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VALUE STREAM MAPPING OF OCEAN IMPORT CONTAINERS: A PROCESS CYCLE EFFICIENCY PERSPECTIVE

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Abstract: International cargo transportation is majorly dependent on marine transport, which moves 80% of the international cargo. With the increase in vessel size and the same yard area available for container transportation, it is important to study the processes and understand the efficiency of the container operations process. This research paper aims to review the import container transportation process and understand the process cycle efficiency through lean six sigma concepts. The process is evaluated from the operations process perspective and documentation process at one of the ports of India. The research has been designed by conducting an industry expert review on the process of container transportation from vessel berthing to gate out for import containers, utilising lean six sigma principles such as value stream mapping (VSM) and process cycle efficiency. The results have contributed to the existing knowledge in identifying the waste in the container handling process and demonstrated the inefficiency in the system from the perspective of waiting time of containers due to customs examination, scanning, and inter-terminal handling and movement. The process cycle efficiency of 40% is calculated by analysing the detailed time of handling containers from vessel berthing to gate out. A new future value stream mapping is proposed considering the process cycle efficiency. Future studies will focus on studying this process for export containers and benchmarking the results with the top-performing ocean ports globally.

1 Introduction

The increasing role of globalisation, together with the increasing speed of all the processes, have led to the fact that in the contemporary world, supply chains have to be changed towards more effective and sustainable systems. Considering that the ports are an important part of the supply chain processes, the influence of the change in the environment could also be seen. An essential role in delivery services is given to marine ports as approximately 80% of products is carried by sea transport [1] and thus inevitably goes via seaports.

International trade largely relies on a marine mode of cargo transportation. The container shipping sector is predominantly constituted by multiple stakeholders that act as individual entities and operate on a silo basis. These independent stakeholders are expected to collaborate in order to transact by coordinating their information exchange. In order to integrate and ensure the collaboration between operations, reliable exchange of information is important to integrate with along with digital technologies. This will enable them to exchange data on a regional and global level, which can increase efficiency and deliver environmental benefits through waiting for time reduction and optimal use of energy and resources [2].

The relationship between vessel size and the companies owning the vessel is illustrated in Figure 1. It can be observed that companies owning vessels is decreasing; however, the size of each vessel is increasing. Thus, a container port terminal has to adopt optimising practices to ensure and manage continuous efficient operations. This can be performed by optimising the current space, processes and standard operating procedures, considering the below factors:

1. Port infrastructure, such as berth areas, cranes, technology.
2. Lean efficient processes and space optimisation.
3. High Investment.
4. Environmental Impact.

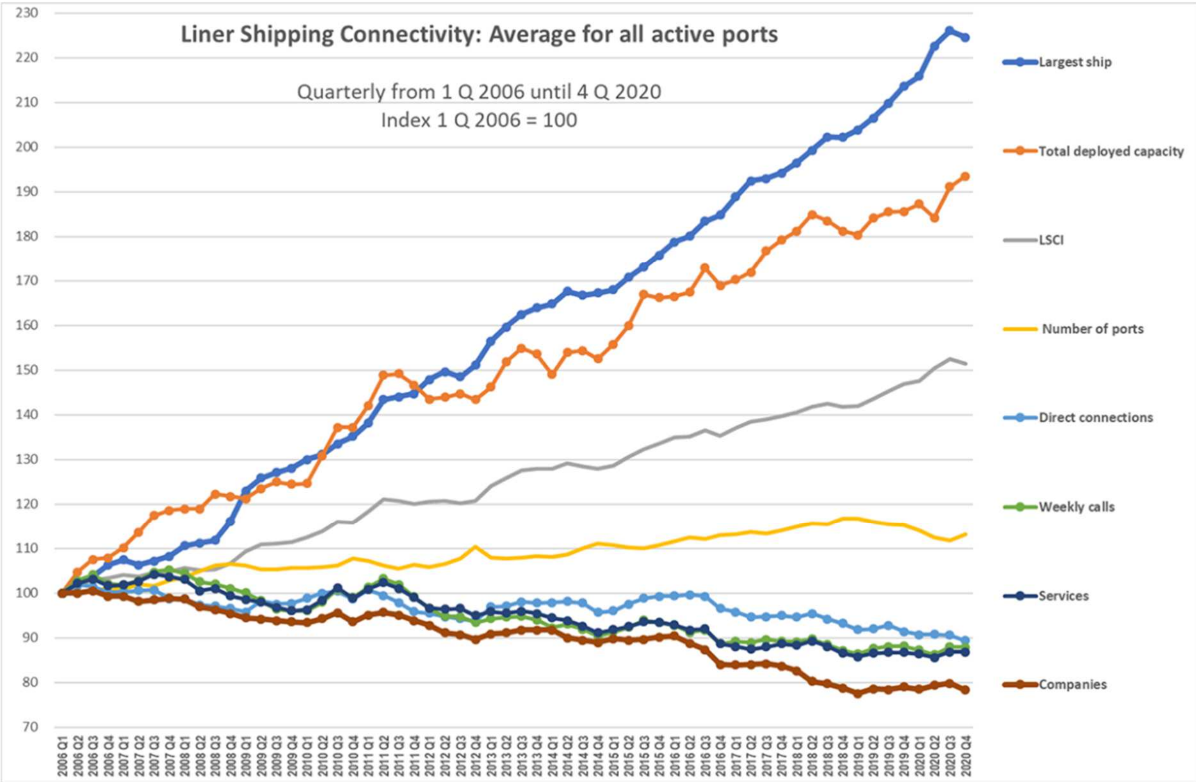

Figure 1 Relationship between vessel size and vessel per country [3]

The container and shipping sectors are important for economic development and influence various segments such as transport infrastructure, warehousing, information and communication in supply chain management. Evolution in the logistics sector may benefit logistical investments, which changes the traditional way of company functioning. In many countries, economic advancement was influenced by expanding export production. Export performance is important, especially for small economies or developing countries [4]. [5] also, highlight that economic growth is positively influenced by trade openness while studying selected Asia countries.

There has been a strong push for information communication technologies in the container logistics sector, along with the introduction of smart port 4.0. Many global and European organisations such as United Nations Economic Commission for Europe (UNECE) and United Nations Center for Trade Facilitation and Electronic Business (UN/CEFACT) are researching smart container technologies for data exchange transactions to build efficient and cost-effective processes.

The ongoing change towards the digitalisation of processes, also known as the fourth Industrial Revolution or Industry 4.0, provided new opportunities for the delivery and supply chains. However, new opportunities are always connected with new challenges that could arise in port management systems. The rising opportunities influence the competition on the market, and the necessity of the change might provide the competitive advantage against road, rail and air. Considering the complexity of ports processes, the process improvement could serve as an advantage in the contemporary world, allowing services to be provided faster, better and/or at a lower price.

They are identifying the role of container terminals in modern supply chain strategies and further integration of container transportation. There is significant scope for research since globalisation demand effective and secure supply strategies [6]. The ports serve as gates for goods and products to enter or to leave the country. Ocean freight greatly depends on port efficiency [7]. Thus, the process optimisation in ports might provide a new perspective for a country. India has twelve major Ocean ports for trading at the global level. Though there have already been attempts to optimise the processes in Indian ports, the key indicators of Indian ports are not effective in comparison with European or Singapore systems.

As many ports in India are struggling nowadays to improve the processes by implementing advanced technologies, the proper analysis might be beneficial to identify the steps that could be removed prior to being digitalised. Several methods have already been used to optimise port processes, such as standardisation [2], SMEA [8] or JIT [9,10]. To better analyse the challenges, the process should be divided into its constituents and then assessed. One of the qualified tools to analyse the actual process efficiency is value stream mapping as a method that opens more horizons for the identification of wastes, non-productive process activities, value-added processes. Many port types of research have been conducted from various aspects, but the approach when VSM is proposed for ports process improvement is not much studied so far [8]. In connection with the Six Sigma methodology that could be applied to monitor and assess statistical indicators of the processes and use the to improve the existing process, it opens new and innovative potentials for setting up a system solution for internal processes in the area of container import by ocean ports in the whole world.

In this research study, an attempt is made to analyse the existing processes in ports in India from the point of view of value-adding and non-value-adding activities and to calculate the process cycle efficiency with the purpose to propose possible optimisation of existing processes. The novelty of this research is the application of VSM in Indian ports based on the information gathered from the port managers. The study comprises the information gathered from port managers by specially developed questionnaires and application of Lean tools, namely VSM, for analysis. The research was conducted in the southern Indian ocean port, and import cycle data for containers were collected for the period of one year to understand the dwell time and the time taken by sub-processes were discussed in detail with the port operations managers to better understand the pattern existing in the given ports.

The paper is structured as per the following details: The first section provided the theoretical background for container logistics, lean six sigma, value stream mapping (VSM) and VSM in container logistics in research studies. The methodology section presents data analysis along with VSM calculation and waste management. The results section illustrates the investigative relationship, data analysis and empirical results. The discussion sections highlight the findings of VSM mapping. The last section presents the concluding results along with limitations and future research scope.

2 Literature review

2.1 Container logistics in research studies

Containers are traditional cargo movement and storage units classified as general-purpose, refrigerated, dry or tank containers. For such a cargo movement in international trade, a crucial role is played by marine transportation. Nearly 80% of the international trade in volume and approximately 70% of the international trade-in value is transported by marine transport and is operated in maritime ports [11,12]. For the majority of the developing countries, the amount is even higher. With expanding economies and advancing globalisation, containerisation is further staged to grow and remain as a preferable mode of cross border cargo movement [13].

With the increase in global trade and container volume, yard managers have to manage the yard operations to ensure terminal efficiency [14]. With such large expansion and increase in the volume of cargo, the limited possibilities include increasing the land area, which is a larger investment of procuring land or optimising operations in an efficient manner to reduce dwell time. Terminal operators operationally plan to reduce the dwell time of the container by determining factors that affect the container time spent at the container terminal operator. A research study conducted by Pekarčíková et al. (2020) emphasised strategic long term planning utilising DDMRP (demand-driven material requirement planning) to explain the location and sizing of shipping containers [15].

Merckx [16] designed a framework to assist the container terminal operators on the pricing scheme for container time spent in the terminal based on the dwell time. Logistics and freight forwarding companies intend to store and stock their containers in a terminal operator or container freight station till their requirement arises in the production [17].

With the advent of technological advancement in e-commerce and road transportation, there is a major thrust towards automation and digitising platforms in container logistics management. For a developed and a developing economy, the port plays an important role in cross trading between economies. For the last decade, there has been a continuous increase in the global trading of containers. This is primarily due to the increase in the global movement of container and trading numbers globally [11,12]. Thus, in a competitive scenario, port terminal operators are under immense competitor to make the container handling process more efficient and a lean process. This research study will include analysing the process of container movement from vessel manifestation to gate out operations utilising lean six sigma and value stream principles. Figure 2 depicts the process of the movement of the container terminal in marine ports, including physical movement and document moving from the supplier (which is a ship) to the customer (which is the delivery company).

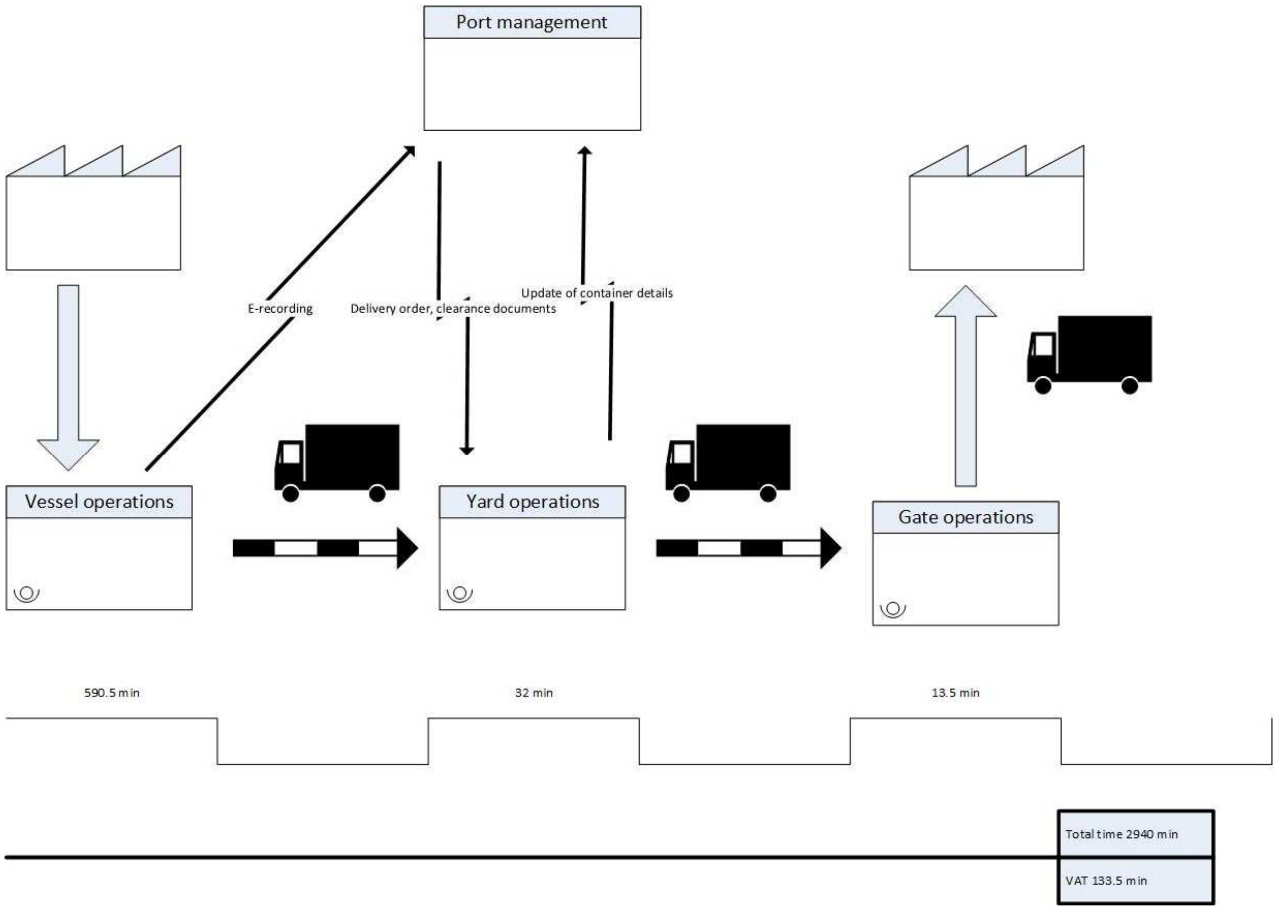

Figure 2 Container movement from vessel berthing to gate out (Source: Own research)

2.2 *Lean and value stream mapping in research studies*

Lean methodology has already been used in ports and has proved itself to be beneficial from the point of view of process analysis [1,7,18]. VSM allows to better understand the port processes and thus could influence port management and influence flow. Lean ports are able to identify wastes and bottlenecks of any process together with defects [7]. The proper understanding of the initial process could also increase the output of investment as the core stages could be defined, and the attention could be shifted from non-value-added processes. As in this study, the VSM is the main tool that is used to calculate process cycle efficiency, the thorough understanding of port processes and the understanding of the Lean VSM tool are required for the research success.

Lean methodology has been applied in many companies worldwide and has proved its positive impact on industrial processes, non-industrial processes and services. However, despite its great success, many companies deny implementing this methodology as they consider lean to be costly in implementation, and they are uncertain about its application in their company [1]. Regardless of this fact, many ports have advantageous experience in implementing lean [1,7,8,18].

As a methodology, Lean appeared in Toyota, and it was developed by Taichii Ohno. It received attention in economically challenged periods as Toyota managed to increase income [19]. Lean followed the principles of Toyota Production System, the basic principle of which was to eliminate seven kinds of wastes, thus creating a more effective production system. In the work of [11] the enhancement of the company competitiveness by the implementation of waste reduction and continuous improvement tools for JIT was indicated. And JIT was considered to be the crucial strategy for competitive advantage.

"Lean management thinking is used to differentiates between waste and value within an organisation" [20]. In lean, the waste (also called "muda") is connected with activities that take time without adding value to the product. "Anything in production that does not add value is considered to be a form of waste" [21]. In connection with the setting up of lean processes at the ocean port, we can identify according to the 7 types of losses the following attributes:

- Overproduction – Containers imported by port terminal with limited real time schedule and unavailability of storage place causing planning errors and congestion.
- Waiting – Planning errors and rehandling causing delay due to custom examination.

- Transportation – Truck scheduling and multiple handling at the yard.
- Over processing – Scanning and examination due to customs risk management system.
- Inventory – Handling at empty yards, freight stations and their maintenance.
- Unnecessary motion – Reshuffle and rehandle of the container at the yard.
- Defects – Container delivery on account of a truck appointment system.

To create a lean port, it is important to create a system where the bottlenecks, defects, and other wastes are identified [7]. To identify the wastes, the tool called VSM that depicts the order of all steps of the process (including information flow and materials flow) is used [1]. The purpose of this tool is to determine value-added activities [22,23] and to identify the "potentials for improvement" [24]. Although transportation is a value-added activity in general [22], the understanding that some of the activities within the process are wastes is crucial. [25] performed a study where they indicated that for operational performance, the most important tools are Just in Time and Automation, while TPM, VSM and Kaizen could lead to less effective or even negative results. The successful results from the implementation of lean and VSM across industries have also been demonstrated [26].

All the activities within a process in VSM are divided into 3 groups: value-added, non-value-added but indispensable and purely non-value-added [27]. Value-added activities are important for our customers from the point of view of creating the final product. Non-value added are activities that are unnecessary in the process and could be eliminated fully [27]. Non-value-added but indispensable are the steps in the process that, although they do not improve our product from the consumer point of view, are compulsory for the completion of value-added activities [7].

VSM is used not only to understand the current process but also to plan the process improvement. Thus, two types of VSM exists – current state VSM and future state mapping. The current state VSM depicts the existing process with its value-adding activities and non-value-adding activities, and it helps to understand the most important problems [28]. The future state VSM represents the situation when the non-added-processes (or wastes) are eliminated [1]. The collection of the initial data, its analysis and transition into future state maps is an essential part of VSM. The optimisation of the value stream map is managed by a key indicator – the value-added index. It represents the ratio between productive and unproductive lead times in the complex process flow.

Considering the above mentioned, VSM could provide sufficient information about the process from the point of view of its analysis, of its further usage and planning and also for measuring the process cycle efficiency.

Value stream mapping – research literature review in the container and port logistics

The research on value stream application in container and port logistics is very limited. The research studies have been performed from the perspective of lean principles, agility, waste evaluation. A detailed illustration of research studies on value stream mapping and container logistics is detailed in Table 1.

The main objective of this research study is to understand and analyse the import process of container handling in a port terminal and then evaluate the detailed time taken for each of the processes as detailed in Figure 2. Adequate diagnostics of the causes of efficiency losses will be the basis for the setting of a future value stream map. Subsequently, performance parameters in the form of process efficiency along with value stream mapping and waste calculation are performed by analysing the data collected from the container terminal. The main theoretical and practical contribution of this research study is in better understanding of container port terminal process for handling import containers utilising lean six sigma principles. As the research conducted for value stream mapping in a container terminal is very limited, the results have provided various directions for future research.

Table 1 Research studies on container logistics and value stream mapping (Source: Own research)

Author	*Methodology*	*Sample and period of study*	*Independent variable*	*Dependent variable*	*Outcome/Suggestion*
Marlow and Paixão Casaca (2003) [7]	*Performance measuring*		*Knowledge*	*Port agility*	*Proposed framework for agile ports*
Paixão and Marlow (2003) [18]	*Literature review*	*Other industries*	*Lean and agility*	*ports, logistics*	*Proposed methodology based on internal and external integration*
Taylor(2008) [29]	*Action research methodology*	*Texton company*	*Current state map: product and information flows*	*KPI*	*Future state map was developed, KPI improvement*
Chen, Cheng and Huang (2013) [30]	*Value stream mapping of material flow,*	*Storage and retrieval SKU's in a warehouse.*	*Value stream mapping*	*Inter logistics warehouse operations*	*Operations time handling made efficient by the*

	information flow and process flow				*implementation of RFID through the insights from value stream mapping.*
Olesen, Powell, Hvolby and Fraser(2015) [31]	*a theory-building approach combining aspects of lean- and intermodal transport theory with practical insights*	*container facilities within the Scandinavian region*	*Lean principles*	*Material flow in container facilities*	*Proposed framework*
Sánchez, Buiza, Beltran, Stanley, Veloqui, Cerbán and Turias (2015) [1]	*Combination of VSM and numerical modelling by using MATLAB*	*Mediterranean Ports and logistics areas (Algeciras and Naples)*	*VSM and MATLAB*	*Post efficiency*	*Improvement's proposals, simulation model*
Kusrini and Parmasari (2020) [8]	*Waste Assessment Model for VSM, improvement using SMED and 5S*	*Port Companies in Indonesia*	*Wastes*	*internal setup time, efficiency of the goods procurement process*	*Reduction of internal setup time of 57,33%, increase in efficiency from 60,81% to 70,20%*
Dewi (2021) [32]	*Statistical method in the form of lean six sigma for exception containers.*	*Containers entering port and excepted by gate automation system*	*Lean Six Sigma*	*Gate automation system containers*	*Identification of low efficiency of gate automation system operations*
Wang, Yin, Khan, Wang and Zheng(2021) [10]	*Logistics system model on JIT and linear modelling for lean production*	*Cruise shipping*	*Modelling on lean production methods utilising JIT and linear modelling*	*Cruise shipping logistics*	*Variations of optimal inbound logistics mode over three different kinds of cruise parts*

3 Research methodology

The given research is based on both qualitative and quantitative research approaches. As the quantitative part, it considers results and data of real-time operations data that is collected from the secondary reports of DMICDC logistics data services through their portal www.ldb.co.in and discussion with the port operations managers to identify the import transaction process along with average time handled per container. This provides the quantitative information connected with the process being analysed with detailed information about time spent on every step of the process. The qualitative part is related to the analysis of the gathered data and the interpretation of the results by the specialists. The research also comprises a literature review part as an attempt to better systemise and analyse the information already available on the topic of the research.

The gathered data is analysed with the usage of one of the tools connected with Lean and/or Lean Six Sigma, which is called Value Stream Mapping (VSM). The data of the process that occurs in the port was divided into three major parts -Vessel Operations, Yard Operations and Gate Operations - and then each of the mentioned parts was analysed separately for the process efficiency. Conclusively, the common pattern was also developed where all three-part were analysed as one process.

As the availability of the data for the sub-processes of container handling from vessel berthing to gate out operations is limited, port managers were asked to analyse the processes for the wastes appearing in the course of the process. For this purpose, a table comprising the explanation of the wastes type was developed by authors and delivered to port managers. In this work, the port managers were also asked to analyse the amount of time connected with those wastes and if the mentioned wastes could be avoided or limited in the process. Based on this data, the VSM was developed where the efficiency of the processes was shown and, consequently, the process cycle efficiency was calculated. A general representation of the steps of the analysis used for the research is depicted in Figure 3 for detailed understanding. As it is illustrated in Figure 3, the research consisted of 7 steps starting with the development of the table for waiting time analysis and finishing at the propositions to evaluate the waste in the Process Cycle efficiency in ports of India.

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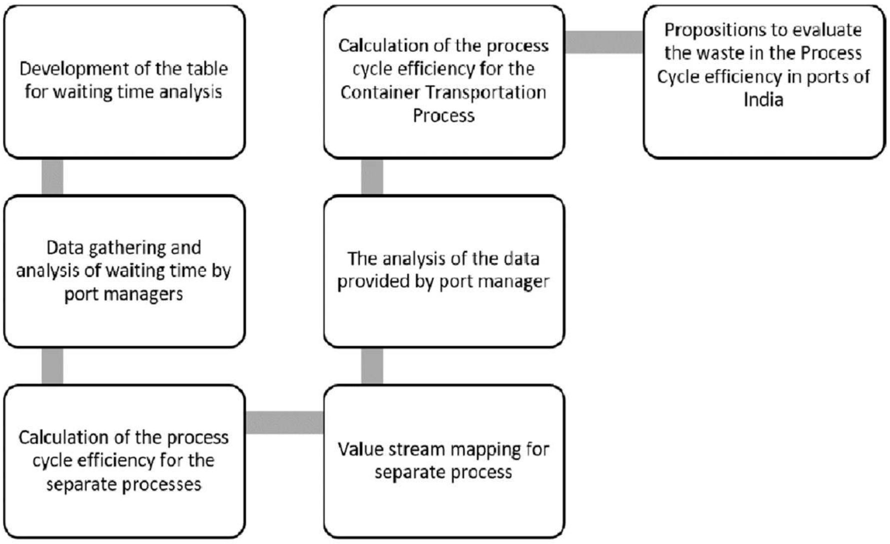
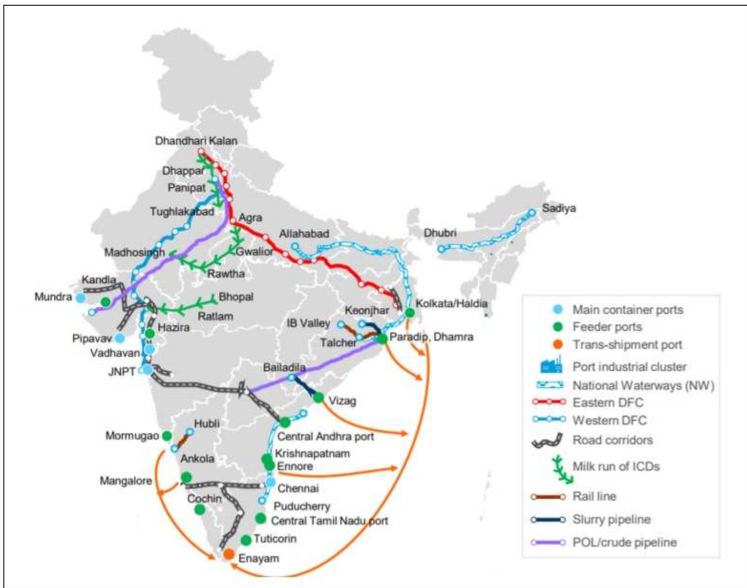


Figure 3 Process of the research analysis

3.1 Process information, data analysis and results

The detailed process for import container handling from vessel berthing to gate out was discussed in detail with the port operations manager. The discussion provided details of every micromanagement which is performed by the container terminal operator for the handling of the container cargo. This process is a complex handling operation and requires material handling equipment which is heavy duty and have to be managed by skilled manpower. Right from the starting of handling vessel berthing to quay cranes handling, this handling of the container during import transactions passes through various sub-operations processes. These sub-activities have been discussed in this paper along with the comparison for the overall dwell time of container spend in the container terminal operations. We have identified that most of the time of the container is spent in the terminal yard either waiting for inspection, scanning, examination, further connection to the next operator, which causes the dwell time to be as high as 24 – 72 hours for the truck and train bound containers. Figure 4 illustrates the dwell time at all the major ocean ports of India. We can understand from the data of December 2020, January 2021, and February 2021 that dwell time varies from as low as 17 hours to as high as 93 hours. Such a high gap in dwell time calls for a study to understand the subprocess and identify the reasons for such a variation in the inefficiency of container handling.



Port	Avg. Dwell time (In hours)
Kandla	39
Mundra	27
Hazira	28
JNPT	26
Mangalore	73
Cochin	56
Tuticorin	23
Chennai	64
Ennore	84
Krishnapatnam	58
Vizag	44
Haldia	90
Kolkata	32

Figure 4 Dwell time comparison at India Ocean ports (Source: [33])

As it is illustrated in Figure 4, the dwell time in different ports in India may vary greatly from 23 hours in Tuticorin to 90 hours in Haldia. As we understood this variation in dwell time of import containers across the ocean ports of India, we carried out a study to understand the detailed process of import container handling at ocean ports and find out the time taken by each process from vessel berthing to gate out and calculate the process efficiency and draw a future value stream mapping for the container handling. The process timelines as defined by the port managers are detailed in Table 2.

Table 2 Summary of handling time, value-added time, waste time and total dwell time (Source: Own research)

Process	*Net Process handling time (In minutes)*	*Value-added time (In minutes)*	*Wastage time (In minutes)*	*Dwell time across ports (In minutes)*
Vessel Operations + Yard Operations + Gate out operations	*636*	*133.5*	*502.5*	*2940*

As we can observe from Table 2, there is a wastage in container handling across terminals due to various factors. Actual handling time (average time obtained via practical data gathering) without any delay for the container is equivalent to 335 minutes; however, due to waiting delay and other complexity associated with handling bulky containers increases the overall container handling time to 2640 minutes (average time based on the discussion with port managers).

To understand how efficient the process is, the process cycle efficiency (1) was calculated according to the formula [34]:

$$Process\ cycle\ efficiency = \frac{Value\ added\ time}{Total\ lead\ time} \tag{1}$$

In our case, total cycle time is taken as Net Process Handling time as the net process could be influenced (2).

$$Process\ cycle\ efficiency\ = \frac{133.5}{636} = \ 0.21\ *\ 100\% \ = 21\%. \tag{2}$$

Thus, in general, the process is not efficient. According to the opinion of specialists that participated in the research, the major reason for the inefficiency is waiting at the gate as the number of containers does not correlate with the number of gates. There is congestion connected with the smooth flow of the process. Although there are variations in Net Process Handling time, the process needs amelioration.

3.2 Future value stream map

Based on the information that was gathered from port managers along with data analysis, future value stream mapping was proposed, where the process is depicted without unnecessary wastes but with the usage of the technologies that are already present in ports. The process cycle efficiency (3) increases from 16% to almost 40% for the improved process, as could be seen in Appendix II, where the value stream map of the improved process is presented.

$$Process\ cycle\ efficiency\ = \frac{133.5}{335} = 0.40\ *\ 100\%\ =\ 40\% \tag{3}$$

This illustrates the process cycle efficiency of 40% and thus examines the importance of technologies for industry 4.0 for identifying this waste and improving upon it. Various types of delay reasons as briefed by port managers are illustrated in Table 3.

Table 3 Major challenges identified for waiting and waste (Source: Own research)

Import container delivery		
Direct Importer	***Container Freight station***	***Inland Container depot***
Customs readiness	*Statutory clearance*	*Container scanners*
Custom duty unpaid	*Readiness or availability of transportation*	*Manual scanners*
Storage capacity with the consignee	*CFS Availability*	

4 Discussion

Technological change is influencing the environment from many perspectives, including the port systems. To be able to respond to market demand, the port should be proactive rather than reactive [18]. One of the ways to achieve it is to use existing process optimisation tools such as VSM, the usage of which was applied in this analysis. The usage of VSM helps to visualise the process and propose a more fitting amelioration. As visibility increases, the connectivity of supply chain elements [7] this paper proves that even complex port processes can be operated more efficiently.

The data analysis and discussion with port operation managers illustrated the challenges of higher dwell time at container terminals. Figure 6, depicts the value stream mapping as a visual representation where the comparison of time for the time taken, value-added, and wastage is illustrated. The green bar depicts the value-added time and the grey one's wastage time. Import containers that are handled from the vessel berthing to gate out operations generally take 335 minutes of handling time, including wastage identified due to customs examination. However, the challenges of rail connectivity and schedule, customs examination, automated scanners, which are expected to cause a delay from 8 hours to 36 hours on account of peak volume, contributes to the median dwell time of 44 hours in handling a container import operation.

A research study evaluated the truck congestion time and reducing waiting time at the terminal for improving efficiency, a part of the complete process was studied to evaluate the efficiency [35]. Another research on six sigma approaches for straddle carrier routing problems utilising VSM to understand the process in detail [36]. This research study has evaluated the process from container berthing to gate out and thus developing a future value stream mapping with improved process cycle efficiency. Research on unit container terminal productivity [8] suggested that the major wastes are unnecessary motion and transport of documents in-unit terminal containers. In this paper, the major waste was identified as waiting, which can contribute to the ports wastes understanding. A research study based upon decision making demonstrated that digital platforms could bring significant changes in inspects and detention charges which are on account of delayed processing such as customs and examination [37].

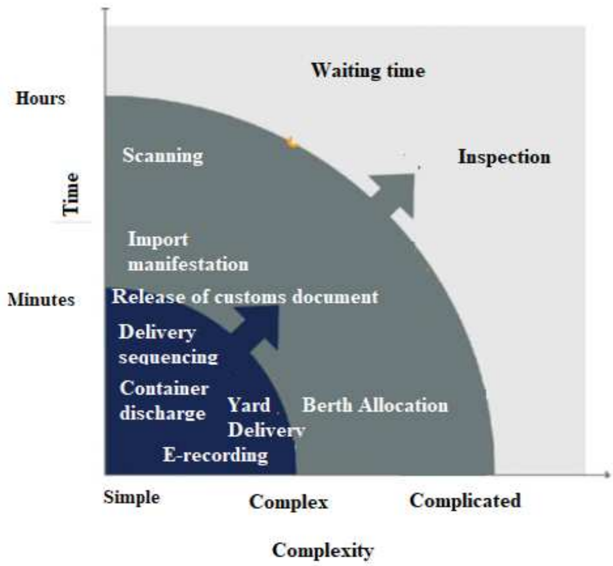


Figure 5 Process complexity model (Source: Author)

Figure 5 illustrates the process-wise complexity model, which is related to the process efficiency from a time and complexity perspective. This model might complement the understanding of the process timing and complexity. Various processes of container handling have been depicted in Figure 5, representing the simple to complicated from the time of operations taken. As we can see, the processes such as inspection and waiting time due to dealing are the most contributed processes for wastage. The port managers illustrated upon challenges of the throughput capacity of quay cranes which can manage 30-32 moves per hour for the unloading of containers to RTG (rubber tyre gantry cranes), which can perform 20 movers per hour are affected during traffic congestion. The operational strategies of twin lift mover are performed to ensure the efficiency of container handling. However, due to the complexity of handling and unavoidable delay, the gross crane rate was reduced, causing a severe impediment on the container handling efficiency. The manager performs various advance planning strategies for the bay plan, vessel stowage plan, considering total stack weight, loading sequence and weight factor. However, various complex handling due to multi-stakeholder causes the operations inefficient.

The confluence of Lean and Industry 4.0 improves the quality, efficiency and flexibility [38]. For marine ports, Industry 4.0 technologies in the form of gate automation, yard automation, and mobile scanners are getting the attention of the container terminal operators, contributing to performing measures that can improve the efficiency and reduce the handling time of containers.

5 Conclusion

This study incorporated a mixed research study in which the process of import containers data is collected from one of the visibility projects in India, logistics data bank, and the respective port managers are discussed for understanding the process cycle efficiency of each subprocess. A detailed data analysis of logistics data bank project along with data collection from port managers for subprocess and detailed value stream mapping understanding for process cycle efficiency was calculated (Appendix I).

The process cycle efficiency of 40 % was evaluated for the import handling containers in which the actual time of handling container with the continuous process is 335 minutes; however, due to the complexity of container handling and other challenging process and delay, the total handling time reaches 2640 minutes A time window equivalent to 335 minutes of handling time which includes wastage or delay on account of delayed customs examination, rail connectivity and schedule, customs examination, automated scanners increase the total dwell time to 44 hours. The results are important for the study from the perspective of mapping industry 4.0 technologies which can assist in reducing this waste and thus increasing the efficiency of container terminals. The future study will focus on understanding the export and transhipment process through a similar process and benchmarking the results with the other high performing ports at the global level. The limitation of this study is the regional level study at the level of India and specific ports for the data and discuss availability.

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References

[1] SÁNCHEZ, M.J.G., BUIZA, G., BELTRAN, J., STANLEY, M.T., VELOQUI, M., CERBÁN, M.M., TURIAS, I.: Logistic management optimization in the ports, *Journal of business and economics*, Vol. 6, No. 11, pp. 1908-1914, 2015. doi:10.15341/jbe(2155-7950)/11.06.2015/009

[2] BECHA, H., LIND, M., SIMHA, A., BOTTIN, F., LARSEN, S.: Standardisation in container shipping is key to boosting economies of scale - the importance of data collaboration between shipping lines, *RISE Research Institutes of Sweden*, 2020.

[3] HOFFMANN, J., HOFFMANN, J.: Bigger ships and fewer companies - two sides of the same coin, *UNCTAD*, [Online], Available: https://unctad.org/news/bigger-ships-and-fewer-companies-two-sides-same-coin [20 Oct 2021], 2021.

[4] RUZEKOVA, V., KITTOVA, Z., STEINHAUSER, D.: Export performance as a measurement of competitiveness, *Journal of Competitiveness*, Vol. 12, No. 1, pp. 145-160, 2020.

[5] SRIYANA, J., AFANDI, A.: Asymmetric effects of trade openness on economic growth in selected ASEAN countries, *E M Ekonomie a Management*, Vol. 23, No. 2, pp. 66-82, 2020.

[6] LAGOUDIS, I.: Overview and gaps in container terminal industry studies, *Maritime Logistics*, Vol. 2012, pp. 175-202, 2012.

[7] MARLOW, P., PAIXÃO CASACA, A.: Measuring lean ports performance, *International Journal of Transport Management*, Vol. 1, No. 4, pp. 189-202, 2003.

[8] KUSRINI, E., PARMASARI, A.: Productivity improvement for a unit terminal container using lean supply chain management and single minute exchange of dies (SMED): A case study at Semarang port in Indonesia, *International Journal of Integrated Engineering*, Vol. 12, No. 1, pp. 122-131, 2020.

[9] FULLERTON, R., MCWATTERS, C.: The production performance benefits from JIT implementation, *Journal of Operations Management*, Vol. 19, No. 1, pp. 81-96, 2001.

[10] WANG, J., YIN, J., KHAN, R., WANG, S. ZHENG, T.: A study of inbound logistics mode based on JIT production in cruise ship construction, *Sustainability*, Vol. 13, No. 3, pp. 1-18, 2021.

[11] MUÑUZURI, J., ONIEVA, L., CORTÉS, P., GUADIX, J.: Using IoT data and applications to improve port-based intermodal supply chains, *Computers & Industrial Engineering*, Vol. 139, No. January, pp. 1-15, 2020.

[12] UNITED NATIONS: Review of maritime transport, *UNCTAD*, [Online], Available: https://unctad.org/system/files/official-document/rmt2018_en.pdf [10 Oct 2021], 2018.

[13] FRUTH, M., TEUTEBERG, F. LIU, S.: Digitization in maritime logistics – What is there and what is missing?, *Cogent Business & Management*, Vol. 4, No. 1, pp. 1-41, 2017.

[14] CHU, C. HUANG, W.: Determining container terminal capacity on the basis of an adopted yard handling system, *Transport Reviews*, Vol. 25, No. 2, pp. 181-199, 2005.

[15] PEKARCIKOVA, M., TREBUŇA, P., KLIMENT, M. ROSOCHA, L.: Material Flow Optimization through E-Kanban System Simulation, *International Journal of Simulation Modelling*, Vol. 19. pp. 243-254, 2020. doi:10.2507/IJSIMM19-2-513

[16] MERCKX, F.: The issue of dwell time charges to optimise container terminal capacity, *IAME Annual Conference*, 2005.

[17] RODRIGUE, J., NOTTEBOOM, T.: The terminalization of supply chains: reassessing the role of terminals in port/hinterland logistical relationships, *Maritime Policy & Management*, Vol. 36, No. 2, pp. 165-183, 2009.

[18] PAIXÃO, A., MARLOW, P.: Fourth generation ports – a question of agility?, *International Journal of Physical Distribution & Logistics Management*, Vol. 33, No. 4, pp. 355-376, 2003.

[19] PEREIRA, A., DINIS-CARVALHO, J., ALVES, A., AREZES, P.: How Industry 4.0 can enhance lean practices, *FME Transactions*, Vol. 47, No. 4, pp. 810-822, 2019.

[20] SONY, M.: Industry 4.0 and lean management: a proposed integration model and research propositions, *Production & Manufacturing Research*, Vol. 6, No. 1, pp. 416-432, 2017.

[21] YEEN GAVIN LAI, N., HOONG WONG, K., HALIM, D., LU, J., SIANG KANG, H., *Industry 4.0 enhanced lean manufacturing*, 2019 8th International Conference on Industrial Technology and Management (ICITM), 2-4 May, Cambridge, pp. 206-211, 2019.

[22] VILLARREAL, B.: The transportation value stream map (TVSM), *European Journal of Industrial Engineering*, Vol. 6, No. 2, 2012.

[23] JORDAN, E., BERLEC, T., RIHAR, L., KUSAR, J.: Simulation of cost-driven value stream mapping, *International Journal of Simulation Modelling*, Vol. 19, No. 3, pp. 458-469, 2020.

[24] MEUDT, T., METTERNICH, J., ABELE, E.: Value stream mapping 4.0: Holistic examination of value stream and information logistics in production, *CIRP Annals*, Vol. 66, No. 1, pp. 413-416, 2017.

[25] BELEKOUKIAS, I., GARZA-REYES, J., KUMAR, V.: The impact of lean methods and tools on the operational performance of manufacturing organisations, *International Journal of Production Research*, Vol. 52, No. 18, pp. 5346-5366, 2014.

[26] SHOU, W., WANG, J., WU, P., WANG, X., CHONG, H.: A cross-sector review on the use of value stream mapping, *International Journal of*

Production Research, Vol. 55, No. 13, pp. 3906-3928, 2017.
[27] HINES, P., RICH, N.: The seven value stream mapping tools, *International Journal of Operations & Production Management*, Vol. 17, No. 1, pp. 46-64, 1997. doi:10.1108/01443579710157989
[28] BOONSOTHONSATIT, G., TONCHIANGSAI, K., CHOOWITSAKUNLERT, S.: *Value stream mapping-based logistics 4.0 readiness for Thailand automotive-part manufacturers*, Proceedings of the 2nd International Conference on Management Science and Industrial Engineering, 7-9 April, Osaka, pp. 309-313, 2020.
[29] TAYLOR, D.: An application of value stream management to the improvement of a global supply chain: a case study in the footwear industry, *International Journal of Logistics Research and Applications*, Vol. 12, No. 1, pp. 45-62, 2008.
[30] CHEN, J., CHENG, C., HUANG, P.: Supply chain management with lean production and RFID application: A case study, *Expert Systems with Applications*, Vol. 40, No. 9, pp. 3389-3397, 2013.
[31] OLESEN, P., POWELL, D., HVOLBY, H., FRASER, K.: Using lean principles to drive operational improvements in intermodal container facilities, *Journal of Facilities Management*, Vol. 13, No. 3, pp. 266-281, 2015.
[32] DEWI, V.: Analysis of container problems in exception area at pt. Terminal Petikemas Surabaya uses the lean six sigma method, *IPTEK The Journal of Engineering*, Vol. 6, No. 3, pp. 40-46, 2021.
[33] SAGRMALA: Updated draft report on capacity enhancement/shelf of projects (including report on National Multi-Modal Transportation Grid) with high level cost estimates for major ports, *SagarMala*, [Online], Available: http://sagarmala.gov.in/sites/default/files/9210939166Draft%20reportoncapacityenhancement.pdf [10 Oct 2021], 2016.
[34] GEORGE, M.: *Lean Six Sigma for Service: How to Use Lean Speed and Six Sigma Quality to Improve Services and Transactions*, McGraw-Hill Education, 2003.
[35] NOORAMIN, A. S., AHOUEI, V. R., SAYAREH, J.: A Six Sigma framework for marine container terminals, *International Journal of Lean Six Sigma*, Vol. 2, No. 3, pp. 241-253, 2011.
[36] MILI, K.: Six Sigma Approach for the Straddle carrier routing problem, *Procedia-Social and Behavioral Sciences*, Vol. 111, pp. 1195-1205, 2014.
[37] URCIUOLI, L., HINTSA, J.: Can digital ecosystems mitigate risks in sea transport operations? Estimating benefits for supply chain stakeholders, *Maritime Economics & Logistics*, Vol. 23, No. 2, pp. 237-267, 2021.
[38] ANTOSZ, K., STADNICKA, D.: *Possibilities of maintenance service process analyses and improvement through six sigma, lean and Industry 4.0 implementation*, In: Chiabert P., Bouras A., Noël F., Ríos J. (eds) Product Lifecycle Management to Support Industry 4.0. PLM 2018, IFIP Advances in Information and Communication Technology, Vol. 540, Springer, Cham., pp. 465-475, 2018. doi:10.1007/978-3-030-01614-2_43

Review process

Single-blind peer review process.

Appendix I

Table 4 Subprocess and time took while handling each activity

Process Type	Process	Type of Process	Average Handling Time	Average Handling Time (Future VSM)	Average Dwell Time (in hours)
Vessel Operations	Vessel Import manifestation	Major	75 minutes	75 minutes	49
	Berth allocation to the vessel	Major	30 minutes	30 minutes	
	Container discharge to the quay	Supporting	2.5 minutes	2.5 minutes	
	Inspection of the containers	Supporting	480 minutes	180 minutes	
	E-recording	Others	1 minute	1 minute	
	Delivery sequencing generation	Supporting	2 minutes	2 minutes	
Yard Operations	Delivery to the yard	Supporting	4 minutes	3 minutes	
	Receipt of delivery order of sealed container customs for the release and container is delivered to the Port Authority	Others	3 minutes	3 minutes	
	Release of clearance document by terminal	Supporting	5 minutes	5 minutes	
	Update of container details along with Bill of Lading details in system and releases delivery request form (DRF) to CFS agent	Supporting	10 minutes	10 minutes	
	The yard dispatcher dispatches equipment to load the import container onto the truck	Supporting	10 minutes	10 minutes	
Gate Operations	Weight and other truck-related processes at gate operations	Supporting	5 minutes	5 minutes	
	Verification by In-Gate staff on the consistency of the documentation details	Supporting	1.5 minutes	1.5 minute	
	Verification by Out-gate staff on the consistency of the documentation details	Others	2 minutes	2 minutes	
	Verification of truck loading weights	Others	5 minutes	5 minutes	

Appendix II

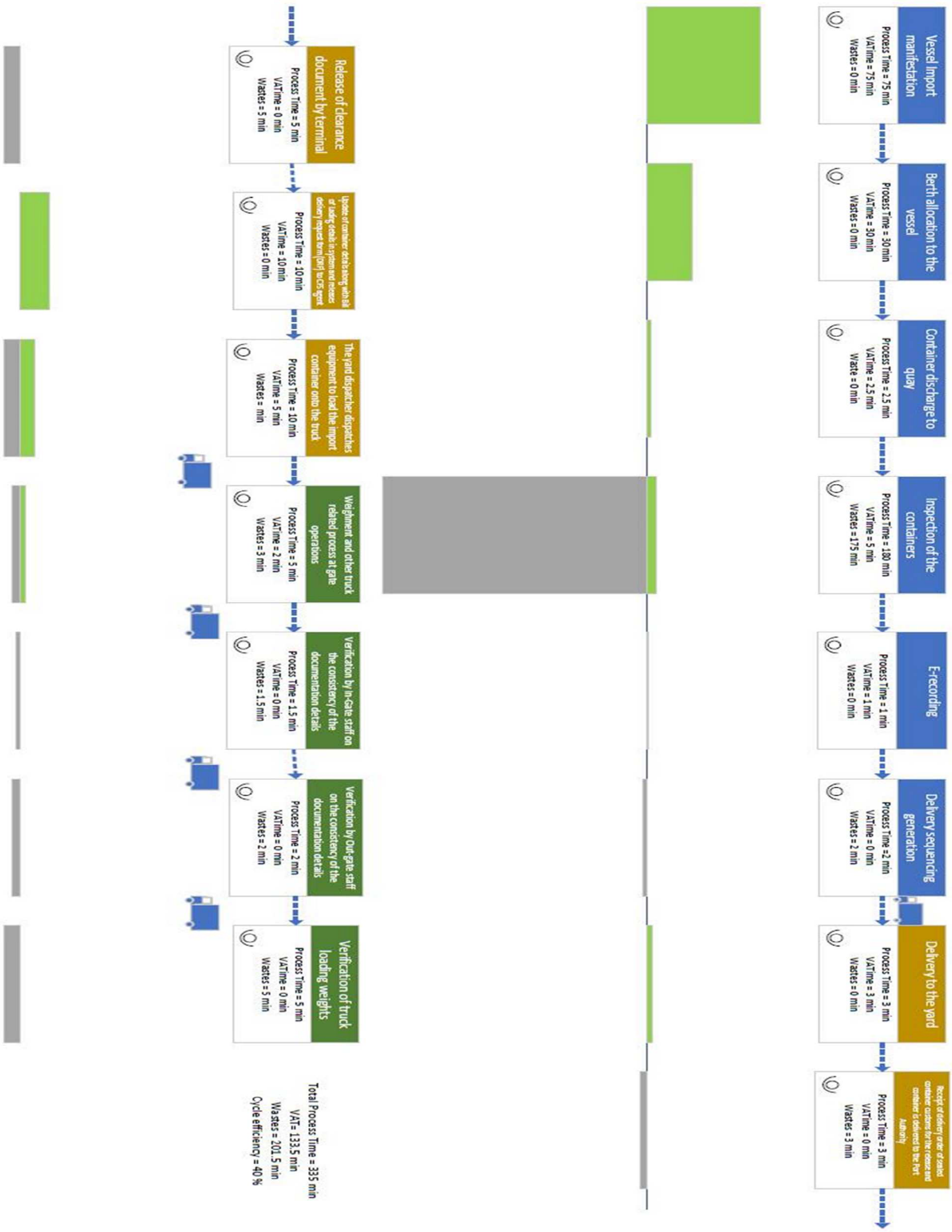

Figure 5 Future Value stream map (Source: Author)