors. The term used to define the capacity in a particular route is the section capacity (Mr. Mukul Jain, Per. Comm. August 2011). The section capacity depends on how much capacity of the rail is already occupied. A train can be either single stacking or double stacking train. In case of double stacking the capacity is more or it can be said it is doubled. If it is assumed that track is free all the time to let the train move, then the time taken by the train would depend on the distance from the point of origin to the point of destination and the speed of the train. But generally in practical scenario the track will not be free for the train to move as per its business requirement. Even in case of proper scheduling like a liner service a cargo train still face maximum congestion issue (Mr. Mukul Jain, Per. Comm. August 2011). The reason for this is that the passenger trains are always given preference over the cargo trains (Mr. Mukul Jain, Per. Comm. August 2011). Only in case of dedicated freight corridors, the cargo trains might run congestion free which is not the case in India presently. So a congestion factor has to be taken into account while calculating the railways capacity. As per the literature and interviews it can be said that there are two factors which affect the capacity of the connectivity between the port and the dry port. These are the availability factor and the congestion factor.
- In case of roads the container are transported by trucks. The trucks can carry one container at a point of time. The roads are generally state and national highway. The time taken by a truck can also be calculated by taking distance as well as speed into consideration. At the same time the trucks are also subjected to congestion due to the traffic in highways. The trucks have to pass through toll gates in order to pay for any infrastructural development which has facilitated the movement of vehicles through road ways. Moreover if the trucks have to pass from one state to another state, there are extra taxes to be paid. All these regulation lead to delay due to the waiting time. So a congestion factor also has to be considered on roads. It can be said that the congestion factor in case of roads would be higher than in case of railways. But the roads would not face issues related to availability if we assume there is unlimited supply of trucks for carriage of containers.
- Another important factor to be considered here is the handling of containers at the dry port. Both for railway as well as the truck the container handling takes different time period. This depends on the kind of handling equipment available. This determines the faster turnaround of the rail as well as trucks. If the train or the trucks can be turn around fast, it would provide more capacity to attend to the next train or truck (Mr. Mukul Jain, Per. Comm. August 2011). So the productivity of the handling equipment is a factor here.

- Another important factor for the dry port is the number of connecting ports in a fair distance range. In terms of import this is not a very critical factor, but in terms of export this becomes a critical factor for a dry port. On the other way around for a port it is important to consider the number of dry port it is connected to while a container is imported. While considering the export if a dry port is connected to more number of ports within a fair distance range, it provides the port with connecting alternatives.
- In the same way number of dry ports near the dry port taken for the analysis is also an important factor. If there are two dry port operators belonging to the same company, then it gives both the dry ports an alternative in case of emergency shutdown of one of the dry ports due to some external factors.

The following formulas have been compiled based on the analysis above.

$$RAC = Number\ of\ tracks * \frac{24}{Handling\ rate\ at\ dry\ port} * Availability * (1 - Congestion)$$

$$ROC = Number\ of\ roads * \frac{24}{Handling\ rate\ at\ dry\ port} * Availability * (1 - Congestion)$$

$$APF = 1 + \frac{Number\ of\ ports}{10}$$

$$ADPF = 1 + \frac{Number\ of\ dry\ ports}{20}$$

$$CF = (RAC * Train\ capacity * TEU\ factor + ROC * TEU\ factor) * APF * ADPF$$

CF = Connectivity Factor.

RAC = Railway connectivity.

ROC = Road connectivity.

APF = Alternative Port Factor.

ADPF = Alternative Dry Port Factor.

As per the literature review and the interviews conducted the formulas above were developed taking the limiting factors and the critical factors into account. An attempt has been made to take most of the factors into account but at the same time only the

important parameters have been chosen for the analysis. Some the data were directly available but some parameters questionnaire was prepared and figures have been determined within the expected range depending on the local condition. The points below would explain the methodology and logic used for the formulation above. All the formulas have been developed by taking into account the development of the capacity and the flexibility of the inland connectivity required for development of resilience of a dry port.

- The RAC indicates the railway connectivity. The formula above has been developed for the railway connectivity between a port and a dry port. The first criterion is the number of railway tracks between the port and the dry port. More the number of tracks more is the connectivity alternative as well as capacity. So the number of tracks has been used as a multiplicative function. The connectivity for the railways has been calculated for a single day so 24 hrs has been taken. It has been divided by the handling capacity in the dry port. The handling capacity in a dry port would depend on the number of handling equipment and the type of handling equipment. This would give the number of trains which can move in the given track in a day if it is assumed that the track is completely free for the trains connecting only the dry port and the port. The number of track when multiplied with the number of trains gives the capacity of the track for the day. But in practical scenario, there are limiting factors such as the Availability factor and the congestion factor. The availability factor is the percentage of time for which track is available for this transit from the port to the dry port or vice-versa. This is a very important parameter in calculation of the Railway capacity since the availability is limited because the track is being used for passenger as well as cargo trains. Another important factor is the congestion in the route. This can be again due to the fact that the track is being over utilized.
- The ROC indicates the connectivity of road. The concepts similar to the railway connectivity have been used here. There would be considerable difference in some the values between the road and rail. Handling rate of a single truck is much lower when compared with the handling rate of a full train. In the same way the availability factor in case of road ways is not an issue as in case of trains. The reason is that mobility and flexibility on road is much more than in case of railways due to understandable reasons. The congestion levels on the road are different due to many reasons.
- The alternative port factor is more of a broader connectivity factor as we go higher in the Supply Chain. If there is more than one port connected to the dry port within a particular distance range, it is always a more resilient option. But the formulation above has been done in such a way that its impact on the final connectivity factor is not very significant. The reason is that even if a port is available in the vicinity, still it is not very easy to set up an alternative connection unless and until it’s a emergency situation.
- In the same way the more dry ports nearby makes the chain more resilient. But at the same time it would not be easy to use the alternate option. It would be even tougher due to factors such as competition between the dry ports. There the implication the alternative dry port factor has been kept lower than the alternative port factor.

- In the final equation for the connectivity factor the RAC and the ROC have been multiplied by the capacity and TEU and then both these capacities have been added to give overall capacity. If there is no rail connectivity to a dry port then the railway capacity would be equivalent to zero. The connectivity capacities have been multiplied with the Alternative Port factor and the Alternative Dry Port factor to give the connectivity of the dry port in terms of capacity and flexibility. The TEU facto has been considered for the two different kind of containers that is the 20 TEU container and the 40 TEU container.

In the points above methodology of formulating the dry port connectivity was explained. In the points below some data used to calculate the connectivity will be explained. The data is more specific to Indian dry ports which have been obtained through personal interviews, surveys and questionnaire with the respective parties.

- Normally the handling of the container in case of trains in the dry port ranges from 1.5 to 3 hrs.
- The handling time in case of trucks is around 5 minutes to 10 minutes which is equivalent to 0.083 hrs to 0.167 hrs.
- The availability is the percentage of time for which the system is available when others are not using it. In case of trains the availability as per the study done ranges from 20% to 30 % of the total time. It means that for rest of the time period the tracks are being used by other trains. In this case the capacity is being measured for the resilience so maximum available capacity is being taken assuming that there is no limiting factor related to the supply of trains. This data was collected from the respective railway authorities related to the relevant dry ports.
- There is another parameter which is important here which is the congestion factor. The congestion in case of railway ranges from 10% to 30%. This happens due to the various factors such as improper planning, late running passenger trains from other zones which are given priority over the cargo trains.
- In case of India all the container carrying trains are single stack container trains. So a train can carry 90 TEU at a single time.
- The trains travel at a speed of 100 km/hr.

The connectivity factor of the dry port and the capacity has to be added in order to determine the overall dry port resilience. The capacity of the dry port has been mentioned in section 5.2 which gives the annual capacity of the dry port. This capacity has to be converted to daily capacity. The connectivity capacity in section 5.3 is measured in terms of TEU on a daily basis. But his connectivity capacity is named as connectivity factor, since it takes all the alternatives into consideration. This is necessary because the resilience should take all kinds of available flexible alternatives into account. In the equation below equal weight has been given to both the connectivity factor as well as the dry port capacity. This would cover both the aspect of supply chain resilience which are the capacity as well as flexibility of a system.

$$DPR = \frac{1}{2}(C + CF)$$

Where

DPR = Dry Port Resilience.

C = Capacity of the Dry Port.

CF = Connectivity Factor.

5.4 Quantification of Container Security

Another important factor analyzed in the thesis is the container security. The importance of container security has been discussed in chapter 3. It is not possible to directly quantify the container security based on certain formula. It is also not possible to use historical data to generate some form of container security parameter. In case of dry ports container security is an important issue. Initially a couple of interviews were taken to determine the important factors which affect container security in a dry port. The interview was conducted based on personal communication. Based on the interview taken a questionnaire was developed to find out the security levels of the dry port under study. The questionnaire was sent to several people related to the dry port industry. The selected parties can be broadly classified in the following manner

- The clients of the dry port are important for this survey. The opinion of the clients about the security levels of a dry port is important. The clients include freight forwarder, logistics agencies, supplier, exporters, and importers.
- The workers working inside the dry port have a important role to play at a operational level. These workers have to face any security or any such concerns during the day to operation of a dry port. So the opinion about the security levels if these workers can be valued.
- The management of the dry port as well as the higher level management of the dry port companies has an important role to play in the policy making for the dry port operations. So the view point of the management as well as the policy makers is important for the survey.
- The custom official involved in final approval of the container stuffing and de-stuffing of the container has an important role to play in the container security.
- The shipping lines involved in the transport of the container in the sea leg of the transport also are an important stake holder in the whole process.

As per the initial feedback received from the following points were used primarily in the questionnaire.

- The quantity and the quality of the equipment available in the dry port used for security purpose.
- The planning and standard procedure related to the security of the dry port. These questions would also deal with the policy making of the dry port related to the security aspect.
- Another importance aspect was the security personnel and their competency. This is an important factor in order to maintain the security level of the dry port.
- The trainings and drills being done to maintain the security level of the dry port is another important feature which has to be measured.

All the four factors explained are important security aspects of the dry port. Questionnaire was prepared in way so that it covers most of the aspects of the security. The questions were prepared for evaluation. The evaluation was done based on ratings which had a range from 1 to 5 with 1 being the lowest and the worst rating and 5 being the highest and the best rating. An average of all these ratings was done for each of the section. Then each of the four sections mentioned above was given equal weight age which will be clearly explained in the formula below.

$$DPS = \frac{1}{4}(E + PP + SPC + TD)$$

Where

DPS = Dry Port Security.

E = Equipment Quality and Quantity.

PP = Planning and Policy.

SPC = Security Personal Competency.

TD = Training and Drills.

The formula above would certain value for the Dry Port Security which would be used in the methodology for further analysis.

5.5 Input data and TEU throughput of the dry port

The other important parameters required for this are the input data for the Data Envelopment Analysis. These input parameters are the ‘Number of Equipments’, ‘Number of employees’ and the ‘Terminal Area’ This data has been directly derived from the dry port. As mentioned before 10 dry ports of a particular region have been taken for study. These dry ports belong to the area near Jawaharlal Nehru Port Trust (JNPT). All the input variables are the basic resources required for functioning of a dry port.

Another important parameter is the TEU throughput. The TEU throughput is the output of the dry port. It would be also used as an output parameter in the DEA model. TEU throughput gives the efficiency of the dry port. The achieved TEU throughput with the input resources as explained above gives the efficiency of a dry port. A summary of statistics for the input and output data have been given below for the 10 dry ports undertaken for study.

5.6 Summary of Statistics

Table 2: Summary of Statistics for the Input Data

	Terminal Area in Square meter	**Number of Equipments**	**Number of employees**
Mean	83,405	3.2	23.42
Standard Deviation	65,348	1.7	6.81
Maximum	320,430	9	42
Minimum	33,490	2	12
Range	286,940	7	30

The data above shows a summary of all the 10 dry ports considered for the study. This data was directly taken from the various Dry Port Authorities.

Table 3: Summary of Statistics for the Output Data

	TEU Throughput	**Dry Port Security (DPS) score**	**Dry Port Resilience (DPR) score**
Mean	61,675	2.31	10.52
Standard Deviation	39,445	1.49	6.51
Maximum	221,324	3.94	21.52
Minimum	25,223	1.13	6.91
Range	196,101	2.81	14.61

The TEU throughput data has been directly taken from the respective dry ports. The calculation of the Dry Port Security has been done as per the method described in section 5.4. Both the above data set are for the year 2010.The Dry Port Resilience has been calculated based on the method used in section 5.3.The output was found in terms of TEU capacity for all the dry ports from the DPR equation formulated in section 5.3. But the DPR has been reduced appropriately into a DPR score. This was done since DPR score not only consisted of the overall TEU capacity but it also covered aspects related to the flexibility options for the dry port.

Chapter 6 – Data Envelopment Analysis and Results

6.1 Introduction

Measuring container security and understanding its role in dry port development has become an important topic in dry port management and dry port economics. The efficiently operating dry ports are important to the global and regional economy. With the widespread use of containers, dry ports have become critical nodes of global supply chain, and increasingly allow more and more countries to share the economic boon of joining the globalization and international trade (Gujar, per.comm, 2011). Deregulation has placed significant pressure on dry ports with regard to their profitability. The dry port industry has become market oriented in the past two years due to the sector bring opened up for private competition.

The dry port productivity, accounts for the amount of output from production process, per unit input resource utilized in a given time, is the initial operational measure in dry port industry (Gujar, per.comm, 2011). The efficient operation with high productivity is significantly beneficial for both public and private dry port operators. The higher dry port productivity can provide dry port operators more charging power which can lead to prosperity and growth from strategic pricing in order to achieve certain objectivity (Haralambides, 2002). Appropriate and rigorous evaluation of the dry port productivity allows each dry port to identify where, how and how much to improve their operational performance in order to be on par with its best practice (Gujar, per.comm, 2011). The mainly applied two methods in dry port productivity studies are Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA).

6.2 Data Envelopment Analysis – Literature Review

Data Envelopment Analysis (DEA) is based upon an application of linear programming and is normally defined as a non parametric method of measuring the efficiency of a decision making unit (DMU) with multiple inputs and outputs (Tongzon, 2001). As a mathematical programming technique DEA has been used by numerous similar DMUs, such as a set of hospitals and schools, to measure their performance and technical efficiencies. In DEA, the production process for each producer, or DMU, is to take a set of inputs producing a set of outputs. DEA determines which of the producers is most efficient, and points out specific inefficiencies of other producers. DEA designs the efficiency frontier with the most efficiency DMUs, so that the addition or reduction of the number of DMUs, inputs and outputs can change the shape and location of the efficiency frontier; and these additions or reductions would also affect the efficiency measurement of a particular DMU.

Scholars apply DEA as one of the main approach to measure the efficiency of different container ports (Hayuth, 1993; Martinez etc., 1999; Tongzon, 2001; Park, 2004; Athanassiou, 2004; Tsing, 2005; Cullinane & etc., 2005; Wang, 2006; & et al.). Representatively, Cullinane & et al (2004) analysed the relationship between privatization and efficiency of the container port. Efficiencies of the selected 30 container ports were evaluated by applying DEA-CCR and DEA-BCC models on the dataset that contained information of output (TEU) and inputs (terminal length, terminal

area, quayside gantry, yard gantry, straddle carrier) of the selected ports from 1992 to 1999. (Cullinane and Wang,2006) examined the efficiency of 69 container terminals from 55 European ports with annual throughput of over 10,000 TEUs in 2002, using DEA-CCR and DEA-BCC model.

6.3 Application of DEA and Results

In this thesis the DEA methodology will be used to find out the efficiency of the dry port as an output. The input data has been shown in chapter 5. The input data fields are the 'number of employees', 'number of equipments' and the ' Terminal area' . The output field would be the 'TEU throughput', 'Dry Port Resilience' and 'Dry Port Security'. The method of the data collection and generation has been given in detail in chapter 5. As discussed in other chapters and literature container security in dry ports is gaining more importance. Moreover the Supply Chain Resilience is gaining more importance as the uncertainty and predictability are becoming more difficult due to the complexities of today's business model. So in this case an attempt has been made to find out the efficiency of the dry port in terms of TEU throughput, Dry Port Security and Dry Port Resilience. This would give a more holistic result of the efficiency of the dry port.

The DEA-CCR and DEA-BCC models have been used for the analysis. Three possible combinations have been used in both DEA-CCR and DEA-BCC method. All the three combinations have the same input but different output combination. The first combination is only the TEU throughput as the output. The second output is the combination of TEU throughput and the Dry Port Security as output. The third output is the combination of the TEU throughput, the Dry Port Security and the Dry Port Resilience. The difference between the CCR and the BCC method is in the convexity constrain. The following tables give the result of the DEA analysis done.

Table 4: DEA-CCR method

	TEU Throughput	TEU Throughput + DPS	TEU Throughput + DPS +DPR
1	0.12	0.15	0.153
2	0.349	0.365	0.425
3	0.214	0.25	0.32
4	0.819	1	1
5	0.43	0.646	0.70
6	1	1	1
7	0.42	0.61	0.621
8	0.236	0.41	0.459
9	0.79	0.813	0.912
10	0.651	0.712	0.845

Table 5: DEA-BCC method

	TEU Throughput	TEU Throughput + DPS	TEU Throughput + DPS +DPR
1	0.13	0.17	0.167
2	0.35	0.412	0.523
3	0.325	0.391	0.49
4	0.913	1	1
5	0.52	0.721	0.834
6	1	1	1
7	0.53	0.745	0.812
8	0.239	0.418	0.460
9	0.812	0.823	0.987
10	0.734	0.718	0.847

Table 6: DEA-Scale Efficiency

	TEU Throughput	TEU Throughput + DPS	TEU Throughput + DPS +DPR
1	0.923077	0.882353	0.916168
2	0.997143	0.885922	0.81262
3	0.658462	0.639386	0.653061
4	0.897043	1	1
5	0.826923	0.895978	0.839329
6	1	1	1
7	0.792453	0.818792	0.764778
8	0.987448	0.980861	0.997826
9	0.972906	0.987849	0.924012
10	0.886921	0.991643	0.997639

The results of the DEA analysis have been shown above. The output has been shown in all the three possible combination. The data set consisted for 6 public dry ports and 4 private dry ports. In terms of efficiency only based on throughput, private dry port show better results than the public dry ports. In the first case in the top 5 out of the 10 there are 3 private ports and other 2 are the public ports. When the factor of security is added to the TEU throughput all the 4 private dry ports hold the first 4 positions followed by the public dry ports. In the third step when the three output factors which are the TEU throughput, Dry Port Security and Dry Port Resilience are combined the public dry ports shows better results with top 3 being public dry ports followed by 2 private dry ports in the top 5. The analysis of these results would be done in the next chapter which is the conclusion of the thesis.

Chapter 7 - Conclusion

7.1 Conclusion

In the introduction chapter a brief explanation related to the various important aspect of this thesis has been done. The growing importance of the inland logistics in the supply chain system has increased the significance of dry ports. At the same time there has growing threat of security to the maritime infrastructure especially in the Indian sub-continent. Research question was developed taking the all the important aspect of container security and supply chain into consideration.

In chapter 2 the regulations related to the port security and the dry port security were reviewed. It was found that the ISPS code is going to be very important regulation for a port to comply with and increase its competitiveness. It was also found that the contracting government has a more important role to play in successful implementation of ISPS code in ports than the IMO due to the nature of the code. As a result the importance of implementing security policy from a political motivation point of view of a government is a very important aspect. It was also found that developing countries such as India, despite all kinds of security threat cannot put capital investment into security infrastructure like their developed counterparts. Because of the developing nature, countries like India have to divert more capital resources to economically feasible projects rather than cost centers such as security. Moreover transparency in sharing information with the neighboring countries is also a huge challenge in case of India. Implementing ISPS code would require a conscious effort from the government to improve the security standards in ports. The legal regimes related to the inland transportation of cargo have not defined the liabilities very clearly. Any unclear definition of liabilities might lead to security lapses due the non-responsibilities of the parties involved. All the parties involved have an economic motive of increasing profit so none of them would properly take up the responsibility as legal regulation do not make them fully liable and moreover security is always a cost center . So as per the analysis done it was found that Rotterdam rules would help to improve the security standard due to clearer definition of liabilities which would force the involved parties to take up adequate measures. The dry port operators are expected to take up the security related responsibility in a more liable way in the future.

As per the literature review done in chapter 2 about the legal regime, it was found that there are issues related to container security especially in the inland part of the transport. So an attempt was made to analyze the problem with a more practical approach. It was found that there lies a problem in the dry ports related to container security in India. As per personal communication and other analysis it was found that the dry ports in India are not giving due importance to the container security issue. This can be due to inadequate investment in container security infrastructure in form of equipments and personnel. This inadequate investment might be due to the lack of an enforcing regulation. So it was concluded in this chapter that there is an issue related to container security in the dry ports and inland transportation of cargo.

In Chapter 4 the resilience of a system was discussed. As per the review and understanding developed, it is very difficult for a company to build on all kind of resilience. A company or the respective organization has to build its resilience on the

most critical resource. In order to build resilience the cost and time factors play an important role. So the decision makers have to decide on an apt cost incurrence and time factor as there is a trade of between the both factors. In case of Supply Chain Resilience the capacity and the flexibility of the system are very important aspects. So in the case of dry ports also the capacity and flexibility factors were considered to be the important factors in building resilience.

In chapter 5 the data collection and data generation methodology has been explained in detail. The input parameter of the terminal area, number of equipment and number of labor were obtained directly for the respective dry port authorities taken up for the thesis. The TEU throughput was also collected for a single year from the respective dry ports. In order to quantify the dry port security score a questionnaire was developed taking all the important aspects of container security into account. The dry port resilience score was calculated based on the dry port capacity and flexibility factors. The dry port capacity was formulated for both the terminal as well as yard capacity. The flexibility was also measured for the yard in form of dry port and port connectivity and also in terms of railways and road connectivity to the dry port. The dry port connectivity capacity, connectivity flexibility and yard flexibility have been integrated into one formulation. This formulation was added to the yard capacity giving equal proportion to both the factor. Some of the data related to resilience calculation was collected directly and some were quantified based in questionnaire.

In chapter 6 the justification of using the DEA methodology was given in form of literature review. The required input and output were used in the model. Both public as well as private dry ports were taken up for study. It was found that the private dry ports are more efficient than public dry ports in most of the cases. In terms of container security the private dry ports score quite high. The public dry ports as expected showed higher resilience due to easier resource availability. The higher dry port security in the private dry ports is believed to be due to more investment in capital and labor to improve security. The public dry ports have more yard and connectivity capacity and flexibility which give them a higher dry port resilience score.

Resilience is an important factor for efficiency measurement but the point here is about how much resilience would be adequate for the dry port. The investment should be first made on improving the security level which would then lower the requirement for too much resilience. But at the same time some amount of resilience is required to counter unexpected security threats or any other form of disruption. The increasing importance of service levels and quality offered by dry ports would make factors such as dry port security and resilience more important in future. As per the obtained results the public dry ports have higher resilience but lower security facilitation. On the other hand private dry ports have higher security to offer but lesser resilience. So the supply chain lacks the required balance which has to be very strategically developed. At present it can be said the private dry ports are more efficient but they have a scope to improve in terms of resilience. For improving their resilience the private dry ports have to identify the critical factors in such a way, where investment to improve resilience adds to their competitive advantage rather than becoming a cost center. In the same way the public dry ports have to improve security levels and reduce unnecessary overcapacity. The

answer lies in improving the flexibility factors by sharing available alternate resources in a fair manner for the balanced growth of the Indian dry port sector.

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