Depot Management in an ISO Tank Container Terminal: Challenges and Opportunities

Rodrigo Pereira do Nascimento
Graduate Program in Computer Science
Institute for Technological Research (IPT), São Paulo, SP, Brazil
rodrigo.nascimento@ensino.ipt.br

Dr. Brenno C. Menezes
Assistant Professor
Hamad Bin Khalifa University (HBKU), Education City, Doha, Qatar
bmenezes@hbku.edu.qa

Abstract

The steep increase in the global tank container fleet, pushes for a precision engineering management of terminals ofISO tank containers on a local and worldwide scale. An ISO tank is a container that is built to the ISO (International Organization for Standardization) stands and designed to carry hazardous and non-hazardous bulk liquids. ISO tanks offer a safe, reliable, and cost-effective transportation package for moving bulk liquids around the world. Several companies are joined to properly transport raw materials and products around the globe, including logistics and supply chain providers as rail carriers, motor carriers, terminal operators, cleaning, and repair facilities, manufactures, brokers, etc. In this paper, we investigate the challenges faced by one of these ISO tank value chain organizations -the depot service providers -in order to find opportunities for improved processes with the support of Industry 4.0 technologies. Inside the depot service facility, such novel capabilities may create an augmented information-driven environment for an optimal operation, thus enabling decision-makers to take actions based on real data provided by daily status updates that will minimize accessorial charges and other expenses instead of human-oriented based decisions and executions.

Keywords
ISO tank container, depot service provider, maritime, IIoT, and optimization.

1. Introduction
A globalized economy involves the transportation of raw materials and finished goods around the globe. For the transportation of gases and all sorts of bulk liquids, tank containers are the most appropriated vessel. There are several types of tank containers to transport various fluids as gases and liquids. Manufacturers must comply with ISO standards to guarantee the tank containers are built following the required specifications to hold and contain the loaded products according to their properties.

According to the International Tank Container Organization (2022), the size of the global tank container fleet in January 2022 was 736,935 representing a growth of 7.3% compared to January 2021.Events such as the COVID-19 pandemic and, more recently, the war between Russia and Ukraine have caused several supply chains issues and increased freight rates, forcing companies to look for alternatives to move products more efficiently. The impact on the global container industry is a shortage of containers. The reasons for the global container industry's supply chain problems have been well-documented in newspapers and trade journals. Increased volumes from a wide range of cargoes from Asia – as well as space-shortages on containerships, port congestion, and inland transport delays – these are all factors which have contributed to increased tank container demand in 2021 (International Tank Container Organization 2022)

Alongside the shortage of space on-board containerships, the tank industry also faces a shortage of tank container cleaning and repair capacity, with investment and expansion of tank depots generally not keeping in line with global tank fleet expansion. The depot service provider is an essential link in the tank container supply chain, but it seems to be the weakest link from a technology perspective. It faces several challenges in keeping up with the evolution and expansion of the other entities involved in the tank container supply chain.

2. Theoretical Review

2.1 ISO Tank Container

According to Huigen (2020), tank containers were designed by Bob Fossey, a younger and enterprising engineer that worked for Williams Fair clough in London. In 1964, Fossey saw the potential for intermodal and multi-modal tank containers. The design of the first ISO tank container happened in 1967.A tank container is a freight container which includes two basic elements, the tank or tanks and the framework and complies with the requirements of the ISO 1496 (International Organization for Standardization 2019). The framework are the tank mountings, end structure and all load-bearing elements do not present for the purposes of containing cargo, which transmits static and dynamic forces arising out of the lifting, handling, securement, and transporting of the tank container as whole (International Organization for Standardization 2019). The tank is the vessel and associated piping and fittings which are designed to contain the cargo carried. Figure 1shows a picture of an ISO tank container.

Figure 1. An example of an ISO tank container.

Although the ISO definition of a tank container only talks about two basic elements (the tank and the framework), there are several other components in a tank container. Figure 2 shows a detailed diagram of its components.

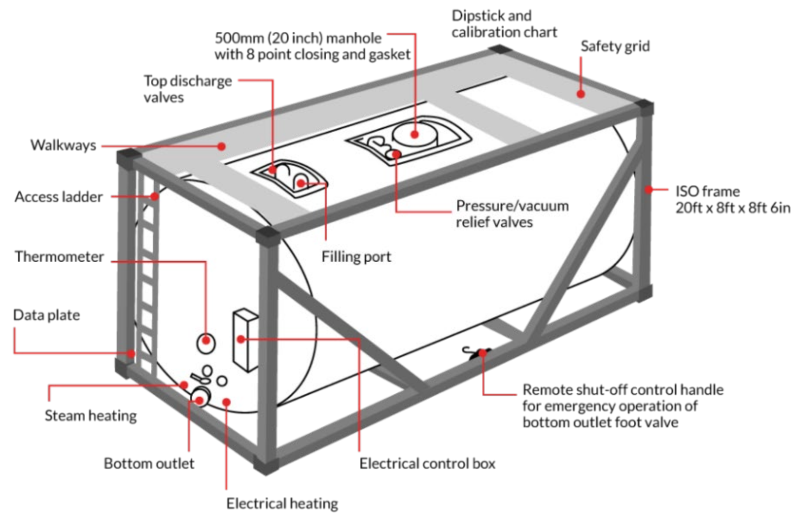

Figure 2. ISO tank parts.

ISO Tank containers carry three types of cargo: liquids, gases, and dry bulk. They are classified according to the type of cargo they are built to carry, and the classification is defined by the International Maritime Dangerous Goods (IMDG) code. Table 1 shows a list of the most common ISO tank container types traveling around the globe transporting goods.

Table 1. ISO Tank Container Classification by the IMDG code.

Tank Container Type	Cargo type
T1	Wine and light liquids
T4	Non-hazardous edible and non-edible oils
T11	Non-hazardous chemicals
T14	Hazardous chemicals and acids
T50	Liquefied petroleum gas, and ammonia gas
T75	Cryogenic; liquefied natural gas, ethylene, and ethane

The IMDG Code was developed as an international code for the maritime transport of dangerous goods in packaged form in order to enhance and harmonize the safe carriage of dangerous goods and to prevent pollution to the environment. The Code sets out in detail the requirements applicable to each individual substance, material, or article, covering matters such as packing, container traffic and stowage, with particular reference to the segregation of incompatible substances (International Maritime Organization 2019).

In addition to all the components mentioned above, there must be a way to identify a tank container for documentation and communication purposes uniquely. The normative ISO 6346 establishes an identification system for freight containers, and it applies to all containers complying with ISO 1496; therefore, any ISO tank container must comply with all requirements established by ISO 6346 for its identification.

The identification code is comprised of:

- An owner or operator code is the first three letters
- A fourth letter is used as an equipment identifier
- A serial number of six Arabic numerals
- A seventh digit (check digit) provides a means of validating the recording and transmission accuracy of the identification code

For instance, the following identification code is a valid code for a tank container: "EURU 146674 0" its owner/operator is a company called Eurotainer.

2.2ISO Tank Container in the Global Supply Chain

There are other alternatives to transport liquid cargo, such as drums and flexi tanks. According to EXSIF Worldwide (n.d.), drums present the following list of issues and concerns:

- **Filling:** Costly and time-consuming with the risk of spillage.
- **Storage:** Expensive, space-consuming, and prone to damage and spillage.
- **Shipping:** The transport of drums is difficult and costly. The risk of damage, spillage, and personal injury is high.
- **Unloading:** Difficult to handle and empty completely with a high risk of injury and pollution.
- **Cleaning:** Expensive and time-consuming to remove residue and clean.
- **Disposal:** Expensive and environmentally unfriendly.

ISO Tank containers mitigate all the issues and concerns mentioned above. They are manufactured using recyclable materials, and by choosing tank containers to move products across the globe, companies can reduce their carbon footprint.In the global tank container industry's workflow, there are five entities involved in the tank container supply chain: tank manufacturers, tank operators, tank lessors, shippers, and depot service providers.

ISO Tank Manufacturers are companies building tank containers following the International Organization for Standardization requirements. The *Global Tank Container Fleet Survey* (2022) states that the Chinese company CIMC Safeway is the largest tank container manufacturer by the number of tanks built in a year.

Tank Container Leasing companies provide tank containers to operators, shippers, and others, usually on contractual term bases, where the lessee takes "quiet" possession and operates that tank as if it were owned (International Tank Container Organization, 2022).

Tank Container Operators are third-party logistics companies that provide a door-to-door service to shippers and others that require transport of bulk liquids, powders, or gases (International Tank Container Organization, 2022).

Shippers (also known as "beneficial cargo owners, "producers, or consignors) are people or companies responsible for transporting cargo from one point to another, usually in terms of exporting and importing.

Depot Service Providers are responsible for cleaning, repairing, components testing, periodic tests, and stowing tank containers until a tank operator or lessor requests one or more for a customer.

Once a tank operator receives an order from a customer, the company triggers the booking of one or more tanks for this customer. Usually, the tank operator requests one or more ISO tank containers (by their ISO tank unique identification numbers) for the depot service provider to supply their customer needs. These ISO tanks are sent to the customer site for loading, then off to their destination. After they reach their destination, they are unloaded/discharged and then sent to the depot service provider for inspection, cleaning, testing, and, if needed, repairing. Figure 3 represents the ISO tank lifecycle in the supply chain.

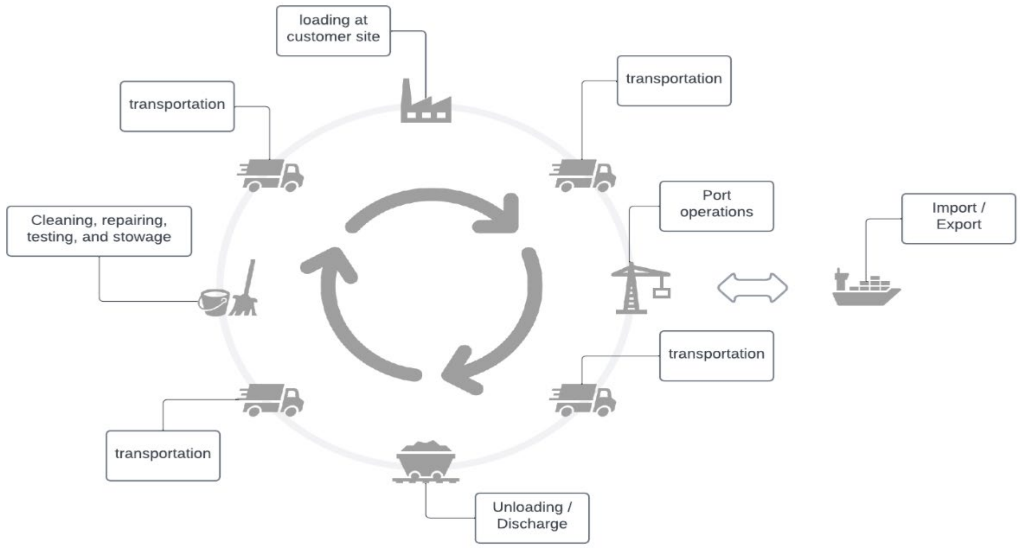

Figure 3. ISO tank container lifecycle in the supply chain.

2.3 Depot Service Provider

Every time an ISO tank is discharged, it must be sent to a depot service provider to prepare it for its next trip. Some tank operators/lessors have a depot service facility on their premises, others will hire a third party, but regardless ofwho will execute the service, the modus operandi is the same.

Cleaning

After the cargo is delivered to the customer, the tank container still contains residue of the cargo's transported material in the vessel, and it needs to be cleaned before the next load to avoid product/cargo cross-contamination. Once a tank container arrives at the depot service facility, it is scheduled for cleaning.

There are several cleaning stations in the depot service facility. The International Tank Container Organization says these cleaning stations must be equipped with all the required health and safety equipment and carry out rigorous safety procedures, including atmosphere monitoring, before allowing personnel to enter a tank. The basic cleaning consists of steaming the tank interior, brushing the whole tank interior using a low caustic detergent, followed by rinsing the tank interior. There are different procedures based on the type of cargo carried by the tank. These procedures are defined by a chemical engineer and verified by local government agencies.

Once the cleaning is done, a tank must be dried immediately to avoid corrosion issues inside the stainless-steel vessel. All the residue carried out during the cleaning process should be collected, treated, and properly disposed of to avoid environmental damage.

Component Testing and Repairing

Every time a tank container arrives in the depot facility, it is inspected. The inspector looks for structural damage following the safety standard created by the International Maritime Organization under the International Convention for Safe Containers (CSC).

The CSClists all the components (Figure 4) that should be inspected for serious structural deficiencies for the following components:

- Top rail
- Bottom rail
- Header
- Sill
- Corner posts

- Corner and intermediate fittings
- Understructure
- Locking rods

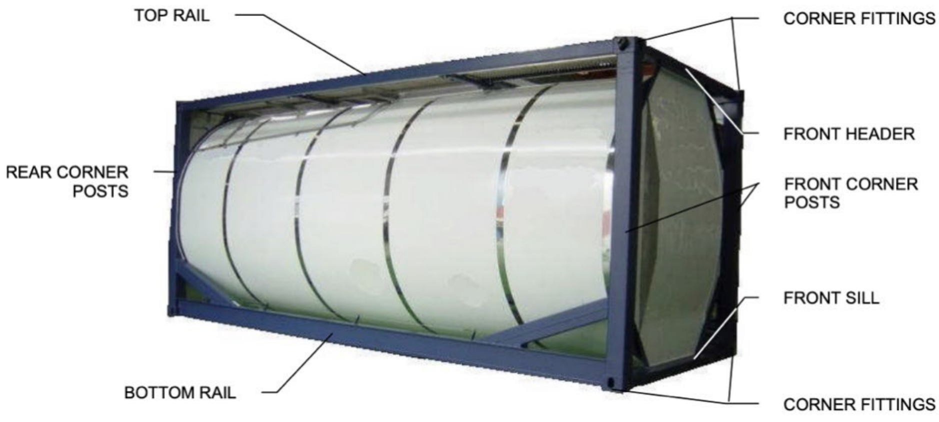

Figure 4. ISO tank components listed 1 in the CSC document.

Any severe damage in any of the parts listed above can create a situation where lives can be at risk giving the port authority the right to stop the transportation. Repairing is an essential service provided by the depot to keep a tank container in shape and available for service following the CSC guidelines.

Stowing
After the cleaning, testing, and repairing are completed, the ISO tank will sit in the yard container until a tank operator requests one or more tanks for a customer. The yard container is a large piece of land where tank containers are stowed. Usually, the space is divided into sections like in a parking lot, and tanks are stacked up. A stack may contain up to five tanks, but it may depend on the capacity of the stacker equipment used by the depot facility.

Each depot defines its own method of picking the location where to put a tank. Some will divide the space by tank operator; some will let the forklift/stacker operator decide which location he thinks is the best to put a tank in the yard container.

3. Decision Support System for Depot Management of an ISO Tank Facility

The goal of depot service facility is to make ISO tanks available for trips as soon as possible. Having a decision support system helping with making better decisions to improve service execution times seems to be totally reasonable. Figure 5 shows the workflow of a depot service facility.

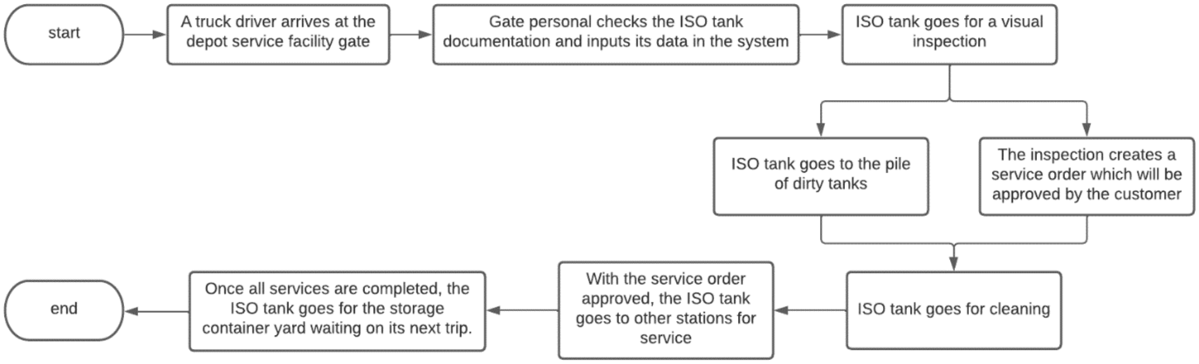

Figure 5. Service Workflow.

Once a truck driver arrives at the gate, a person gets the information required to handle the ISO tank in the facility. They collect data about the ISO tank, and the truck driver. This is the first point of data entry into the depot management system.

Next, the ISO tank goes to the inspection area waiting until an inspector comes to do a visual inspection creating a service order in the system. From a system's point of view, there is not enough information to understand how long an ISO tank waits for inspection, and how long is the inspection process per se, meaning the only time related information available in the system are: (a) the date/time an ISO tank arrives at the gate, and (b) the date/time the inspector created the service order.

Similarly, there is not enough information to evaluate service efficiency along the service workflow, mostly because the information required for such evaluation is not available in the system. To be able to create a decision support system for a depot service facility, it seems crucial to automatically track the ISO tank movements in space and time inside the depot service facility.

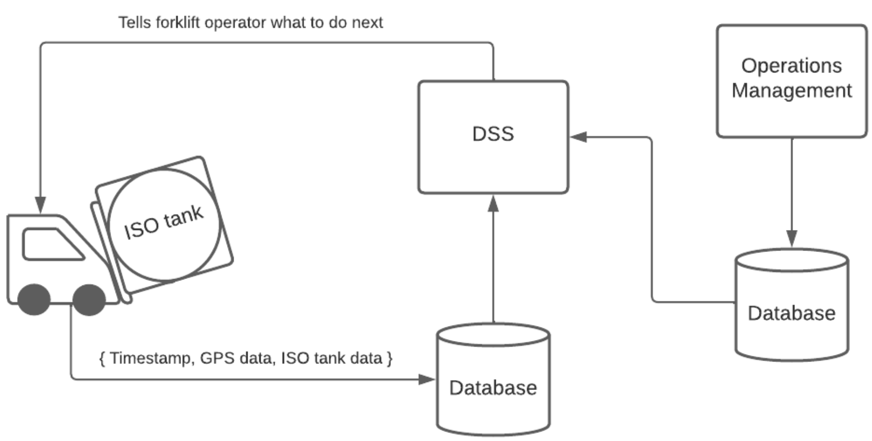

Figure 6. High-level Decision Support System (DSS) workflow

By combining and analyzing the spatial and temporal information with the operations management information (Figure 6), a decision support system can make recommendations to the forklift operator about what to do next with an ISO tank perhaps minimizing the amount of forklift movements inside the depot service facility.

4. Depot Service Operation Challenges and Opportunities

The main question is: "how do we minimize service time for all services without compromising the quality of service?"

Fora proper match of the service time, determining when a tank is placed on cleaning, or repairing, or testing station is fundamental. This also includes when the tanks are prepared to leave these stations. By tracking tanks' movements, assignments, and any other logistics operation inside the depot service facility using IoT devices, a better decision-making of the steps of the operations can be made.

Communication and computing capabilities to track tanks inside the depot services facility without or with minor human intervention may be challenging. Existing solutions relying on RFID technology would require changing some workflows because it would demand the attachment and removal of the RFID tag from the tank container. According to Wang et al. (2006),some practical and critical issues need to be addressed, with the main issue being the high cost of RFID active tags and readers, making the adoption of this solution by a depot service provider impracticable.

Considering the maturity level of the industry 4.0 and artificial intelligence, it is an opportunity to use computer vision techniques to read the tank container's identification number and record its ID and location information on a database. By tracking the tanks' space and time variations, it allows the development of key performance indicators (KPI) for their logistics operations. Currently, the depot service facilities operate without a systematic database on the tank locations and the operation itself. Below is a list of possible KPIs for monitoring the operations performance:

- Average handling in/out time
- Average cleaning time
- Average repairing time
- Average testing time
- Residence time in the storage container yard
- Average residence time in the storage container yard per tank operator/lessor

When determining the average time to clean up a tank (containing residue of a specific type) can enable the operations manager to plan the allocation of the cleaning stations ahead of time. Information such as the residence time per tank, average residence time per tank operator/lessor, tank's location in the storage container yard, and the forecast of requested tanks per tank operator can be used by a decision support system to help define the best location per tank in the storage container yard. Having the information about all tanks' locations at any given time presents an excellent opportunity to create a depot service provider digital twin. A digital twin would allow a depot service provider to simulate changes in the depot service facility, such as increasing the number of cleaning stations or adding a new street for forklift/stacker transit, and understanding their impact before actually dedicating financial and people resources to execute them.

5. Conclusion

It seems possible to improve service times by adding technology to the depot service provider facility. The tanks' location and all their events over time are crucial information for the depot service operations. It gives the ability to create key performance indicators for monitoring the operations providing data for the operations manager to make better decisions. It enables optimizations in the yard container space planning, focusing on reducing forklift/stacker movements, perhaps causing a reduction in CO_2 emissions. It powers the ability to create a depot digital twin that can be used to simulate improvements in the facility. The digital twin can also be used by tank operators/lessors to visualize the position of their tank containers in the yard container before booking tanks for a customer.

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Biographies

Rodrigo P. do Nascimento is a Master student of Applied Computing as part of the Computer Science program in Institute of Technological Research (IPT). Currently, he works at NetApp, Inc. as senior software engineer dedicated to measure systems' performance for several NetApp products and solutions with emphasis on Internet of Things systems. His current fields of research are the areas of Industrial Internet of Things, optimization, and machine learning.

Brenno C. Menezesis an Assistant Professor at Hamad Bin Khalifa University, college of science and engineering, division of engineering management and decision sciences (Qatar).Heholds a BSc and an MSc in Process Engineering from Federal University of Rio de Janeiro, Brazil. He has more than fifteen years of international experience as a process engineer and researcher in Smart Manufacturing and Engineering Management. Dr. Menezes has published many papers in top academic international journals, such as Computers and Chemical Engineering, Industrial Engineering Chemistry Research, and Computer Aided Process Engineering, among many others. His current fields of research include the areas of simulation and optimization, LNG value chain, precision agriculture, and machine learning.