An Algorithmic Approach for 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 analyzed 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) traverses 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

I. Introduction

Leading National newspaper “Business Standard” in 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”.

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.

A. 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, and

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. 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) as per Fig. 1 below.

Source: DG-Shipping, India

Fig. 1. Prominent Ports in India (7,500 Kilometers of Coast).

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.

II. 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 [1]. India relies more on road transportation as per Table I 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 [23].

Further, from Table I, 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., SO_2, CO_2, CO, NO_2, etc. Recent studies endorse that emission of CO_2 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 per cent of its total energy consumption [27].

TABLE I. India's Freight Transport is More Road Oriented

(Weight-distance)				
#	**In Billions Ton-Per Km (s)**			**Emmission per ton-kmg CO2 equivalent**
	5,183	**5930**	**1325**	
Air	<1	<1	<1	>1000
Water	30 (Squared)	13.73	5.66	14.47
Freight Rail	46.35	47.95	35.38	27.4
By Road	22.81	36.32	51.55	63.63
	China	**USA**	**India**	

(Source: World Economic Forum; China Statistic Yearbook; Planning Commission India; NHAI; Indian Railways; DG Shipping; Bureau of Transportation Statistics US; McKinsey)

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; [12] 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 [32], [53].

This set of literature specifically attempted to isolate primary challenges as:

- Insignificant Kutcha roads and limited connectivity among network.
- Halting of vehicles indiscriminately at check posts of state border [7] (reason for delay – statistically 38.19 per cent of transit time delay is associated to these unscheduled halting).
- Porous system and weak regulations for starting a trucking business.
- Freight prices being subjected to surge pricing.
- Absence of tracking systems for rail freight, for distributed cargo management.
- Low infrastructure for disconnected rail & road connectedness.

Inefficient berthing of ship and unusual delay in time for loading and unloading that lead to abnormally high turnaround time of vessels [47].

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 [2]. 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 [4]. 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 [24].

The coalescent approach adopted by this study can assist India to increase its Maritime transport share to 42.91 per cent [20].

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 per cent of Indian Gross Domestic Product) to USD $ 13942 Million or even higher (can reach a total of 4.91 per cent 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 per cent [18] and [48].

III. 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 modeling 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 [50] will lead to increase more pressure on the existing logistics infrastructure. Four Dimensional components as per Table II outlined below characterize the network of Indian logistics [44], [13].

The study attempts to integrate the following six key success factors (as per Fig. 2) to propose a multimodal system as a plausible solution to some of the challenges India address as on date [6].

A. 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, [26]. Access to Rail Network (Freight), Financial Centers, 3rd Party Logistic providers and inter-modal transport [40]. The key components of Logistics Park are: (a) Transportation, (b) Storage Facilities, and (c) 360 0 degree service operations as a single window clearance.

B. Multimodal Logistics Parks (MMLP)

Multimodal Logistics Park can augment Indian transportation infrastructure to rationalize expenditure on transportation [28]. The most important characteristic; it helps to reduce the overall transit time [25].

TABLE II. DIMENSIONS AND APPLICATIONS PROFILE

#	Dimensions		Application area
1	Integrated Framework	Components in Networked Roads	Maritime Frieght Network
			Golden Quadrilateral
			Interlinking Road and Rail
2	Enablers	Enabler to support Structure	Logistics Parks
3	Payback	Proposed Change	Automation of e-Pass
4	Budgets	New Focus	Seaways

Source: Author Collated

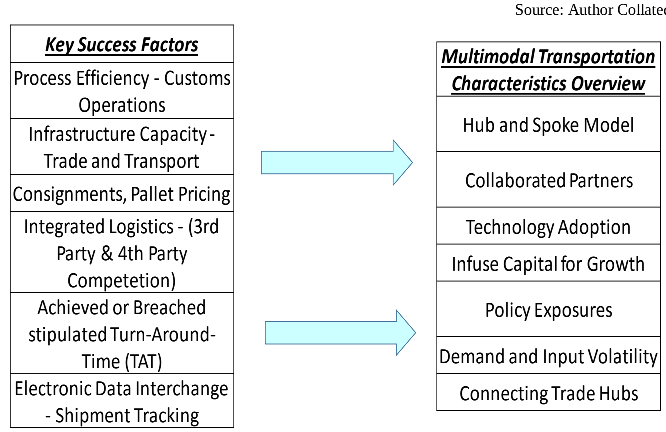


Fig. 2. Key Success Factors of Multimodal Logistics.

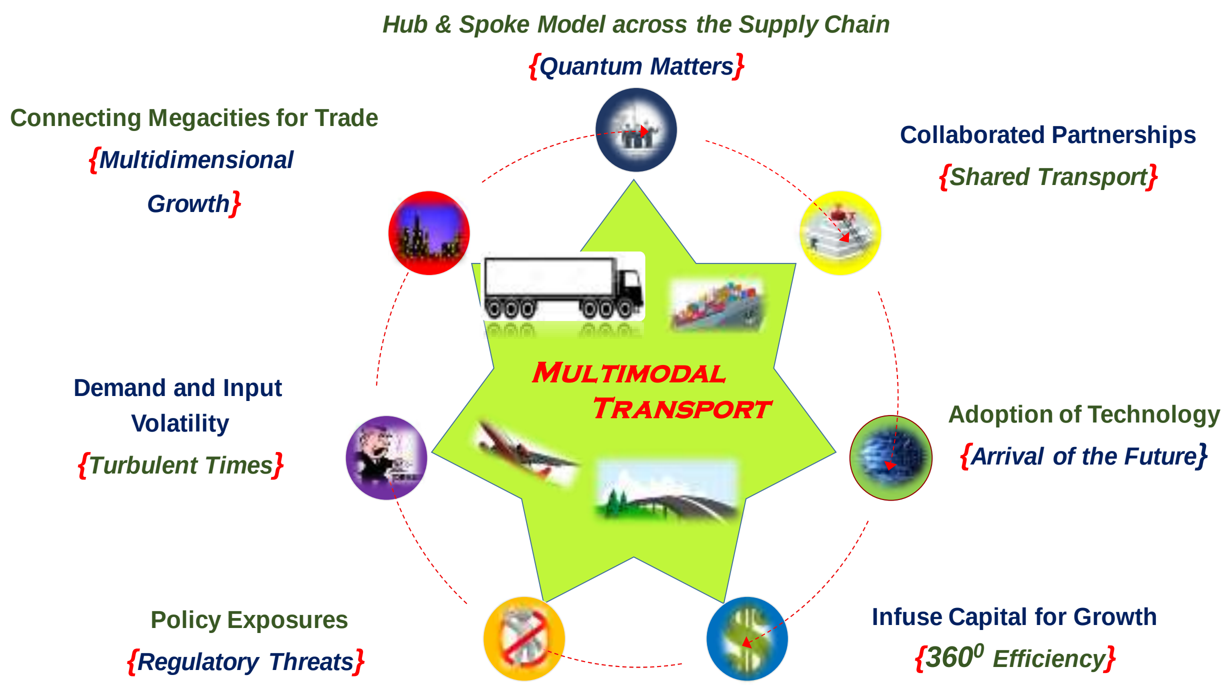


Fig. 3. The all-encompassing Multimodal Logistics.

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 [41]. 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:

1) Automating container transportation system, improved hinterland and inter modal connectivity.

2) 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 in Fig. 3 is a master model of the all-encompassing Multimodal Logistics Park.

IV. Literature Review

The study explores the paradigm of connecting hinterland through port based multimodal logistics deployment via published research work s as part of the literature and identify associative affairs detailing integration with a view so as to recognize the procedure prior to integration [35]. 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 [3].

It is quite prominent that, in India, [45] “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)” [9].

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 [37], fundamental structure of multimodal framework establishment that can yield in tangible results which can be specific to these commodities.

This study seeks to analyze four dimensions which are being modelled for possible enablement of Multimodal Logistics.

a) Incorporate a methodical change in the way Indian Logistics operates as compared to Global Practices.

b) Incorporate the Variables of Transportation Paradigm being modeled which can build enablers for realizing port led transportation and development.

c) Depict multiple key Success Factors for MMLF that build’s Institutions which operate within the Multimodal Logistics Framework.

d) Present model characteristics which enable technology creation to assist and sustain new greenfield projects. In stage-1; the study seeks to understand the multifaceted and inter connected structures including methodology [52], [54].

Global Research practices aligned to the research work for the transportation segment are presented in Fig. 4.

Global Practices	Author
Rationalization and Optimization of customs procedures and transport tariffs	A. Zafer Acar and Pınar Gürol (2016), Adil Baykasoğlu, Kemal Subulan(2016)
Encouragement of Free Trade Agreements & Most Favoured Nation aspects	Maisam Abbasi, Fredrik Nilsson (2016), Khalid Aljohani, Russell G. Thompson (2016)
Integration of Legacy Systems and ERP's	M.P. Fanti, G. Iacobellis, W. Ukovich, V. Boschian, C. Stylios (2015)
Applied Artificial Intelligence and Real-Time Systems	Elisa Negri, Sara Perotti, Luca Fumagalli, Gino Marchet, Marco Garetti (2017)
Business Core Processing and Outsourcing (3rd & 4th Party Logistcs)	Malcolm Townsend, Thanh Le Quoc, Gaurav Kapoor, Hao Hu, Selwyn Piramuthu (2017)
Optimal Capacity of Freight Shipments	Roar Adland, Fred Espen Benth, Steen Koekebakker (2017)
Ensuring a Greener Carbon Footprint along the entire Chain	Harilaos N. Psaraftis (2016), Lhoussaine Ameknassi, Daoud Aït-Kadi, Nidhal Rezg (2016)

Fig. 4. Literature Review of Global Practices [14], [17].

A. Profit Considerations and Optimal Inventory

As a replacement for altering the decision responsibility in higher association 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) [33], [36]. Other key Success Factors are presented in Fig. 5 (below).

Key Success Factors	Author
Process Efficiency - Customs Operations	Adil Baykasoğlu, Kemal Subulan (2016), Michael A. McNicholas (2016), Teodor Gabriel Crainic, Michel Gendreau, Jean-Yves Potvin (2009)
Infrastructure Capacity - Trade and Transport	Khalid Aljohani, Russell G. Thompson (2016), Yücel Candemir, Dilay Çelebi (2017)
Consignments, Pallet Pricing	Paolo Ferrari (2016), Stefano Manzo, Kim Bang Salling (2016)
Integrated Logistics - (3rd Party & 4th Party Competetion)	Chandra Prakash, M.K. Barua (2016), Roy Zúñiga, Carlos Martínez (2016)
Achieved or Breached stipulated Turn-Around-Time (TAT)	Venkatesh Mani, Angappa Gunasekaran, Thanos Papadopoulos, Benjamin Hazen, Rameshwar Dubey (2016)
Electronic Data Interchange - Shippment Tracking	Hsin-Hung Pan, Shu-Ching Wang, Kuo-Qin Yan (2014)

Fig. 5. Literature Review of Key Success Factors for MMLF [38].

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 per cent 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 [30], [34]. The research 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 [43], [19].

B. Possible Technology for New Green Field Projects

If above mentioned shifts as per Fig. 6 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) [21], [49]. 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 [42], [8].

Multimodal - Characteristics Overview	Author
Hub and Spoke Model	Nader Azizi, Satyaveer Chauhan, Said Salhi, Navneet Vidyarthi (2016)
Collaborated Partners	Taehee Lee, Hyunjeong Nam (2016), Cristina Sancha, Cristina Gimenez, Vicenta Sierra (2016)
Technology Adoption	Teodor Gabriel Crainic, Michel Gendreau, Jean-Yves Potvin (2009)
Infuse Capital for Growth	R. Perez-Franco, S. Phadnis, C. Caplice, Y. Sheffi (2016), David A. Wuttke, Constantin Blome, H. Sebastian Heese, Margarita Protopappa-Sieke (2016)
Policy Exposures	Paolo Ferrari (2016), Stefano Manzo, Kim Bang Salling (2016
Demand and Input Volatility	Ole Ottemöller, Hanno Friedrich (2017), Roar Adland, Fred Espen Benth, Steen Koekebakker (2017)
Connecting Trade Hubs	Sibel A. Alumur, Bahar Y. Kara, Oya E. Karasan (2012), Viacheslav Fialkin, Elena Veremeenko (2017)

Fig. 6. Literature Review of Modal Characteristics [55].

V. MODEL DISCUSSIONS: METHODOLOGY

For enabling multi-modal logistics, the below participants and their characteristics are pivotal:

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

A. Analyzing Collaboration in Supply Chains

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 [29].

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 [10], [46]. 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 modeled 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 [11] [39]. 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 modeled. Carbon output as per Shapley value is derived using the principle Shapley function as below:

$$y_j = \sum_{s \subseteq R/j} P(M)\left(d\left(M \cup \{j\}\right) - d\left(M\right)\right) \quad ..A$$

where '*j*' is a random 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

$$t_{|Q|}(Q,n) \quad (1)$$

The average of $t_{|Q|}(Q,n)$ is taken for the cases where $n_{|Q|} = n$ to arrive at the rate

$T(n)$ is associated to a consignment of quantum n,

$$T(n) = E(t_{|Q|}(Q,n) / n_{|Q|} = n) \quad (2)$$

For an order pool

$$Q = (n_1, ..., n_{|Q|}) \quad (3)$$

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

$$\alpha_i = \min\{\omega_i \rho_{i-1}, \#(n_i)\} \quad (4)$$

and $\rho_i = \rho_{i-1} - \alpha_i$ (5)

With p_0 some given positive number and weights by

$$\omega_i = n_i / (n_i + ... + n_{|Q|}) \quad (6)$$

Note that $\omega_{|Q|} = 1$.The allocation α_i is such that if $n_i = n_{i+1}$ then

$$\alpha_i = \alpha_{i+1} \quad (7)$$

Future tabulations can associate α_i to yield n_i as an effective collaboration and is sorted according to decreasing size. Now the desired quantum:

$$Q = (n_1, ..., n_{|Q|}) \quad (8)$$

is termed

$$n_1 \geq n_2 \geq ... n_{|Q|} \quad (9)$$

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.

B. 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 [16]. 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 $\mu = \{b_1, b_2, b_3 .... b_k\}$ 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_1 has an initial instance time s_i and a closing time r_1, where $0 \leq r_1 \prec s_i \prec \infty$.

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 as per Fig. 7.

Greedy interlinking of sub-nodes of the transport mode and the rational chosen choice problem:

$$\mu_{a,b} = \{P_k \in \mu : f_a \leq r_l \prec f_b \prec s_m\} \quad \ldots(10)$$

$\mu_{a,b}$ would be the subset of all initiated function. First in first out procedure is adopted and functionally,

$$a_0 \leq a_1 \leq a_2 \leq a_3 \leq ... \leq a_n \leq a_{n+1} \quad \ldots (11)$$

i	1	2	3	4	5	6	7	8	9	10	11
r_i	2	4	1	6	4	6	7	9	9	3	13
s_i	5	6	7	8	9	10	11	12	13	14	15

Fig. 7. Illustration of advantages by enabling Multimodal Logistics

Subsets comprising of maximum functional elements are compatible mutually as an optimal choice:

$$b_{j,l} = b_{j,k} \cup \{r_k\} \cup b_{k,l} \quad (12)$$

1) 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 $C = i+1, ... p-1$. 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

$$r[a,b] = \begin{cases} 0 \\ \max\limits_{\substack{a \prec k \prec b \\ s_k \in \mu_{a,b}}} \{r[a,k] + r[k,b] + 1\} \end{cases}$$
$$\begin{aligned} &if\ \mu_{a,b} = \varnothing \\ &if\ \mu_{a,b} \neq \varnothing \end{aligned} \quad (13)$$

2) Transformation to a greedy response from a dynamic – program

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

$$f_i = \min\{f_c : p_k \in \mu_{a,b}\} \quad (14)$$

Then

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

b) 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 programming of other variables that determine the modal mix in the unscheduled remainder of time quotient [51].

3) 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 as per Fig. 8. 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 [15].

$$a_0 \le a_1 \le a_2 \le a_3 \le ... \le a_n \le a_{n+1}. \quad [15]$$

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** $a \le b$ and $r_a \prec f_i$ $\triangleright$ find the first activity in $\mu_{a,b+1}$
3. **do** $a \leftarrow a+1$
4. **if** $a \le b$
5. **then return** $\{r_i\} \cup$ *RECURSIVE LOGISTIC FUNCTION"* (r, f, a, b)
6. **else return** $\varnothing \leftarrow$ *Object location* root of the summation.

4) 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 [5]. The functional model is depicted in Fig. 8 (below).

1. $l \leftarrow length[a]$
2. $R \leftarrow \{s_1\}$
3. $i \leftarrow 1$
4. ***for*** $r \leftarrow 2$ to l
5. ***do if*** $a_r \ge f_i$
6. ***then*** $R \leftarrow R \cup \{r_i\}$
7. $i \leftarrow n$
8. ***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 [22] incrementally profit and time optimization mandates the end delivery R. That is,

$$f_i = \max\{f_k : n_k \in R\} \quad (16)$$

Similar to the recursive iteration, [31] GREEDY-LOGISTICAL-OPERATOR schedules a functional activity set of *l* activities in $\lambda(l)$ in shortest duration assuming that the collaboration is pre-fixed and time and cost parameters are arrived at.

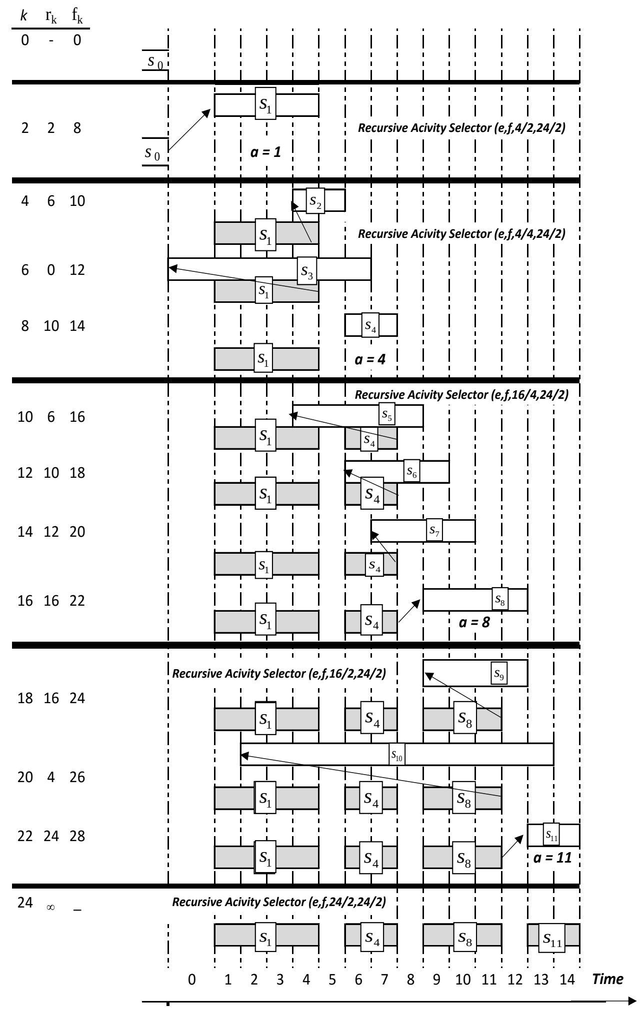


Fig. 8. Recursive Logistic Function as start (s) with variables (a), Greedy Logistic Function (a, b).

VI. Data Analysis, Interpretation and Suggestions

India imports crude predominantly at only four 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:

- 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.

- Bulk Shipments from Major Ports Cement & Fertilizers of 78-88 MMTPA estimated INR 4,200-6,200 Crores saving by 2026.
- Transit time reduction in the container shipment segment by 120 hours can be estimated INR 4,300-5,700 Crores saving by 2026.

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.

A. *Coastal Shipping for Existing/Planned Capacities*

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. The routes are presented in Fig. 9.

B. *Bulk commodities: Iron Ore, Grains and Cement*

Bulk Freight Stations as per below Fig. 10 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.

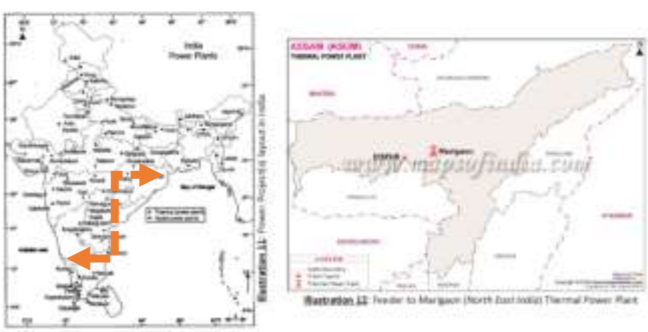


Fig. 9. Shipment of Coal in the Indian Subcontinent.

Fig. 10. Transhipment of Bulk in the Southern Part of the Country.

Grains and Cement, the other two commodities analyzed 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 per Fig. 10 above.

As portrayed in Table III 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.

TABLE III. SOURCING QUANTUM FROM GOVERNMENT WAREHOUSE TO DESTINATION CONNECTING NORTH AND SOUTH INDIA MMTA

#	2013-14	2014-15	2015-16	2016-17	2017-18
Wheat	268	271	282	299	308
Soyabean	93	102	106	112	132
Total Grains	**361**	**373**	**388**	**411**	**440**
Dry Bulk	3857	4205	4373	4635	4812
% Grains / Total Dry Bulk	**9.36**	**8.87**	**8.87**	**8.87**	**9.14**

Source: National Bulk Handling Corporation, 2018 (***Q₂***)

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.

C. *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. A summation is presented in Fig. 11.

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.

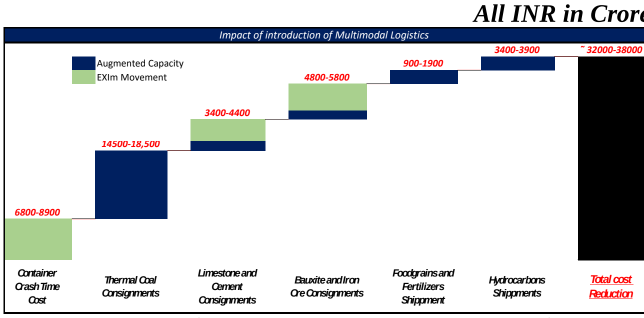
d) Enable Direct Freight Corridor within Western India and Eastern India: Exclusive railway lines to interlink ports with the warehouses at Pipavav, Hazira, Mundra, Kandla. On the Eastern front, Chennai, Krishnapatnam, Ennore, Kakinada and Visakhapatnam.

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.

D. 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 have witnessed a SEVEN per cent 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.

All INR in Crores



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

Fig. 11. Possible Reduction in Expenditure with the implementation of Multimodal Logistics.

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

2) 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.

3) New dedicated freight corridor for transhipment from West Bengal to Andhra Pradesh connecting Odisha with capacity of 1.2 Mn TEU.

VII. 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 (Raut, Gardas, Jha, & Priyadarshinee, 2017). The study reflected on ways to operationalize "Maritime" as the spearhead to harness development as depicted in Fig. 12.

1) 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 of India.

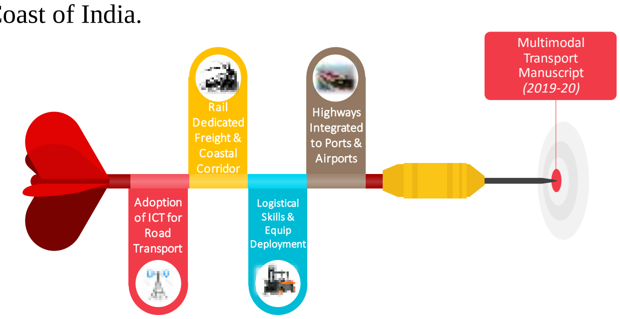


Fig. 12. The roadmap to arrive at the Multimodal Structure.

2) The identified variables of this study are attempted to be modeled 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.

3) For the aspect of recursive frameworks in dynamic programming, 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.

4) 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. As a measurable output the following can mooted to initiate the process of a Port-Led Development as called upon by the national leaders.

5) The enablement of transportations warehouses and strategic centers as a key component of a connectivity plan around each operational port to facilitate cargo labeling 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.

6) 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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