Smart Container Inventory Management: A Conceptual Approach

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Abstract— **Containerization has provided substantial contribution to the global supply chain. However, it is quite a paradox to be noted that carriers do not practice or pursue a standard container inventory management system. Each individual carrier develops an inventory management mechanism that suits to their vision, mission, and objectives. These practices are hardly shared between carriers and most of them believe that container inventory management is purely the tacit knowledge of their container controllers and nothing to argue on their decisions. This attitude impedes the industry gaining the experience curve advantage and learn by mistakes. Therefore, same mistake tends to take place quite often which is highly absurd. The paper challenges this reality and recommends a realistic approach to manage the container inventories of carriers that help reduce global container inventory imbalance. The conceptual model comprises Multidimensional carrier index and country index; 3F CIM conceptual model; 6R container supply model; and Virtual container pool.**

Keywords— **container shipping, Virtual container pool, carrier, container supply**

I. INTRODUCTION

One of the most striking developments in the global economy since World War II has been the tremendous growth in international trade [1]. Shipping is a business that grew up with the world economy, exploring and exploiting the ebb and flow of trade [2]. From 1981 to 2009, global transport of containerized cargo increased approximately 3.3 times faster than the world's GDP [3]. World's very first all-container ship "Gateway city" was found in 1950 [4] and containerization was commercially implemented in the US in the mid-1950s [1] and is the driver of the twentieth century economic globalization and world container port throughput increased by an estimated 3.8 per cent to 601.8 million 20-foot equivalent units (TEUs) in 2012 [5]. Containerization was not just about ships but a new way of organizing transport [2] has made a momentous change globally in the system of freight transport. However, container fleet size and the complexity of the container shipping network [6] have increased dramatically bringing more challenges to the operation of the container shipping system. Shipping is a derived demand of international trade in economic terms [7]. The system, that proved its potential as an increasingly efficient and swift method of transport, led to greatly reduced transport costs, and supported a vast increase in international trade. Cross-border transportation is an engine to promote the foreign trade [8]. However, as in most cases containerization brings the world a serious burden due to container inventory imbalance (CII). Ninety six percent of carriers consider CII as a significant issue but only 58% have a standard CIM policy [9]. This provides a sufficient insight as to why a conceptual approach is required to mitigate its alarming negative impacts.

'Container' means, an article of transport equipment of a permanent character and accordingly strong enough to be suitable for repeated use [10] or any type of container, transportable tank or flat, swap body, or any similar unit load used to consolidate goods, and any equipment ancillary to such unit load [11]. Container ships and containers are supplementary to each other thus Container Shipping Lines (CSL) cannot transport cargo if containers are not available [12]. Containers[1] are capable of transporting efficiently over long distances, and facilitate multimodal transport without intermediate reloading at any mid points. The total existing fully cellular[2] fleet as at 14th November 2016 (all sizes / all positions) stands at 6.038 fully cellular ships for 20,713,884 [13]. Containers are built to standardized dimensions, and can be loaded and unloaded, stacked, capable of being transported efficiently over long distances, and transferred from one mode of transport to another without intermediate reloading at any mid points. The terminal related variable fees connected to different segments and services (e.g., fee per handled container, trailer, swap-body, storage of load units, etc.) [14].

A considerable amount of investments has been made in purchasing containers and vessels and building port infrastructures [6]. The maximum 'utilisation' of containers can be achieved if they are on consistent move with freighted cargo [15]. Container ports provide the primary interface where physical exchange between buyers and sellers of containerized shipping capacity can be consolidated and

[1] Container - A truck trailer body that can be detached from the chassis for loading into a vessel, a rail car or stacked in a container depot. Containers may be ventilated, insulated, refrigerated, flat rack, vehicle rack, open top, bulk liquid or equipped with interior devices. A container may be 20 feet, 40 feet, 45 feet, 48 feet or 53 feet in length, 8'0" or 8'6" in width, and 8'6" or 9'6" in height.

[2] Cellular fleet – the fleet of Container vessels

realized [16]. Containers are usually supplied to exporters for stuffing of cargo at respective ports by the agents of carriers (Some exporters have their own container fleet for private use and this study does not consider their practices). The containers have a useful life of about 12 to 15 years [17] and the standard twenty-foot container costs about $2,000 to manufacture while forty-footer costs about $3,000. Therefore, a twenty-foot container costs $1.71 per cubic feet to manufacture while a forty-foot container costs $0.80, which underlines the preference for larger volumes as a more effective usage of assets [17]. However, according to Alderton, [18] the life expectancy of a container depends on many factors, but it is approximately 8 years and it frequently needed repairs and maintenance. Technically, containers are governed by the ISO (the International Standards Organization) and the CSC (the Container Safety Convention). In 1968, the ISO defined a container as an 'article of transport equipment' [18].

Controlling logistics costs allows companies to maintain a competitive edge and countries to experience trade growth, since lower logistics costs translate into competitive export and import [19].While for light commodities the load unit is secondary, for ponderous commodities the twenty-foot container is the most suitable. This is a principal factor behind the fact that the twenty-foot container still accounts for more than 27% of the world container fleet. Aabout 20% of total container flows at sea around the world are empty, and the costs of repositioning are about USD 400 per container [20]. For hinterland transportation, the availability of containers can be an issue as maritime shipping companies own most of the global container assets and prefer these containers to be within the maritime system where they generate income for the carriers as opposed to hinterland where they generate income for truck, rail and barge companies [17]. Apart from the empty container reposition (MTY Repo) there are two other sources to container supply namely, leasing and purchasing. These sources provide a kind of reactive solution to container inventory imbalance (CII). A considerable amount of investments has been made in purchasing containers and vessels and building port infrastructures [6].

II. CONCEPTUALISING THE CII

The present CIM solutions are relative rather than proactive [21] .Key problems to be solved are to find a mechanism to decrease the container imbalance thus better utilization of resources. This need to answer what is the current situation, what are the factors that determines the degree of willingness with respect to container sharing (interchange), how to organize those factors in a hierarchical system in order to understand as to what extent each of them influence the container fleet imbalance, how to improve those critical factors, and what benefits are expected through collaboration. The process of planning the research milestones a detailed study should be carried out.

During the exploratory study, it was noted that stakeholders of the shipping industry have following perceptions.

1. The collaboration of Container Shipping Lines may improve utilization of empty container inventories and therefore, the cost of transportation may have influenced by Container exchange mechanism
2. Container sharing may affect the expected payoff of shipping lines
3. Business culture of carriers and organizational Policies of carriers effect the decision of container exchange
4. Marketing rational of carriers with respect to collaborating with competitors may affect container exchange
5. Legal Implications pertaining to containers effect the decision of container exchange
6. Complexity of container Inventory Control of carriers effects the decision of container exchange
7. Legal procedures and the degree of tolerance to potential legal implications of collaboration effect container exchange
8. Level of presence of international politics effect container sharing
9. Availability of Container tracking systems effect container sharing
10. Level of consideration to environment pollution due to excessive movements of empty containers effects container exchange
11. Degree of collaboration may depend on the organizational Policies, vision and mission effects container exchange
12. Decision making level of the organization (whether upper or middle) effects container exchange
13. Level of freedom to take decisions independently by agents' effects container exchange
14. Level of consideration on losses due to holding of empty container stocks effect container exchange
15. Total container fleet of the organization effects container exchange
16. Ability of incorporating empty reposition cost in establishing freight rates effects container exchange
17. Degree to which the business culture and commercial practices of carriers facilitate collaboration effects container exchange
18. Degree of resilience to the expected complexity container Inventory Control that may cause due to collaboration effects container exchange
19. Degree of organization's sensitivity towards stakeholders' interests may affect container exchange

Therefore, it was identified that the outcome of the research may have a bearing to these views and should answer the related issues.

The container exchange, irrespective of its very visible advantages, may generate some complications particularly in terms of legal parameters. Usually a carrier has three sources of empty containers that are used for their export bookings. They are, (i) the carrier owned containers (COC), (ii) on-hired or leased containers, and (iii) shippers owned containers (SOC). Therefore, at a given time carriers may have containers of all these categories dispersed globally, in sailing ships, in the hands of exporters, importers, container yards, port terminals, customs warehouses, on the roads on trucks, on rails or simply abandoned with a third-party due to some issues. Therefore, monitoring the container inventory is a serious activity of a carrier. With the introduction of alliances agreements between carriers and commencement of slot sharing activities this was further complicated. Now the

containers are commonly in the alliance vessels. This has created a situation that carriers must handle their competitors' containers in addition to their own. Similarly, carriers have to release their containers in the hands of competitors according to the alliance agreements. Initially, this created many marketing disadvantages to carriers as their highly sensitive customer data lost its security. But given the economies of scale advantage that supersedes these barriers had paved the way for successful collaboration among carriers for slot exchange. The possible legal implication that will aggravate with container exchange should be explained with this background. After successful implementation of CE system there can be a possibility of an export cargo belong to exporter e, stuffed into a container belong to carrier c, freight handled by forwarder f, loaded on board a ship owned/chartered by carrier s, stacked in a slot owned by carrier a. Therefore, in an event of a legal implication the number of parties that will be involved is getting higher and higher. However, one can also argue that this complication is already in existence even now. If the c is replaced by a leasing company which is in existence does not make any difference. Therefore, the critical factor that needs to be considered here is that a similar or even stronger legal documentation should be in place for effective implementation of the CE model. The statistical significance ($p<0.050$) reflects that there is a relationship between Benefits and Complying with the legal procedures will be an additional burden to exchange containers.

1. The study reveals that container exchange has a potential in solving the container imbalance issue. However, the industry does not show a unanimous agreement to the concept. The comments received during the interviews reveals that the carriers are not highly influenced with the concept mainly because of branding issues. And the industry has no literature that gives scientific analysis of the solution. In other words, the industry hypothetically believes that if a country has a trade imbalance (i.e. the variation between imports and exports) the container imbalance in something inevitable. When this is true, it applies to any shipping line serving in that country or port. This makes sense as there should be two parties namely, one is deficit and other is excessed if at all to originate an 'exchange'.
   This myopic view of the industry is in fact discouraging the carriers to explore the possibilities in finding a solution through container exchange. Therefore, it should be proved to the industry with the use of real industry data with respect to opportunities available. In other words, the number of carriers that need empty containers (offeree) and those who can provide containers to them (offeror) at a given time at a given location should be highlighted. This factor has some relevance to the queuing theory as well. The mathematics underlying queuing theory is quite like those underlying seemingly unrelated subjects as inventories, dams, and insurance [1].

2. For example, the industry gauges the seriousness of the container imbalance simply calculating the stock levels in the beginning of the year and the end of the year. However, there are more activities taking place during the year when consider the monthly or weekly imbalances. Therefore, a case study to investigate the realistic movement on monthly bases (or weekly basis provided the data accessibility) by each carrier should be recommended. This may need a theoretical Modelling of Collaboration among Shipping Lines with respect to Container Sharing and proposing a unit of measurement to quantify the outcome of container exchange.
3. It would be necessary to identify and evaluate the existing solutions to mitigate Container Inventory Imbalance Problem prior finding a new solution. It is then obviously require identifying the factors that influence the existing practices. As the outcome of such study it would be worthwhile to develop an operating model that incorporates existing CIM strategies and practices of CSL. In terms of generalising the results with other countries it may be important to explore a mechanism that could evaluate a country's competence in CIM. If the competence is low the respective country needs more efforts in rectifying their short comings to improve their index. Accordingly, development of a Global CIM competence Index would be useful
4. Once the groundwork for an effective CIM mechanism is constructed the study may require exploring the container exchange possibilities based on real data. It may also explore any other potential solutions to container inventory imbalance problem in contrast to container exchange mechanism. After such unbiased evaluation, the study may further explore the efforts of minimizing the Container Inventory Imbalance through Collaboration among Carriers.
5. The most significant factor in the whole study is that the container exchange has not been effective even though carriers in principle agree the concept. It may be due to some peculiarity on the organizational behaviour of carriers. Therefore, further discussion on container exchange between CSL would be vital to understand the behavioural aspects of CSL that leads to the absence of collaboration. This should be followed by development of Container Exchange Simulation Model and introduction of Virtual Container Pool.
6. To attract carriers to the container exchange concept, evaluating the potential benefits and pitfalls of container exchange between CSL should be required. This may be done as case study in Sri Lanka. Further research may be required with respect to optimization of container Utilization through minimizing empty container repositioning and evaluate the degree of opinion on the collaboration among shipping lines to view the industry point of view. The container exchange simulation model may be validated using the views of industry experts in view of further research and development of On-line software application to facilitate implementation and the sustainability of the new concept is recommended

The conceptual approach of the research should be constructed on 2 fundamental objectives of CIM namely, maximization of customer satisfaction and minimization of container idle duration and empty container reposition. It is presumed that the introduction of an innovative container inventory management system fuelled by collaboration between carriers may help minimize container imbalance. This proposed container exchange is derived from the collaboration between carriers and provides an extension to the existing slot exchange mechanism between consortium partners. Figure 1 illustrates the basic "operationalization" of the main research.

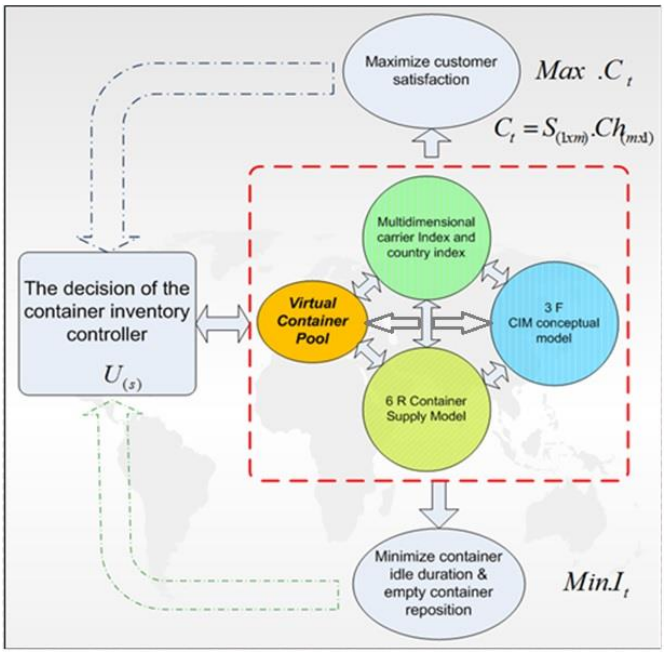

Fig.1 Conceptual framework of smart CIM

The effective and efficient CIM means striking the right balance between customer satisfaction and cost of container imbalance (i.e. $Max.C_t$ and $Min.I_t$ at the time *t*). The cost of container imbalance is defined as container idle duration and empty container reposition for this research. The decision of the container inventory controller $U_{(s)}$ is to make both ends satisfied. The customer satisfaction is given by

$$C_t = S_{(1\times m)}.Ch_{(m\times 1)},$$

Where, *S* is a raw vector consisting of the perceived utility scores of *m* service factors, *Ch* is a column vector consisting (0 ,1) where the corresponding element 1, represent the desired level of the given service factor, 0 represent the absence of the desired level. To achieve the optimum level of satisfaction all the elements of the column vector should be unity.

Each objective of the main research is covered by different material and methods of each sub researches. However, the research location, respondents, literature, and container data are common to all sub researches as they were conducted in Sri Lanka with the intention of generalizing its outcome in the global context. Sri Lanka attracts majority of mega carriers to its main ports due primarily due to strategic geographic location. Seventeen out of the top twenty container carriers in the world operate regular services in the busiest commercial port in the country, Colombo. Approximately 75 percent of the global container capacity is operated [1] by those top carriers. Accordingly, the sample is expected to be relatively reflective of the general views of the global shipping industry. Therefore, it is presumed that the results can be generalized for the benefit of the global shipping community. There are two formal organizations that represent CSL in Sri Lanka namely, Ceylon Association of Shipping Agents which is composed of 135 licensed ships' agents, and Sri Lanka. The other association, Sri Lanka Association of Vessel Operators comprises 14 members. The views of exporters also obtained wherever applicable and there are approximately thousand exporting companies (including non-regular) in Sri Lanka according to unpublished data.

The core issue that prevails in the industry is to find a mechanism to decrease the cost incurred on container inventory imbalance thus better utilization of resources. In most cases, an imbalance occurs because of inaccurate forecasts [22]. It is understood from the exploratory study that there is no collaboration among shipping lines with respect to container interchange. Chapter three explains that the effectiveness container exchange mechanism has a relationship with the level of Complexity of Inventory Control; empty reposition surcharge; and Capacity of container inventory. Also, carriers are likely to exchange containers if there is a mechanism to evaluate the overall benefit in financial terms and it has relationship with the level of Complexity of Inventory Control; empty reposition surcharge; Capacity of container inventory; additional burden on legal procedures; Organizational Level Support; and the Decision-making level of the organization. The container carriers those who experience excess inventory at a port ant a particular time may offer containers to carriers those who suffer shortages. As a result, both carriers may reach balanced inventories in an ideal situation.

The common agony of the carriers who hold excess inventory is the substantial cost associated in empty repositioning out from that port and idle inventory that lead to ground rent, monitoring, loss of return on investment, extra maintenance (against rust and other natural/environmental phenomena) at CFS. On the other hand, the line with deficit inventory tend to experience regular cargo booking cancellation thus always at a risk of losing customers on the long run. Cargo booking cancellation is a significant issue as it not only affects the revenue to the line but negatively impacts on the long-term forecast and budgets. Liners usually consider exports from one port to another port in the respective port rotation as the prime source of empty containers to the later. Therefore, cancellation of booking will have a continuous negative impact throughout the supply chain for all ports connected the liner service. To avoid this chain of effect, lines tend to import empty containers or on-hire boxes. Both these options add cost to the line. The sharing may reduce the need for empty reposition.

III. Appraisal of Conceptual Model

The model underpins a strategic approach of CIM and comprises 4 key tools namely, Multidimensional carrier index and country index; 3F CIM conceptual model; 6R container supply model; and Virtual container pool.

A. Multidimensional carrier index and country index

Multidimensional country index refers to the CIM competence level of a country. It is vital to have an appraisal of the country's competency level regarding the container inventory management because each country will have container inventory imbalance levels, seasonal fluctuation that are exclusive to them, slot cost variations and port handling costs for empty container reposition. The multidimensional CIM index of Sri Lanka is calculated at 0.586 [23].

Multidimensional carrier index provides the level of CIM competence of an individual carrier. This helps the management of the respective carrier to enhance the knowledge and skills of their container control staff. Sometimes, it may remind them to review the strategies used in CIM because usually there are no standard practice how carriers should manage their container inventories. It is expected that carriers may assess their individual competence (CCI) while the country's CIM index (MCI) provides the overall competence level of the shipping industry with respect to CIM in each country [23].

B. The 3F CIM conceptual model

The CIM mix, provides an independent opinion about the key dimensions that should be the focus of a carrier's attention when managing its container inventories [22]. It is comprised of 3 key aspects in CIM. Under each of these three dimensions, six strategies are elaborated that facilitate effective and efficient CIM. This approach provides an objective, "proactive" solution rather than the more common, ad hoc "reaction" to market conditions related to empty container repositioning. This mechanism enables carriers to act more effectively and efficiently as they regularly evaluate their decision through an indicator that consists of criteria validated by the industry experts.

C. 6R container supply model

Shipping supply is a very complicated phenomenon. Unlike a common consumer good that the demand forecast is dependent of rather strength forward consumer centred factors, shipping supply has its own indirect characteristics. For example, the supply can increase by adding more ships, increasing the size of ships, increasing the speed of ships, increasing productivity of ports and reduced port stay, change of shipping route and many other strategic approach and may not necessary related to ship size and number of ships. The 6 R's in this model refer to, right quantity of containers, right types (such as standard; open top, reefer etc), right size (20' 40'45' etc), right quality containers to be supplied by the carrier at the right time and at the right location. These requirements are initiated by the exporters.

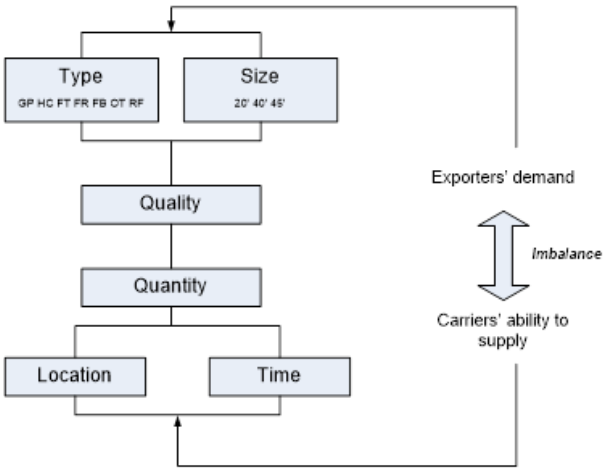

Fig.2 The components that create an imbalance in container operations

Accordingly, carriers need careful assessment of these factors to strike the right balance between the demand and supply.

D. Virtual container pool

The concept of Virtual Container Pool (VCP) is based on the container exchange between carriers on a global platform. Each carrier has the full control of their containers with respect to release or hold for their own use. Shao et al., [24] formulate this problem as maximum matching in a large general graph, and propose a distributed matching algorithm to solve this problem. We also propose several optimization techniques to improve the efficiency of our algorithm. The fundamental prerequisite in a container exchange is that there should be a carrier who is in shortage and another carrier in excess. In the chapter eight, as per the case study in Sri Lanka, it is evidenced that the prerequisite is met. Therefore, it is worthwhile investigating this concept further. Lines may exchange containers provided it enhances value of the supply chain to all participants. The basic requirements that demands this action is that one carrier should be experiencing a deficit of containers (either the size or the type in demand) while another carrier has surplus on the identical size and the type of containers at the same time horizon and in the same location. The offeror however primarily needs to make sure that they have ongoing services (and agents to undertake handling) at the intended destination. Secondly, there should be a demand for empty containers by the offeror at the time that the respective containers are scheduled to reach. This demand should be either greater or equal to the number of containers they offer to the other carrier (offeree). The fundamental prerequisite to exercise CE is the variability of inventories that one or more carriers with excess containers while others with deficit at a given location and at a given time [25]. Leading CSL already has provisions in their contracts to interchange containers. However, the general perception among CSL is that, there could be CI monitoring issues associated with respect to interchanging of containers [26].

In addition to vessel sharing these alliances gradually extended the collaboration to other areas such as, service rationalization, operating expense sharing, equipment interchange, and joint service contracts. Therefore, nothing should prevent regional corporation in maritime logistics per present developments. However, it is easier said than done and more complicated by nature [27]. The carriers have unanimously agreed that VCP could be considered an effective CIM solution although they do not exchange containers at present. The ability to synchronize the capacity, complexity, empty reposition surcharge to ascertain the benefits of CE are influential factors on developing a VCP [25]. Therefore, the success of VCP mainly depends on the ability of overcoming this psychological barrier. This can be only done through the awareness, clarity and visibility of the concept [15].

As illustrated in the Fig 1, the key CIM methodologies are usually interrelated and interconnected. One activity can follow other or all 4 can be activated simultaneously. For example, a carrier can first ascertain its Multidimensional carriers index first and them administer the 3F CIM conceptual model. The same firm could improve its CIM by applying the 6R container supply model followed by entering to the Virtual container pool. However, a carrier joining the virtual container pool should not be the final activity of the effective CIM

process. The sustainability of an efficient and effective virtual container pool would highly depend of consistent monitoring and prompt decision making. This process requires combined efforts of all these complimentary tools mentioned above.

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