Mathematical Modeling to Augment the Espousal of Multimodal Logistics in Maritime Transportation

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Abstract  
Starting from the 3rd millennium BC, Indian maritime trade has augmented the life of a common man and businesses alike. This study, finds that India can leverage on the 7,500 long coast line and derive holistic development in terms of interconnected ports with hinterland connectivity and realize lower expenditure coupled with reduced carbon emission. This research anlyzed a decade of cargo data from origination to destination and found that, around 82.95 per cent (953 MMTPA in 2017–18) of road based consignments in India comprised of Fertilizers, Hydrocarbons, Coal, Lubricants and Oil. Essentially, a quantum of this i.e., 78.39 per cent of MMTPA cargo consignments (State Owned Hydrocarbons) traverse on Indian roads. The study drew parameters of this transportation paradigm and modeled the same using Artificial Intelligence to depict a monumental opportunity to rationalize costs, improve efficiency and reduce carbon emission to strengthen the argument for the employment of Multimodal Logistics in the Maritime Sector. Subsequent to model derivation the same set of parameters are plotted as an efficient transit map of Interstate transit lines connecting 16 major hubs which now handle bulk cargo shipped by all modes of transport. For the pollution segment a collaborative game theoretic approach i.e., Shapley value is proposed for improved decision making. This study presents data driven and compelling research evidence to portray the benefits of collaboration between firms in terms of time and cost. The study also proposes the need and method to improve hinterland connectivity using a scalable greedy algorithm which is tested with real time data of Coal and Bulk Cargo. As a scientific value addition, this study presents a mathematical model that can be implemented across geographies seamlessly using Information Communication Technology.

Keywords: Maritime Transport, Multimodal Logistics, Game Theory, Greedy Algorithm, Freight Management, Intermodal Transportation.

1. Introduction  
Leading National newspaper “Business Standard” had on the morning of 16-May-17, shared with the Indian transportation and logistics fraternity that with an expenditure budget of Rs. 33,000 crores, the process to build 15 Multimodal parks across strategic coordinates has been initiated, reflecting a monumental infrastructural building regime for the next decade or more. A glimpse into the details of this announcement led to the discovery of an all-encompassing ginormous transportation paradigm and a grand vision to fuel growth by “Port Led Development” as championed by the Honorable Indian Prime Minister “Shri Narendra Modi”.

The paradigm of Maritime Transport is pivotal and is fundamental to development, especially in India where it is estimated that this sector provides employment for more than 45 million people (Sibel A, 2012). The 12th Planning Commission of India has documented that appropriate focus towards ‘integrating logistic responses’ needs to be created in place of broken distribution and transportation services. The paradigm of ‘Multimodal’ which interconnects along with agents and modal lines (air, rail, sea & road) and the most recent pipeline, can improve the efficiency and effectiveness of goods transported from one destination to another. This aspect of profitable improvement of efficient hinterland connectivity is a key focus of this manuscript. As an extension to this, future research can be in the segment of port infrastructure development and efficient port management including customs and inter modal transportation.
The associated growth of Indian economy by 7.3 per cent for 2017-18 (CIA Fact Book) has practically increased the demand for all modes of transportation and services; additionally, the increased demand signifies the importance of establishment of an efficient multimodal logistics infrastructure in India.

With the enactment of systematic programs for the revamp of the Logistics sector, now will be a right time where the Nation can deliberate on this infrastructural solution. Only one-third of the transportation system had been constructed in the past, thus giving a scope of two-third of infrastructure to be constructed in future. From past experiences and adopting international practices, India can draft a novel Maritime strategy that can assist to minimize investment, maximize cost efficiency and reduce different types of losses by the creation of better transportation infrastructure.

A primary goal of this research is to contribute to the National Transportation policy framework by way of designing a scalable and sustainable model in order to transform the Nation’s logistics infrastructure. It tries to portray the scenario of Indian logistics in year 2020. It identifies the facts about the Indian logistics infrastructure and emphasizes the need for growth and development in order to satisfy the demand of the large Indian population.

Research Objectives

This manuscript seeks to objectively analyze the fundamental mechanism of the Indian Logistics Sector encompassing all modes of transport. This study also endeavors to act as an enabler for seamless implementation of

(a) Policy guidance and Plan perspective,
(b) Coordinate planning protocols for a multitude of products.
(c) Structure and create building blocks for implementation by global stakeholders.

To addresses the need to ameliorate exports and optimize pricing by enabling micro, small, medium enterprises inside the port complex(s) thus rationalize time and expenditure with 100 per cent compliance to norms in terms of shipping bulk cargo and containers across international waters, this study as a first objective seeks to explore if there can be a collaboration between the participants of road, rail and sea to possibly shift from the present national dependence on road transportation to the new resurgent Maritime sector.

Yield of 1st objective

- Can help realize the creation of a cohesive institutional arrangement by way of a modal mix to facilitate domestic and international cargo especially Thermal Coal and POL in the Freight Network of Northern India from Haldia to Mundra and JNPT, Mumbai.
- Significantly reduces operational costs by strategic enablement of Industrial units and technology enabled mega warehouses near the twelve major Indian ports and other important non-major ports like Mundra and Krishnapatnam.

The second objective seeks to analyze strategically the scale of economies and provide resources for capacity augmentation in a scalable and sustainable procedure for upgradation of existing ports (i.e., 12 Major Ports and 200 Non-Major Ports)

Yield of 2nd objective

- To assist port led development by expansion of capacity, incorporating green field mechanism, improve and interlink hinterland to coastal corridors, possible multimodal infrastructure
establishment at strategic locations, encourage inland water borne movement of cargo alongside costal shipping and revamp Coastal Economic Zones to support EXIM as well as domestic shipments.

Illustration 1: Prominent Ports in India (7,500 Kilometers of Coast Line)

**Third Objective**, orients towards an economic perspective; and seeks to portray the financial advantage gained by shifting from road transport (per truck load capacity price) to the maritime sector for movement of freight.

**Yield of 3rd Objective**

✓ Approximately 18.52 per cent of Indian population reside in the 72 coastal districts which are geographically in Nine states and Three Union Territories (*as depicted in Illustration 1*). The entire Indian Sea coast is approx. 7,500 kilometers long. This coastal population of the nine states contribute to

I. 59.51 per cent of the Indian Gross Domestic Product (GDP),
II. Trade Index is dominated with a 94.71 per cent share
III. 10.18 per cent of trade by value through Seaways.

Ironically, despite of these indicators and promising growth avenues, the infrastructure is weak at ports and beyond in terms of rail and road. There are inherent inefficiencies in terms of high input cost which lead to loss of competitiveness, which this study seeks to address and provide viable solutions.

2. **Significance Of The Study**

In the Transportation and Logistics sector, a basic and important criterion is to find solutions to the question “what drives future value creation?”. Given that today’s scenario of the transportation and logistics sector are getting shaped by the dynamic and ever changing global mega trends for a better future (Adil Baykasoğlu, November 2016).

India relies more on road transportation and takes top place as compared to many other high freight nations. India relies three times more on road transport despite the fact that India’s freight traffic is comprised largely of bulky materials that move over longer distances, which could be served
more economically by Rails and Waterways when compared to neighboring China (Khalid Aljohani, December 2016).

<table>
<thead>
<tr>
<th>#</th>
<th>In Billions Ton -Per Km(s)</th>
<th>Emission per ton-km g CO2 equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>&lt; 1</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Water</td>
<td>30 (Squared)</td>
<td>&lt; 1</td>
</tr>
<tr>
<td>Freight Rail</td>
<td>5,183  5,930  1,325</td>
<td>&gt; 1000</td>
</tr>
<tr>
<td>By Road</td>
<td>22.81  36.32  51.55</td>
<td>63.63</td>
</tr>
</tbody>
</table>

Table 1: India’s freight transport is more Road Oriented

Further, from Table 1, it can be ascertained that India is highly dependent on road transportation for long distances which affect(s) adversely and abuses our environment with harmful emissions viz., SO2, CO2, CO, NO2 etc. Recent studies endorse that emission of CO2 is 84g per ton-km in roadways, 28 gm per ton-km in railways and 15 gm per ton-km in waterways. Despite this fact India uses road network predominantly for bulk transport. Only if India can shift moderately from roadways to railways it could be able to save about 5.71 percent of its total energy consumption (Maisam Abbasi, July 2016).

This study supports the notion that sustainable supply chain modal(s) can critically enable India’s economy to grow and develop. The government needs to increase the budget share for logistics infrastructure for rapid transit of bulk goods. It is estimated that India’s freight movement is going to increase by 2.5 to 3 folds in coming years to which existing logistics infrastructure won’t be able to (Yücel Candemir, 2017) handle efficiently. This would definitely slow down the pace of growth and development in India.

The recent interdisciplinary and proven methodology associated to Logistics, Supply Chain Management, Warehousing, Freight Management and Containers handling is “Multimodal Logistics”. From this perspective enablement of Multimodal Logistics was mooted in the 12th Five Year Plan; (David Gillen, November 2016) National (Government) Transport Development Policy Committee (NTDPC - 2016-17); Other reports i.e., Report on Indian Transport (Moving India to 2032), Internationally acclaimed “Annual (2016-17) Logistics Report of KPMG”, the policy manual “Industry Outlook for 2017-18 by Price Waterhouse Coopers” (PwC) and “McKinsey’s”, Projects and Infrastructure Team’s report for the year 2016-17 seek and advocate the deployment of a “Multimodal Structure” as a possible solution to the Indian transportation sector (Michael A. McNicholas, 2016).

<table>
<thead>
<tr>
<th>Source:</th>
<th>World Economic Forum; China Statistic Yearbook; Planning Commission India;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NHAI; Indian Railways; DG Shipping; Bureau of Transportation Statistics US;</td>
</tr>
<tr>
<td></td>
<td>McKinsey</td>
</tr>
</tbody>
</table>

a) This set of literature specifically attempted to isolate primary challenges as
b) Insignificant Kutcha roads and limited connectivity among network,
c) Halting of vehicles indiscriminately at check posts of state border (Carlo Vaghi, 2016). (serious reason for delay—statistically 38.19 per cent of transit time delay is associated to these unscheduled halting),
d) Porous system and weak regulations for starting a trucking business,
e) Freight prices being subjected to surge pricing,
f) Absence of tracking systems for rail freight, for distributed cargo management
g) Low infrastructure for disconnected rail & road connectedness,
h) Inefficient berthing of ship and unusual delay in time for loading and unloading that lead to abnormally high turnaround time of vessels (Teodor Gabriel Crainic, December 2009).

**MMTA % 2013-14**

<table>
<thead>
<tr>
<th>#</th>
<th>Cargo</th>
<th>Net Share</th>
<th>% Share</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>POL</td>
<td>349</td>
<td>36%</td>
</tr>
<tr>
<td>2</td>
<td>Coal</td>
<td>229</td>
<td>24%</td>
</tr>
<tr>
<td>3</td>
<td>Containers</td>
<td>113</td>
<td>12%</td>
</tr>
<tr>
<td>4</td>
<td>Iron Ore</td>
<td>42</td>
<td>4%</td>
</tr>
<tr>
<td>5</td>
<td>Fertilizers</td>
<td>28</td>
<td>3%</td>
</tr>
<tr>
<td>6</td>
<td>Other Cargo</td>
<td>192</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>953</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Source:* Indian Transport Ministry Report for 2013-14

Table 2: Net Share of Volume Handled – Metric Tons

The above Table 2 portray(s) that a shift to ocean based freight would greatly benefit and hence can target for the creation of multimodal systemic transport — viz., building greenfield ports (Harilao N, 2016) and increased handling capability of major ports apart from easing traffic on very high and voluminous routes. In this, this study seeks that for major transportation quantum Multimodal Logistics be deployed i.e., approx. 78.39 per cent of MMTPA consignments (Within India) comprise of Fertilizers, Processed Oil & Lubricants, Hydrocarbons, Thermal Coal, Forms of Iron ore and bulk Containers.

At a national scale, this study calls for and portrays a systematic model (*inclusive of gained profits and time*) for the integration of freight modal mix, specific trade and economic zones, interconnectivity towards and inside the port, and improvement or building suitable infrastructure for scaling of operations (Agata Mesjasz-Lech, 2016). This study asserts that the possible solution can be inclusive of:

(a) Rationalization of Operational costs,
(b) Enablement of seamless Cold Chain(s),
(c) Systematic Containerization,
(d) Establishment of ancillaries like ICD’s and CFS’s and
(e) Operationalization of dry ports and possibly forward link them to integrators like logistics parks.

There is still a very high scope and infrastructure requirement in India (Ayse Sena Eruguz, September 2017). Therefore, the required infrastructure could be re-designed to address the rapidly burgeoning demand. For this India needs to adopt a positive outlook, and cross-integrate each mode of transportation (air, water and land). It should be matched and optimized to the needs and available resources from origination to destination.

In particular, India will have to move from roadways to seaways, and should also realize the potential scope of its waterways (Lhoussaine Ameoknassi, December 2016). The coalescent approach adopted by this study can assist India to increase its Maritime transport share to 42.91 per cent (Hyun Jung Nam, July 2017).
If India delays to register this paradigm shift, the pollution caused from present {not-up-to-the-mark logistics framework} would be very high viz., from USD $ 44.16 billion (equal to 3.92 percent of Indian Gross Domestic Product) to USD $ 13942 Million or even higher (can reach a total of 4.91 percent of India’s GDP) by 2020. Therefore, this study asserts the serious requirement to tackle this situation by integrating and coordinating of different modes. This can help India to reduce this waste generation by half and can also lead to reduction in fuel consumption by 15-20 percent (Harilaos N. Psaraftis, 2016) and (Thomas Poulsen, Rasmus Lema, June 2017).

3. Theoretical Overview

This study seeks to derive the benefits of collaboration by way of Game Theory applications of tariff and profit (as single parameters). Transport tariff, cost structure and determination, marginal costs and Shapley value along with semi-proportional transport costs. Profit maximization, and simulation results were assessed to identify relevant theoretical foundations.

For reflecting on the possible advantage of optimizing modes of transport, algorithms are employed; a greedy algorithm is employed as the decision making is dynamic and transient when the demand for merging cross functional entities and multimodal logistics are modelling using dynamic programing for scheduling. Different mode of transportation in India is a heritage handed over by British empire during its colonial rule over India. The present framework is what the British have ideated about two centuries ago; even in 2018, most of Indian cargo moves on the same network.

In lieu of this Indian transportation network is not properly designed and cannot handle increasing freight. Growth and development of Indian economy (Viacheslav Fialkin, 2017) will lead to increase more pressure on the existing logistics infrastructure. Four Dimensional components as per Table 3 outlined below characterize the network of Indian logistics(Sibel A. December 2012), (Dezhi Zhang, March 2016).

3.1 Balanced Modal Network

Indian freight transport system and existing networks need to take a paradigm shift on four interlinked components(Elisa Negri, June 2017). 
(i) Systematic and Structured Financial Investments,
(ii) optimal mode adoption,
(iii) improve usage of existing assets and
(iv) constructing technological enablers.

<table>
<thead>
<tr>
<th>#</th>
<th>Dimensions</th>
<th>Application Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Integrated Framework</td>
<td>Components in Networked Roads</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maritime Freight Network</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Golden Quadrilateral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Interlinking Road and Rail</td>
</tr>
<tr>
<td>2</td>
<td>Enablers</td>
<td>enabler to support Structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Logistics Parks</td>
</tr>
<tr>
<td>3</td>
<td>Payback</td>
<td>Proposed Change</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automation of e-Pass</td>
</tr>
<tr>
<td>4</td>
<td>Budgets</td>
<td>New Focus</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Seaways</td>
</tr>
</tbody>
</table>

Table 3: Dimensions and Applications Profile

The study attempts to integrate the following six key success factors (as per illustration 2) to propose a multimodal system as a plausible solution to some of the challenges India address as on date.(Boban Melović, 2015)
Illustration 2: Key success factors of Multimodal Logistics

3.2 Constructing and Optimizing Multimodality

Multi modal transportation or multimodal logistics park is a facility that provides a singular access to all transportation. It is a complex facilitation comprising of earmarked spaces for all operations required from a transportation perspective. Container Terminals, Stowage Facilities, Warehouses, (M.P. Fanti, September 2015). Access to Rail Network (Freight), Financial Centers, 3rd Party Logistic providers and inter-modal transport(Rafik Makhloufi, 2015). The key components of Logistics Park are: (a) Transportation (b) Storage Facilities and (c) 360 degree service operations as a single window clearance. Detailed interlinkage (at a global level) is presented as per Illustration 3 presented below

Illustration 3: Global Practices that can be adopted into Operational Variables

3.3 Multimodal Logistics Parks (MMLP):

Multi Modal logistics park can augment Indian transportation infrastructure to rationalize expenditure on transportation(Malcolm Townsend, October 2017). The most important characteristic; it helps to reduce the overall transit time(Grazia Speranza M, February 2018). In-turn this helps to decrease inventory carrying cost for both, the ultimate customer as well as the logistics operator. It also helps to utilize all the resources optimally with decreased transit time (Roar Adland, November 2017). MMLP contributes in equitable growth of all modes of transportation, proper utilization of
pooled assets like railways. Proper implementation of green technology can reduce greenhouse gases emission and help to decrease dependency on fossil fuels such as crude oil, coal etc. The advantages are, (a) Automating container transportation system, improved hinterland and inter modal connectivity (b)Implementing intelligent transport system, use of Global positioning software to track movement of freight and manage interconnected transport. Implementation of environmentally designed hybrid trains.

Depicted below is a master model of the all-encompassing Multimodal Logistics Park as Illustration - 4

Illustration 4: The all-encompassing Multimodal Logistics

4. Literature Review

The study explores the paradigm of connecting hinterland through port based multimodal logistics deployment via published research works as part of the literature and identify associative affairs detailing integration with a view so as to recognize the procedure prior to integration (Ole Ottemöller, September 2017). For the achievement of the objective to ensure hinterland connectivity, it is important to analyze the aspect of “what gets transported by roads”, which is contributing to the high transportation cost as compared to other modes of transport(Allan Woodburn, September 2017).It is quite prominent that, in India, (Stefano Manzo, 2016) “FIVE” commodities add-up to 79.62 per cent of entire import-export shipments in India with dynamic origination and destination coordinates across the nation. These are (a) Coking Coal, (b) Petrol & Diesel (c) Processed Oil & Lubricants (d) Ore of Iron (e) Agricultural Grade Fertilizers and bulk movement related “Container(s)”(Chaug-Ing Hsu, September 2009). The literature which deals with the factors that determine partnerships between institutions and corporates who operate in the transportation space for these products can give insights in terms of forming the (Paolo Ferrari, July 2016), fundamental structure of multimodal framework establishment that can yield in tangible results which can (Specific to these commodities)

This study seeks to analyze four dimensions which are being modelled for possible enablement of Multimodal Logistics. Illustration – 5 below Incorporate a methodical change in the way Indian Logistics operates as compared to Global Practices. Illustration – 6 incorporates the Variables of Transportation Paradigm being modelled which can build enablers for realizing port led transportation and development. Illustration - 7 below depicts multiple key Success Factors for MMLF that build’s Institutions which operate within the Multimodal Logistics Framework Illustration - 8 presents model characteristics which enable technology creation to assist and sustain new greenfield projects. In stage-1; the study seeks to understand the multifaceted and interconnected structures including methodology(Xinqing Xiao, May 2017), (Yunlong Yu, September 2017).
4.1 Incorporate a methodical change in the way Indian Logistics operates

<table>
<thead>
<tr>
<th>Global Practices</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ensuring a Greener Carbon Footprint along the entire Chain</td>
<td>Harilaos N. Psaraftis (2016), Lhoussaine Ameknassi, Daoud Al-Kadi, Nidhal Rezg (2016)</td>
</tr>
</tbody>
</table>

Illustration 5: Literature Review of Global Practices

4.2 Profit Considerations and optimal inventory

As a replacement for altering the decision responsibility in highersociation arrangements, harmonization among constituent firms can share profits. While in unconditional terms, government spends very less for the growth and development of logistics industry while the cost of operations and maintenance is quite high of this industry in India because of inefficiencies. India spends 12.21 per cent of Gross Domestic Product on transportation and is higher than the expenses incurred by that of North America (9.46 per cent) and Germany (7.91 per cent) (Mike Brison, April 2017), (Oludaisi Adekomaya, June 2016).

4.2.1 Build enablers for realizing port led transportation and development

<table>
<thead>
<tr>
<th>Operational Variables</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue Considerations of the chosen mode of Transport</td>
<td>Stefano Manzo, Kim Bang Salling (2016), Paolo Ferrari (2016)</td>
</tr>
<tr>
<td>Chosen interlinkage of transport modes</td>
<td>Elsa Negri, Sara Perotti, Luca Fumagalli, Gino Marchet, Marco Garetti (2017)</td>
</tr>
<tr>
<td>Cold - Information Systems</td>
<td>Oludaisi Adekomaya, Tamba Jaminu, Rotimi Sadiku, Zhongjie Huan (2016), Hsin-I Hsiao, Kuan-Lin Huang (2016)</td>
</tr>
<tr>
<td>Green Cold Chains (Technically &amp; Sustainably)</td>
<td>Lhoussaine Ameknassi, Daoud Al-Kadi, Nidhal Rezg (2016), Dezhi Zhang, Qingwen Zhan, Yuche Chen, Shuangyan Li (2016)</td>
</tr>
</tbody>
</table>

Illustration 6: Literature Review for Operational Variables in the Transportation space

North American Infrastructure Organizations consider and believe that Indian Logistics Infrastructure is very poor and inefficient. For example, the expenses for Freight by rail and the
maritime transport are approximately 68.29 per cent more than that of their expenses for all modes of employed transport in the USA.

Similarly, the road cost is also high by 30.05 percent in India compared to US. This leads to increase the prices as well as lower the rate of competency. It also hampers the economic growth of the country. (Megan Thomas, November 2016), (Nader Azizi, January 2016).

There search suggests, poor logistics infrastructure cost an extra of 45 billion USD to one’s economy i.e. 4.3 percent of GDP every year. One unknown fact is that two-third of these costs are hidden from outside world (Sakib M. Khan, 2017), (Hsin-Hung Pan, March 2014). Literature on Coordination Mechanisms in Supply Chains, Formal Model Formulation and Analysis, Numerical Examples with Aligning Incentives,

4.3 Cost Attribution and Simulation of Expenditure Vs Tariffs.
In the expenditure analysis component, the key prominent factors are allocation details, marginal and Shapley allocation, possible Simulation details.

4.3.1 Build Institutions to encompass Multimodal Logistics Framework

<table>
<thead>
<tr>
<th>Key Success Factors</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consignments, Pallet Pricing</td>
<td>Paolo Ferrari (2016), Stefano Manzo, Kim Bang Salling (2016)</td>
</tr>
<tr>
<td>Achieved or Breached stipulated Turn-Around-Time (TAT)</td>
<td>Venkatesh Mani, Angappa Gunasekaran, Thanos Papadopoulos, Benjamin Hazen, Rameshwar Dubey (2016)</td>
</tr>
<tr>
<td>Electronic Data Interchange - Shipment Tracking</td>
<td>Hsin-Hung Pan, Shu-Ching Wang, Kuo-Qin Yan (2014)</td>
</tr>
</tbody>
</table>

Illustration 7: Literature Review of Key Success Factors for MMLF

4.3.2 Possible Technology Creation to assist and sustain new greenfield projects
If above mentioned shifts are Implemented, India would be able to bring down its logistics cost by almost one-third of its logistics waste USD 100 billion by 2020. Further it could be lowered to USD 7127 Million (THREE percent of Indian Gross Domestic Product) (Jens Ehm, 2016), (Venkatesh Mani, August 2016). If government could increase the investment on this industry to USD 700 billion. It would result to lower commercial deployment of energy in excess of 1.25 per cent.

This calls for an integrated plan and policy which needs to target on improved energy efficiency, reducing economic waste and to have greater share of rail. Such plan will require to enable
a multitude of programs such as coastal freight corridor, road maintenance, technology adoption, last mile roads, last mile rail, dedicated rail freight corridor, skill development and equipment and service standards (Roy Zúñiga, October 2016), (Chandra Prakash, July 2016).

<table>
<thead>
<tr>
<th>Multimodal - Characteristics Overview</th>
<th>Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hub and Spoke Model</td>
<td>Nader Azizi, Satyaveer Chauhan, Said Salhi, Navneet Vidyarthi (2016)</td>
</tr>
<tr>
<td>Collaborated Partners</td>
<td>Taeehee Lee, Hyunjeong Nam (2016), Cristina Sancha, Cristina Gimenez, Vicenta Sierra (2016)</td>
</tr>
<tr>
<td>Technology Adoption</td>
<td>Teodor Gabriel Crainic, Michel Gendreau, Jean-Yves Potvin (2009)</td>
</tr>
<tr>
<td>Policy Exposures</td>
<td>Paolo Ferrari (2016), Stefano Manzo, Kim Bang Salling (2016)</td>
</tr>
<tr>
<td>Demand and Input Volatility</td>
<td>Ole Ottemöller, Hanno Friedrich (2017), Roar Adland, Fred Espen Benth, Steen Koekebakker (2017)</td>
</tr>
</tbody>
</table>

Illustration 8: Literature Review of Modal Characteristics

To enable a new transportation framework pan India needs the strategic partnership of multiple stakeholders within central and state government.

5. Model Discussion - Methodology

For enabling Multi-modal logistics, the below participants and their characteristics are pivotal.

1. Business Processes in the Freight and Containers Segment
2. The Routing and geo-mapping of the National expressways integrated to Ports
3. Parameters associated to the Interconnectedness of roads with adoption of Technology
4. Introduction of the Shapley Value and its constructs

5.1 Analyzing Collaboration in Supply Chains – Unique Proposition for realization of financial parameters Cost and Profit.

From Game Theory, the Shapley value as a proven methodology is adopted for this study and illustrates the incremental gains that are related to each participant in the market place. It determines the gains that can be derived from each level of collaboration extended by both players on an individual basis. The summation of the gains can be evaluated prior to executing a market strategy. The weighted costs and gains are determined for each sequence of actions that the players can perform. (Martin Shubik, 1978)

For the interaction of variables associated to the partnership formation for facilitation of inter-modal and multimodal logistics for the Indian context this mathematical model can be applied by Shapley allocation (Cristina Sancha, January 2016), (Taehee Lee, December 2016).

Shapley method is the most optimal technique in the Logistics paradigm derived from economics and is a chosen because of the multitude of option for variable definitions and building constructs. This method renders a path to parametrize the created value by collaboration to its respective input participants in the Indian Transportation Sector. Historically, the Shapley values for
non-dependent input (Martin Shubik, 1978) variables are tabulated for understanding variance as a key parameter. The application of Shapley values for this structure of inputs modelled as dependent variables. This study addresses only the basic constructs and the associated appropriateness of the established Shapley Method to primary dependent clusters of variable(s), and not to iterate or computational methodology (David A. Wuttke, August 2016), (Perez-Franco R, December 2016).

Shapley value is a mono variate outcome in cooperative games, as postulated by Shapley S Lloyd way back in 1953. It helps analyze incremental contribution of each participant to the partnership and all permutations of the games as desired or modelled. Carbon output as per Shapley value is derived using

\[ y_j = \sum_{i \in R_j} P(M)(d(M \cup \{j\}) - d(M)) \quad \text{…..Principal Function of Shapley} \]

where ‘j’ is an arandom participant either as an originator or as a factor load, \( y_j \) is the associated CO\(_2\) of participant ‘j’, \( P(M) \) is the probability of the participated outcome \( M \), \( d(M) \) is attributed to the carbon output of the partnership as a yield function of participation outcome ‘\( M^* \)’ and \( d(M \cup \{j\}) - d(M) \) is attributed to the incremental emission of CO\(_2\) induced by adding participant ‘\( j \)’ into the partnership ‘\( M^* \)’.

Based on the above primary functionality, below derivation describes how costs can be formally realized and described by marginal procedure of partnerships. The impact of the last arrived order being of size \( n \) is

\[ t_{[q]}(Q,n) \quad \text{..[1]} \]

The average of \( t_{[q]}(Q,n) \) is taken for the cases where \( n_{[q]} = n \) to arrive at the rate

\[ T(n) \text{ is associated to a consignment of quantum } n, \]

\[ T(n) = E(t_{[q]}(Q,n) / n_{[q]} = n) \quad \text{..[2]} \]

For an order pool

\[ Q = (n_1, ..., n_{[q]}), \quad \text{..[3]} \]

The following recursions are taken into consideration, for tabulating \( (\alpha_i) \), this is termed as allocations, and iterative variables \( (p_i) \), termed as reminders,

\[ \alpha_i = \min\{\alpha_{i-1}, \#(n_i)\} \quad \text{..[4]} \]

and \( \rho_i = \rho_{i-1} - \alpha_i \quad \text{..[5]} \)

With \( p_0 \) some given positive number and weights by

\[ \omega_i = n_i / (n_1 + ... + n_{[q]}) \quad \text{..[6]} \]

Note that \( \alpha_{[q]} = 1 \). The allocation \( \alpha_i \) is such that if \( n_i = n_{i+1} \) then

\[ \alpha_i = \alpha_{i+1} \quad \text{..[7]} \]

Future tabulations can associate \( \alpha_i \) to yield \( n_i \) as an effective collaboration and is sorted according to decreasing size. Now the desired quantum

\[ Q = (n_1, ..., n_{[q]}) \quad \text{..[8]} \]

is termed
The set of instructions can be iterated only if any $n \in Q$. The yield set can comprise of $\#(n) = 1$ for all $n$ that comprises of all instructions associated to collaboration for cost and time advantage among competing associates.

5.2 Algorithmic Approach for Multimodal Logistics

A greedy algorithm adopts a solution path and arrives at a local optimality at each stage and can scale exponentially to arrive at a global optimum across various activities interlinking of activities at the same time. In the current study, a greedy heuristic is determined to yield desired results in a quick time and is scalable across the parties willing to collaborate for deriving mutual benefits.

Each iteration or collaboration can be subjected to the Huffman Method of deduction and arrival at optimality. Huffman Code depends on the greedy-choice characteristics and the aspect of optimal substructure (Fu-Sheng Chang, May 2014). To prove relatedness of this algorithm to Multimodal Logistics, instead of demonstrations, the pseudocode is derived initially.

This will assist in clarification that the choice will follow the optimality of a Greedy algorithm property. Allocating that $P$ would comprise of a set of $k$ elements and each element is $p \in P$ with bounded frequency of $f(p)$.

The heuristic constructs the loop $A$ to an optimality from the end point. The loop begins with the set $|P|$ and ends with a sequence of $|P| - 1$ creating a loop-tree illustration.

A lesser priority queue $L$, iterated as a function, is applied to merge together two of the lesser frequented objects. The yield is a new characteristic and the associated frequency would be the summation of the merged entities (Fu-Sheng Chang, May 2014).

Let $\mu = \{b_1, b_2, b_3, \ldots, b_k\}$ of $k$ proposed activities which seek for a common mode of transport like a Cape Size Vessel, that can process only one consignment at a time. Each decision activity function of $q_i$ has an initial instance time $s_i$ and a closing time $r_i$, where $0 \leq r_i < s_i < \infty$.

The below is a constituent option of one activity and one selection between the multimodality and logistic operators. The linking and de-linking of the nodes would assist us in terms of a dynamic understanding of where to interlink so that optimality may be achieved as a function prior to executing and interlinking operations.

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<tr>
<th>$i$</th>
<th>1</th>
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<tbody>
<tr>
<td>$r_i$</td>
<td>2</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>4</td>
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<td>7</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>13</td>
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<tr>
<td>$s_i$</td>
<td>5</td>
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</table>

Illustration 9: Illustration of advantages derived by enabling Multimodal Logistics
Greedy interlinking of sub-nodes of the transport mode and the rational chosen choice problem

$$\mu_{a,b} = \{P_k \in \mu : f_a \leq r_i < f_b < s_m\} \quad \ldots[10]$$

$\mu_{a,b}$ would be the subset of all initiated function. First in first out procedure is adopted and functionally,
Subsets comprising of maximum functional elements that are compatible mutually as an optimal choice

\[ b_{j,i} = b_{j,k} \cup \{r_i\} \cup b_{k,i} \] 

\[ \text{...[12]} \]

5.3 A Greedy Recursive Solution

The constant \( C \) value is the optimal choice comprising of both cost and time. This optimality is the quantum that we seek for at real time. There are \( p - i - 1 \) profit values for \( C \), to derive in \( C = i + 1, \ldots, p - 1 \). The best possible choice to form a multimodal solution is the maximum subset \( \mu_{a,b} \). The optimal modal is the choice of \( C \). The complete recursive recurrence yield would be

\[
 r[a,b] = \begin{cases} 
 0 & \text{if } \mu_{a,b} = \emptyset \\
 \max_{a < k < b} \left\{ r[a,k] + r[k,b] + 1 \right\} & \text{if } \mu_{a,b} \neq \emptyset 
\end{cases}
\]

\[ \text{...[13]} \]

5.4 Transformation to a greedy response from a dynamic – program

5.4.1 Lemma 1.1

Initiated activity parameter \( \mu_{a,b} \) is chosen; let \( r_i \) be the interlink with the most optimal choice and time greedy

\[
 f_i = \min \left\{ f_c : p_k \in \mu_{a,b} \right\}
\]

\[ \text{...[14]} \]

Then...

1. Modal Function \( r_i \) is applied as mutually interlinked activity for cost and time optimization for activities defined as per \( \mu_{a,b} \).

2. The complete Supply Chain modal-optimization \( \mu_{a,b} \) is defined as NULL, as to opting for \( r_i \) would ensure that the previous set of nodes used for the multimodal of \( \mu_{a,b} \) is not an empty optimality.

The interlinked activity-solution \( r_i \) needs to be chosen with the least time variation that is (Paweł B, January 2018-Accepted Manuscript) applicable from an inter-modal group of logistic functions.

The chosen modality is termed as a “greedy” choice as it renders the saved time quotient for possible programing of other variables that determine the modal mix in the unscheduled remainder of time quotient (Weishi Shao, December 2017).

5.5 The Recursive Greedy Algorithm

On the Maritime transport front, this study asserts that, an algorithm functioning in a pure greedy top-down approach is termed as a “RECURSIVE LOGISTIC FUNCTION” decision. The initial sequence and completion duration can be collated as arrays of \( r \) and \( s \), and the functional indices of \( l \) and \( m \) that can design a solution for the sub-modal, \( S_{l,m+1} \). This function will qualify a maximum quantum of interconnected nodes that are internally connected. For a single activity selector that is integrated with a forward function, increases the completion time as per (Ellen Kenia Fraga Coelho, November 2017)

\[
a_0 \leq a_1 \leq a_2 \leq a_3 \leq \ldots \leq a_n \leq a_{n+1}.
\]

\[ \text{...[15]} \]
This study seeks to segregate these modal participants into $R(m, \log m)$ which randomly connects loops which give maximum reduction in terms of time and cost parameters.

**“RECURSIVE LOGISTIC FUNCTION”** $(r, f, i, s)$

1. $a \leftarrow k + 1$
2. while $a \leq b$ and $r_a < f_i$ do find the first activity in $\mu_{a, b+1}$
3. $a \leftarrow a + 1$
4. if $a \leq b$
5. then return $\{r_i\} \cup \text{RECURSIVE LOGISTIC FUNCTION”} (r, f, a, b)$
6. else return $\emptyset \leftarrow \text{Object location}$ root of the summation.

### 5.6 An Iterative Greedy Algorithm

Mathematically, it is simple to transform a recursive method to an iterative procedure. **RECURSIVE LOGISTIC FUNCTION”** $(r, f, a, b)$ ends with a recursive condition only to be succeeded by a Set Union operator. (Bilel Marzouki, 2017).

The functional model is depicted in **Illustration 10 as** follows

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<tr>
<th>$k$</th>
<th>$t_a$</th>
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- **Recursive Activity Selector** $(a, 4/2, 24/2)$

- **Recursive Activity Selector** $(a, 4/4, 24/2)$

- **Recursive Activity Selector** $(a, 16/4, 24/2)$

- **Recursive Activity Selector** $(a, 16/2, 24/2)$

- **Recursive Activity Selector** $(a, 24/2, 24/2)$

- **Object location** root of the summation.

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</table>
GREEDY LOGISTIC FUNCTION \((a, b)\)

1. \(l \leftarrow \text{length}[a]\)
2. \(R \leftarrow \{s_i\}\)
3. \(i \leftarrow 1\)
4. \(\text{for } r \leftarrow 2 \text{ to } l\)
5. \(\text{do if } a_r \geq f_i\)
6. \(\text{then } R \leftarrow R \cup \{r_i\}\)
7. \(i \leftarrow n\)
8. \(\text{return } R\)

The procedure works as follows. The logistic component \(a\) associates with newer counterparts of transport modes \(R\) yields activity \(a_r\) as a recursive component. As the functions are (Jonas Volland, June 2017) incrementally profit and time optimization mandates the end delivery \(R\). That is,

\[ f_i = \max \{f_k : n_k \in R\} \quad \ldots[16]\]

Similar to the recursive iteration, (Meiyan Lin, April 2017) GREEDY-LOGISTICAL-OPERATORS schedules a functional activity set of lactivities in \(\lambda(l)\) in shortest duration assuming that the collaboration is pre-fixed and time and cost parameters are arrived at.

6. Data Analysis, Interpretation and Suggestions

India imports crude predominantly at only 4 of the major ports across its large 7,500 kms of its coastal corridor. This study has chosen the segment of Crude oil receipt versus its transport on road which impacts both the cost and time parameters coupled with the aspect of pollution.

The above derived Algorithm can be applied to rationalize both variables of cost and travel duration.

A comparison of the transported consignments for thermal coal, oil and lubricants (POL), fertilizers, containers and iron ore is presented which averages around 78.53 per cent of total freight quantum volumes of 1372 MMTPA in 2016–17) currently handled from the major ports in India.

*The study asserts that should the initiative of multimodal logistics be commissioned from the Eight major ports, logistics cost–saving opportunity could be around INR 34,000-38,000 Crores per annum, by optimizing freight transportation. Four key initiatives could drive these savings:*

1. Inland water shipping can handle about 221-241 MMTPA from the incremental capacity in the next 5-6 years across the five commodities as above and estimated cost reduction would be around 19,500-24,500 Crores by 2026
2. Bulk Shipments from Major Ports Cement & Fertilizers of 78-88 MMTPA estimated INR 4,200-6,200 Crores saving by 2026
3. Transit time reduction in the container shipment segment by 120 hours can be estimated INR 4,300-5,700 Crores saving by 2026
4. A transition to rail transport for containers from roadways from current 17.6 percent by 2026 can reduce expenditure by 1,800-2,800 INR crores.
6.1 Coastal shipping for existing/planned capacities

6.1.1 Coal:

In 2016–17, around 1,317 MMTPA of thermal coal was shipped by Indian railways alone. Around 48 MMTPA moved through waterways given the accounted price of INR 0.19 per tonne km vs. INR 1.19 to 1.37 per tonne km. Given the 1/6th price of transport via rail, Indian can for the 392 thermal plants deploy waterways to interconnect and ferry 95 to 118 MMTPA coal and ease the undue stress on rail based transportation and reduce expenditure by INR 12,370 by 2025.

Referring the illustration(s) 11 and 12, in the water routes that connect North East segment of India through the Eastern Coast, spanning 1236 Kilometres (Connected by Ports with 20 Meters draft), the greedy algorithm derived attests that raw material for 9 power plants with capacity of 11.5 GW on the National Waterway-1 network system consumes 19 to 23 million tonnes of coal as projected by year 2026. This can be ameliorated to carry 24-32 MMTPA from the Eastern Port Paradip to Port Talcher from Ib Valley through the National Waterway-5 and act as a feeder to Marigaon Thermal Power Station. This can render 97,634 rail-rake(s) to fertilizers instead of thermal coal over a span of 240 days in a year. Similar interlinking can be extrapolated to other segments in India for Ocean Freight and Inland Waterways by connecting them to Exclusive Freight Corridors and Logistic Parks.

6.2 Bulk commodities: Iron Ore, Grains and Cement

Bulk Freight Stations have always been set-up next to the natural reserves of raw material. 76 per cent of capacity outlay follows this structure. Multimodal Logistics, on the other hand, offers transportation cost optimization, ease of raw material flow, and improved linkages with international markets.
Grains and Cement, the two commodities analysed estimates that a potential of approximately 84–94 MMTPA (~42 MMTPA for Cement & ~42 MMTPA for Dry Bulk) can be improved at existing costs by 2026.

Multimodal Logistics routing raw material from mine to coast as a fundamental structure as derived by the Greedy Algorithm asserts that, an average transportation expenditure of INR 670 to INR 940 per tonne can be optimized as portrayed in illustrations 13 and 14.

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<tbody>
<tr>
<td>Wheat</td>
<td>268</td>
<td>271</td>
<td>282</td>
<td>299</td>
<td>308</td>
</tr>
<tr>
<td>Soyabean</td>
<td>93</td>
<td>102</td>
<td>106</td>
<td>112</td>
<td>132</td>
</tr>
<tr>
<td>Total Grains</td>
<td>361</td>
<td>373</td>
<td>388</td>
<td>411</td>
<td>440</td>
</tr>
<tr>
<td>Dry Bulk</td>
<td>3857</td>
<td>4205</td>
<td>4373</td>
<td>4635</td>
<td>4812</td>
</tr>
<tr>
<td>% Grains / Total Dry Bulk</td>
<td>9.36</td>
<td>8.87</td>
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**Source**: National Bulk Handling Corporation, 2018 (Q2)

Table 4: Sourcing quantum from Government Warehouse to Destination connecting North and South India

As portrayed in Table 4, major bulk freight is routed through identified locations for North Andhra Pradesh and Tamil Nadu, Odisha, connecting Telangana and Southern Maharashtra, a distance of approximately 1650 Kilometres. Maharashtra. This study asserts that, Logistic Parks with ICD’s could be established close to distribution centres like Krishnapatnam which is well connected through inland waterways. For Limestone, the study proposes Vijayawada in Andhra Pradesh and the Gujarat clusters from Vadodara based on the reserve of raw material for limestone.

6.3 Reduce time to export by five days

Hinterland container shipment in India averages 30 days, which is about 25 in other parts of South East Asia which houses five large ports for the same distance. This unwanted transit time compels exporters to earmark higher buffer duration (Xu, 2018). This research proposes three initiatives for optimizing container transit time by 80-100 hours:

a) **Interconnect Highways with Ports with Logistics Parks as the convergence points**: The Bharatmala initiative and the Golden Quadrilateral can be earmarked with dedicated freight-friendly corridors and establish custom houses at the logistics parks, with RFID enabled EXIM container sealing which reduces inspection time and reduce unwanted halting of containers by adopting exclusive pre-paid toll tags across all modes of transport.

b) **Simplification of customs reforms**: The automated Customs Clearance currently deployed at Mumbai (M/s JNPT), Gujarat (M/s Mundra) and AP (M/s Krishnapatnam), associated to the EXIM license to generate unique routing numbers to permit single-window document validation extended to 24 X 7 and 365 days a year for participants of import and export

c) **Redeploy containers to railways transport**: Which is otherwise skewed in favour of road transport in India. This can reduce crude imports by 1.15 Mn KL. The greedy algorithm proposed by this study identifies EIGHT priority routes for road to rail deployment that currently deploys 2.19 Mn TEU from highways but are capacitated to ferry 3.09 Mn TEU by railways.
d) **Enable Direct Freight Corridor within Western India and Eastern India:** Exclusive railway lines to interlink ports with the warehouses at Pipavav, Hazira, Mundra, Kandla. On the Eastern front, Chennai, Krishnapatnam, Ennore, Kakinada and Visakhapatnam.

e) **Enable Inland Container Depot:** The Greedy Algorithm as proposed has identified an opportunity in that, city Tughlakabad gets 13 rail rakes a day, as against higher transport demands from trade centers of Bhopal and Agra receive less than 1 rail-rake per day. The study proposes, an exclusive Milk-run from Gujarat through the Inland water ways to other parts of India.

### 6.4 Bulk Cargo Transport

Major ports in India have handled around 1318 MMTPA of bulk cargo in 2016–17. This study estimates that by 2026, this segment can go up to 1,975 MMTPA. EXIM bulk can go higher by 3.5 per cent to reach 1,030 MMTPA. The port based bulk freight, is poised to improve by 20 per cent to breach 421 million tonnes by 2026. This demands enabling dedicated logistics parks with multimodal capabilities at specific ports to manage 12.73 Mn TEU container traffic in 2016–17. Container shipments has witnessed a SEVEN percent over the last five years as has the extent of containerization from 52 per cent in 2015–16 to 28.75 per cent in 2016–17. This study estimates that container traffic will register a 6.45 per cent rate to attain 22.75 Mn TEU by 2026. The following infrastructure for Multimodal transportation will need to be installed to address this increased traffic.

<table>
<thead>
<tr>
<th>All INR in Crores</th>
</tr>
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<tbody>
<tr>
<td>3400-3900</td>
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<tr>
<td>3200-3800</td>
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### Illustration 15: Possible Reduction in Expenditure with the implementation of Multimodal Logistics

**Source:** Compiled from Various Sources and Extrapolation from the Algorithm derived

I. Transhipment facility at a Southernmost tip connecting Indian Ocean and Bay of Bengal with capacity of 11-14 Mn TEU

II. Increase capacity of Western port M/s Mundra Port and M/s Navasheva Port by 1.95-2.45 Mn TEU and on the East Ennore, Paradip, Krishnapatnam and Visakhapatnam to be ameliorated.

III. New dedicated freight corridor for transhipment from West Bengal to Andhra Pradesh connecting Odisha with capacity of 1.2

### 7. Summary And Conclusions

In the marine transportation paradigm, integration of stakeholders services and product lines as a collaboration improves competitiveness. Collaboration can occur in terms of an ICT enabled shared logistic design to enable reduction of empty kilometers across larger transit lines, freight management in terms of shared load and warehouses, possible implementation of multimodal logistics. The study reflected on ways to operationalize “Maritime” as the spearhead to harness development as depicted in Illustration 16.
This can be realized by application of analytical methods for transportation intensive units and is representative of expenses, time duration, as primary variables to be optimized for better profitability. Game theory applications can ascertain the equilibrium point for such kind of collaboration and Shapley values derive the maximum benefit from dependent variables as discussed. This model can be seamlessly extrapolated and multiple variables can be added as filters to derive needed results. The manuscript portrays the positive impact of collaboration in terms of costs and time rationalization. The implementation of the transportation space by way of waterways would be possible by integration of non-major and major ports on the Southern and Western coast.

Illustration 16: The roadmap to arrive at the Multimodal Structure

The identified variables of this study are attempted to be modelled using a greedy algorithm which is best suited when participants are multiple and decision making need to be dynamic. The study has identified variables to optimize the operations of all participants in the transportation segment, shared information aspects are pooled as a dependent variable, and as the other participant, being In-Time associated information, variables of Electronic Data Interfaces with market mechanism and operationalization of methodology, quantifiable messages, authenticity of information.

For the aspect of recursive frameworks in dynamic programing, the applicable paradigm is identified in terms of Information Communication Technology framework, quantum metric experience (recorded digitally). The two constructs time-span and market capitalization are taken as exogenous variables. The aspects of Mutual understanding, Long-Term relation & viability, leadership exchange facilitation, economic characteristics coupled with Market Conditions, supplier’s market competitiveness, market and product characteristics, augmenting low demand and volume, network breakages, fluctuating demand constructs are taken as a third cluster.

These three clusters are integral for the future of Indian Supply Chain networks especially from a multi-modal perspective. It is very crucial to understand the end user financing avenues as this will shed light as to what problems or advantages the MSMEs face when acquiring finance. The methods and models applied in the transportation space gives an inside view of the macro process taking place in the back end (Raut, Gardas, Jha, & Priyadarshinee, 2017). As a measurable output the following can mooted to initiate the process of a Port-Led Development as called upon by the national leaders.

The enablement of transportations warehouses and strategic centers as a key component of a connectivity plan around each operational port to facilitate cargo labelling and processing using
scientific methods, based on the quantum numbers for the last five years in terms of cost and time. Once the optimality is arrived, design the same for each stakeholder and possibly integrate them using multimodal logistics. For smooth and seamless movement of freight, the existing industrial corridors need to be scaled and newer avenues identified. Possibly strategic enablement of warehouses along the Golden Quadrilateral road network to handle bulk logistics through the maritime sector.

The present legislation of multiple authorities and approvals for similar cargo; this system which replicates from each state as and when cargo moves needs to be reduced and can lead to reduction in transit durations. Possible geo-tagging of trucks and consignments can be looked into apart from reducing documentation for export and import containers initially and then scaled to cargo in a progressive manner. Real time systems and artificial intelligence can be harnessed to ensure that all stakeholders inclusive of the government departments interact with each other with improved efficiency and effectiveness.

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