"Tracking and Fleet Optimization of Reusable Transport Items in the Shipping Industry"

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ABSTRACT

This thesis explores the strategies, methodologies and tools for an optimal management of Reusable Transport Items, such as containers or chassis, in an extensive multi-depots network. We use an ocean shipping company operating globally to propose a broad, comprehensive and integrated system for an optimal management of the fleet, embracing technology, processes and monitoring system.

The ability to track these assets is the first step to visibility and fleet optimization and we will question the opportunity for a company to invest in a real time tracking technology. In highly complex logistic networks, the challenge is to get the right equipment at the right place at the right time, in a cost efficient manner and with a fleet size as small as possible. Beyond increased visibility through tracking capabilities, we show that choosing an appropriate utilization metrics helps identify and quantify other areas of improvement. Using actual data, we evaluate to what extent the fleet size can be reduced by improving asset utilization and how leasing also impacts operating costs. We also show how the structural imbalance of trade (some regions being net exporters while others are net importers) impacts both global repositioning policy and local inventory policy, with depots of different profiles requiring different policies. Understanding this systematic and systemic approach of fleet management, we assess the contribution of tracking technology capabilities to these potential improvements.

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Contents

List of figures and tables

1. Introduction and motivation

Most major ocean shipping companies have to manage transport items they use to handle and carry their customers' cargo. The boom of volumes moved globally makes this issue even more significant and complex and heavy to manage. The complexity of this problem is a direct consequence of the structural trade imbalance. Some regions export massively, while others import massively. The pattern is the same for containers, chassis or other RTIs, even if the structure and flows might be different in each case, probably because of the different nature of products carried by different shippers. As a result, when a chassis or a container has reached its final destination and is staying empty in the destination depot, companies need to reposition it empty to a depot where it will be used for a new shipment.

Figure 1 shows the trade imbalance in the containerized business. As mentioned above, this imbalance concerns both for containers of for chassis. We can see for example that, in 2009, 11.5M containers were shipped from Asia to USA, but only 6.9M were shipped back from USA to Asia. And the flows from USA to Europe did not compensate for this accumulation of empty containers that will have to be repositioned empty to export regions.

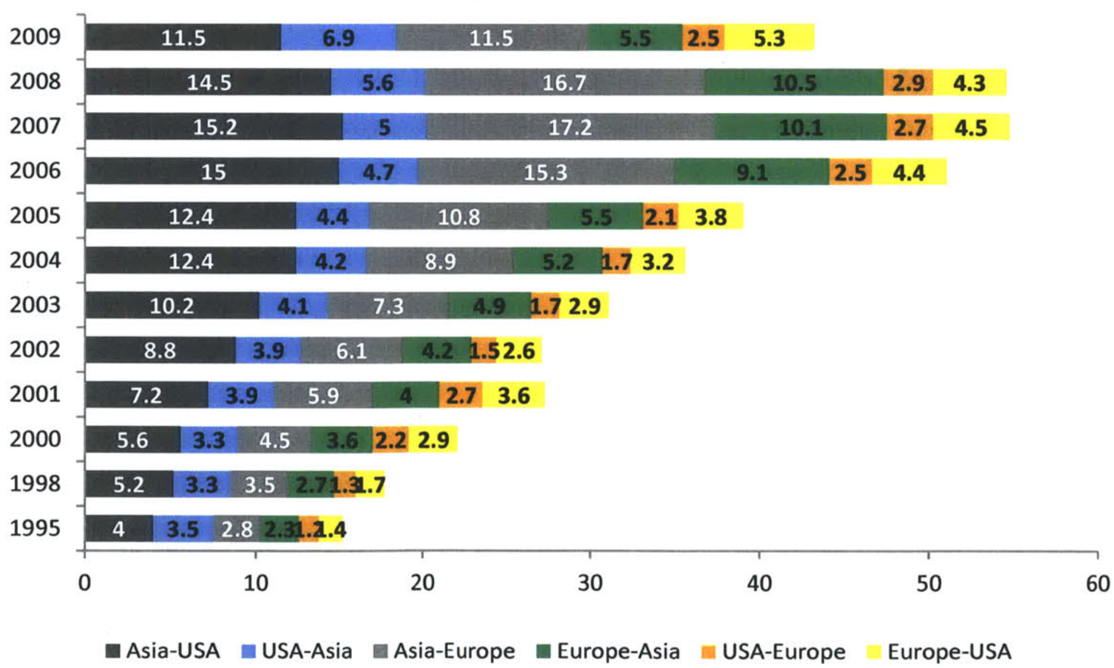


Figure 1: Containerized cargo flows along major trade routes, 1995-2009 (in million TEUs)

The structural trade imbalance in ocean shipping especially, massive flows of RTIs from port to port (in a many to many relationship) and increasing number of transportation assets used require companies to be able to track, manage and reposition empty containers efficiently, with the ultimate goal to have the right equipment at the right place at the right time, in a cost efficient manner. Each asset might follow many different routes, and companies need to know where these assets are and how they are used (their status) to be able to reallocate them to the right location. Similar concerns affect trucking and rail industries as well.

In this thesis we will study the case of an ocean shipping company (The Company) operating globally. The Company ships, among others, break-bulk cargo (locomotives, yachts, multi-tons steel plates, cranes…) that need specific, heavy and expensive chassis to be handled.

As the other ocean shipping companies, The Company has to address complex issues regarding the management of this fleet of chassis. The Company operates in tens of terminals, with tens of vessels, and thousands of chassis. However it happens that The Company loses track of some chassis. "Lost" items can embrace chassis that will never be recovered (stolen or used erroneously by another ocean shipping company…) or misplaced (supposed to be in a location of The Company's network, but physically in another one). This purely operational issue raises the question of The Company's ability to track each chassis, and of which appropriate technology could help track and recover lost or misplaced items. Real time technology is available for that purpose and can provide continuous tracking through autonomous devices. The Company is currently using a half-manual tracking system, which provides many information regarding the status of the chassis (is it empty or filled with cargo, sailing or in port for example), the last location where the status was updated and the date it was updated. This means that knowing the exact location and status of each asset relies on the accuracy of the data recorded in the system, knowing that some terminals are using scanning devices for updates, while others record updates in the system manually.

Tracking and improved visibility should allow The Company to operate more efficiently and, as a result, reduce the cost of operating the fleet of chassis. In this thesis, we will evaluate the costs and benefits The Company could get from a real time tracking technology. Then we will identify the drivers of the fleet costs. We will evaluate the benefits The Company could get from optimizing the size and utilization of the fleet. We will show that utilization rate is a key component determining the size of the fleet required to manage a given volume of demand. Therefore it is critical to use the appropriate metrics to measure asset utilization. Based on tracking data available, we will first evaluate actual asset utilization and the study how optimizing this utilization can significantly reduce the costs of operating the fleet. In addition to savings based on improved asset utilization, we will show how leasing policy impacts operating costs. Leasing is bringing another factor of complication in fleet management. Leased assets are operated the same way as owned assets only until they have to be redelivered and steered to a predefined location. So when analyzing the contribution of improved visibility over fleet sizing and costs, we will also evaluate the potential benefits The Company could get from optimizing the distribution of owned versus leased assets, knowing that leasing a chassis is more expensive than owning it.

Contribution of this thesis

This thesis will help understand the complexity of operating reusable transport assets, and should help shipping companies identify key drivers they can leverage to operate in a more efficient manner. It explores the strategies, methodologies and tools for an optimal management of Reusable Transport Items, in an extensive multi-depots network. Using an ocean shipping company operating globally, we propose a broad, comprehensive and integrated system for an optimal management of the fleet, embracing technology, processes and monitoring system. Understanding this systematic and systemic approach of fleet management, we assess the contribution of tracking technology capabilities to these potential improvements.

In the first section, we will perform literature review presenting how research has addressed this issue of transportation asset tracking and optimization. The second section presents the method we used to assess key metrics of fleet management, and supporting models that could be used to optimize the fleet inventory. The third section is dedicated to describing the key sources of complexity in managing reusable transport items in general and for The Company in particular. We then present tracking technologies, starting with The Company's existing tracking system to elaborate then on real time tracking technology, its expected benefits and costs. In the fifth section, we analyze The Company's tracking data to identify key drivers of costs, and evaluate key areas of improvement and savings. We will finally perform a synthesis of our findings and recommendations in the last section.

2. Literature review

Introduction

Fleet sizing of transport or handling equipment (containers in the ocean shipping industry, chassis in trucks or railroad companies, empty cars for car rental companies, and so on…) has inspired much research and many studies. Research has explored the issue through many different approaches, for example: technologies used in different environments, technical descriptions of these technologies, building mathematical models to define the optimal fleet size of containers or empty cars, description of the closed supply chain loop and ways to monitor and optimize this loop, optimal repositioning of empties policy, or specific fleet sizing models for specific industries or environments. Some research looks at several issues together. Jing-Xin Dong and Dong-Ping Song (2009) for example built a complex model combining both fleet sizing and empties repositioning policies. Based on a case study, O. Johansson and D. Hellström (2007) evaluated the benefits of implementing a tracking technology.

In this thesis, we will build on the available research by analyzing The Company's specific activities, processes and data, in order to bridge all issues regarding the management of reusable transport items, from tracking to improving asset utilization and reducing operating costs. We want to mention here that we found different definitions of the acronym RTI in different research papers: Returnable Transport Item or Reusable Transport Item. The comment might seem innocent, but we think the distinction between returnable and reusable has a great impact on the analysis of our problem. *Returnable* item implies items evolving in a closed loop supply chain and returning to their original location in a predefined way. In our case, the items *do not* return to their original location but might be affected to many different destinations, either empty or filled with cargo. This uncertainty in the flows of each item brings a very high level of complexity in fleet sizing and repositioning models. We will elaborate further in our thesis about the complexity of these flows in The Company's environment.

In this literature review, we present studies and research that have addressed our current problem or a part of this problem. The first section presents a general landscape of the technologies that are being used to track assets, especially for ship liners using containers. The second section presents the bridge that can be made between the pure tracking technology and the financial benefits that it might generate. This section will question the notion of visibility, as opposed to tracking. The last section presents the most recent research that has been done to address issues of fleet sizing and repositioning of empty equipment.

2.1. Tracking technology

Tracking technology is employed to provide visibility. Broadly, there are three ways used to track returnable assets in the ocean shipping industry. These are manual tracking, tracking with RFID (radio frequency identification), and real time tracking such as GPS (global positioning system).

Currently The Company tracks its trailers and other assets manually. This is usually done by documenting or scanning equipment numbers when the trailer status changes and then keying moves or updates into the asset management system. The drawback of this tracking method is the risk to data integrity, which can be caused by the time delay between physical checking and system input as well as by human errors. There are discrepancies between physical status and system information, which sometimes cause confusion and lack of accuracy in inventory planning. Having workers go out to the port terminal to track trailers is also time consuming and costly. This is also why The Company has been looking for a better way to track the fleet. Based on historical data we analyzed, the current tracking system that The Company is using provides an accuracy of around 98%, which is already a very good performance for a manual tracking system.

Jon Pizzagalli evaluates the opportunity to implement a system to track equipment, material and other resources on construction job sites. He specifically analyzes how and to what extent a bar code based system can bring both significant financial and operational benefits to the construction industry. The author notes that a bar code system might be appropriate to track assets in simple logistics networks, with just a few basic flows, and that this system requires wide-spread tools to read them across the network, which is a major limitation in our case.

Another method is to utilize RFID technology. RFID has been widely used in warehouse management and store management in recent years. To effectively use RFID to track an item, the tag cannot be blocked by another metal object, and the effective distance needs to be short in order for the reader to be able to read the tag, at around 40 feet. Research has proposed that RFID technology be used on container tracking and this is further supported by the fact that all major international trading countries have approved active RFID products based on ISO standards. The global RF community is moving to authorize the common frequencies to enable RFID usage around the world. It is generally believed that container yards are just too big for RFID tracking to be used. However, by using 'Electronic Product Code (EPC) network', Yuan and Huang proposed to use RFID on containers (Yuan, Z. and Huang, D, 2008). Roll trailers are similar in many ways to containers. They are both used for ocean shipping goods around the world, their usage is essentially characterized by a very high imbalance in trade, need to be repositioned empty to the location where they are structurally needed, and so on… so technologies that successfully track containers could potentially track trailers efficiently as well. RFID might be a cost-effective way to track some specific kinds of assets, but might be not appropriate for assets moving globally in an open network and in a port environment.

The third method is to use GPS tracking. Charles Assaf shows how new technologies in general and GPS (Global Positioning System) in particular have brought about major improvements in tracking systems, by enabling users to monitor any web-enabled device in real time.

GPS tracking has been largely used in the ocean shipping industry to help track containers, and the GPS devices used on containers provide more information than just location. Depending on the container type and the cargo inside, GPS devices can be used to send information on temperature, humidity, number of container doors opened and closed, etc. This information is critical for container tracking, but may not be useful for chassis. We mostly want to know the location of a particular chassis, and whether there's any cargo loaded on it or not. There are a full range of different GPS products in the market, from the most sophisticated ones which can provide many kinds of intelligence, to the simplest form in which the device provides only the real time location of the equipment. The cost of GPS devices varies a lot, too. For the application suitable for The Company case, we think the basic simple devices are probably sufficient to carry the information needed. We care about the responsiveness, precision, and cost of a particular GPS device.

Research shows that GPS tracking also has its own risks. Users rely heavily on the subscription service and the reliability of the technology itself might be an issue (James Caroll, 2006). Caroll also explores the different scenarios in which a GPS system may work well versus those in which it cannot be used properly. For example, the frequency of data transmission, the exact type of information transmitted, etc. System integrity and the work procedure are also discussed from the users' perspective. The insight is important to the The Company research project as what's required is a stable, practical system that can provide visibility. The potential risk should be minimized and communicated sufficiently to both the end users and to management to manage expectations.

Of these three options, GPS is probably the most expensive, but could provide almost real-time tracking and more accurate location data; RFID is cheaper, but has many technical difficulties to overcome, and successful application in asset tracking has not been proved yet; manual tracking takes time and is prone to human error, while it may be the cheapest way to track the trailers. In this thesis, we will present the costs and benefits The Company could expect in its own environment. Can one or the other meet the requirement of the asset tracking purposes? What's the cost and additional benefit for using a new different technology? Besides the immediate purchasing cost of the devices and equipment themselves, there are some additional sunk or hidden costs to be weighted. On the other hand, the benefits should not be limited to the sole recovery of lost items. We will evaluate how an improved tracking technology can contribute to other major business improvements. So what other changes, both from the work process perspective and from the organizational readiness perspective, are required to make the new technology valuable? These are questions this paper will answer, to help drive future decision makings for The Company.

2.2. Deriving benefits from the technology

The Council of Supply Chain Management Professionals (2009) defines visibility as "the ability to access or view pertinent data or information as it relates to logistics and the supply chain, regardless of the point in the chain where the data exists". This definition remarkably echoes our case, as one challenge The Company faces is gaps between terminal in terms of processes and tools used to track trailers and update the system; so the data actually exists in all points of the chain, but the way it is processed is variable, which might bring inefficiencies in the system.

Asset tracking and visibility have become a significant way to create value in business, thanks to the globalization of operations and increasing volumes of trade. According to Julia Kuzeljevich "...the fastest growing efforts for container tracking will be in asset utilization at port and container terminals which will not apply technology to containers themselves but to the assets that move them – primarily chassis, drayage trucks, cranes, etc... for better scheduling." This remark strengthens the criticality of having the right equipment at the right place at the right time, as well as the importance of planning enabled by increased visibility. David Schrier (ABI Research analyst, "Container Security and Tracking") is confident that "the mass market devices will be those that can provide basic electronic supply chain management at a reasonable cost while working reliably within the port environment". Operational and physical constraints inherent to port and vessels operations will play a major role in the choice of technology to be implemented on RTIs. Schrier's remark is key, as the port environment actually raises several limitation (including physical limitations) that might make the investment in real time tracking technology less appropriate.

2.2.1. Defining the problem

Visibility, fleet sizing and repositioning have been discussed a lot in various research. As research was progressing, complexity of models have been increasing. And more complexity has been added to fit to some specific environments (car rentals, containers loops, returnable packages…). In this section, we want to define some key basic concepts that have been developed in previous studies.

Distribution system

D. Hellström and O. Johansson (2009) identify 3 types of control strategies for RTI systems:

- "Switch-pool" system: when a loaded RTI is delivered, an empty RTI is picked up
- "Transfer" system: the sender has full responsibility for tracking, administering, maintaining and storing RTIs.
- "Depot" system: RTIs are managed by a central depot, which provides empty RTIs to the sender, and collects returned RTIs. Financial incentives are in place to ensure high turnover and returns.

The fleet of trailers used by The Company is arranged in a multi-depot system, as opposed to a star system. Indeed, a RTI leaving from location X will not necessarily come back to the same terminal after its journey. It will be available empty at the destination terminal. Thus The Company follows a many-to-many configuration, with many trailers from many ports potentially heading to many other ports. In this configuration, RTIs can be returned to a terminal which is not the original sender. This remark brings us back to the importance of the difference between *reusable* transport items and *returnable* transport items. Returnable assets evolve in a closed loop supply chain, while The

Company's asset flows are essentially open and uncertain, making the system much more complex, even if some global pattern exist that can help anticipate needs in different locations.

Losses

Ruth Carrasco Gallego and Eva Ponce present three sources of fleet shrinkage:

- "Quality losses" are basically the result of damages to RTIs for which reconditioning is economically not a viable option;
- "Incidental losses" are directly derived from management and organization issues, and typically correspond to misplaced items. For some unexpected reasons, these items are not tracked properly in the system. They are finally declared as lost articles if not found.
- "Structural losses" are stolen items, which happen to be relatively rare in our case.

In our case, the trailers used by The Company can last on average 20 to 30 years with periodic maintenance operations, and rollchassis have a high value; so Quality losses would probably represent a small portion of losses. Structural losses also represent a very tiny portion of lost items; however, these structural losses could include items that are intentionally or not intentionally used by other carriers. So, in our case, "incidental losses" are probably the most common sources of shrinkage or inefficiency. We think the most valuable contribution of asset tracking is in how it can help solve misplacement issues.

Metrics

Gallego also highlights three basic metrics required to manage reusable articles: return rate, cycle time and on-hand inventory at each location. In our case, having the right equipment at the right location (terminal) at the right time is the ultimate objective of RTI management. On-hand inventory at each location is therefore key, and has to be incorporated in a wider global forecasting process.

Fleet sizing

Ability to evaluate the optimal fleet size of a company's RTIs can have significant financial impacts, first regarding the initial investment and capital costs, but also regarding the ability to respond efficiently to demand.

Gallego also indicates that there is no clear methodology in industry for calculating the fleet size of returnable items. Note that she specifically analyses "traditional" returnable articles, such as those used in the beer or grocery industry, evolving in closed loop supply chains. We will see further in the section that highly complex models have addressed the issue of containers in globally opened loops.

Trying to estimate the fleet size of returnable items, the research defines the fleet size as the total number of RTIs required (demand) divided by the number of times each RTI will be used during the same time reference. Then they incorporate safety factors protecting against variability both in demand and cycle time:

$$N = \frac{D}{T} \cdot (1 + k_D \cdot \sigma_D) \cdot (1 + k_{CT} \cdot \sigma_{CT})$$

Where N is the fleet size dimension, D is total demandT the average number of times an asset is used during time t. $k_D \cdot \sigma_D$ and $k_{CT} \cdot \sigma_{CT}$ are the safety factors protecting against both demand an cycle time variability. However, further modeling shall be performed in order to account for seasonality, or any other "predictable" factors.

Bojkow (1991), analyzing returnable containers management, defines the "trippage" ratio as the number of trips made by a reusable article in its lifetime. He provides a basic calculation of this metric, that very few authors have investigated:

$$Trippage = \frac{Ia}{Ia+Ra}$$

Where *Ia* represents the number of items issued during a given time period and *Ia* + *Ra* represents the number of "lost" items during the same period. This ratio helps provide better visibility over the fleet, by providing an input for the evaluation of the fleet size. However, it is applicable in a model where RTIs have to come back to their original location to be refilled. This is not the case in our research.

Pankratz (1991) built a regression model to establish a relationship between RTIs issued and returned. Returns in period t are a function of issues in the previous periods. Returns in period t are a function of issues in past periods:

$$y_t = v_0 x_t + v_1 x_{t-1} + v_2 x_{t-2} + \ldots + N_t$$

Where vi are the probabilities that an article issued in t returns in the system i periods afterwards (so in t+i), and Nt represents noise.

However, again, this system implies that the items return to their origin.

Jagatheesan and Kilcullen (2011) demonstrate how including cycle time variability improves the fleet sizing strategy of a company using railcars.

2.2.2. Visibility: a matter of management

Mc Kerrow (1996), Twede (1999) and Witt (2000) noted that despite their critical importance to distribution and often high value, RTIs are often managed with very limited visibility or control, implicitly suggesting that significant areas of improvement do exist. In addition, several researchers consider that improving visibility is a decisive lever to realize significant savings in the supply chain. Johansson and Hellström (2007) recall that studies have shown that 80% of operating costs for third-party-owned assets could be saved with better visibility over RTIs' movements and location (Angeles, 2005), and that such visibility also helps minimize the fleet size (Frazelle, 2002). They remark thought that increased visibility over assets is not sufficient alone, and in order to get benefits from it, firms must have the ability to use this information, collect and analyze data. Our thesis also provides a methodology to understand how asset management improvements need an integrated and global approach of the problem.

Johansson and Hellström investigate the impact of asset visibility on costs in a RTI system. They built a simulation model aimed at identifying the most critical parameters (e.g. cycle time, mean time to repair, shrinkage, failure…) in the a given RTI system. Their simulation demonstrates that a system in which management has a tracking system and a lower shrinkage (resulting from appropriate management actions allowed by improved visibility) generates 34% savings on the total costs of the RTI system. In other words, cost can be reduced by 34% if asset visibility is coupled with the proper managerial actions. They also find that replacement costs due to shrinkage (so investments without capacity increase) take a major portion of total operating costs. The authors also remark that the investment in a tracking system generates not only lower costs in replacement (due to lower shrinkage) but also lower investment costs, as a result of a better estimation of fleet size. They find that investment costs in RTIs can be reduced by 52% if the firm makes this investment along with the investment in a tracking system. Note that these are the results of a specific tracking system (RFID and bar code labels with three identification locations) for only one DC operations. In this context, the benefits revealed by the simulation largely compensate for the 2% cost increase for the tracking system itself. The authors also emphasize that "tracking systems do not in themselves provide any benefits". Instead, benefits will come from the firm's ability to use the increased information efficiently. In order for shrinkage to be controlled, continuous management actions are required.

It is important to note though that to get these benefits in this specific environment, they compare a new tracking system with a former system with no tracking capabilities at all (so the starting point for comparison is very low).

2.2.3. Repositioning

Many researchers have investigated the issue of repositioning empty equipment. The increasing trade imbalance and significant costs of repositioning make this issue a critical one for ship liners, and is probably a great opportunity of improvement and source of efficiencies.

Song and Earl (2008) investigated the issue of repositioning empties and defining the optimal fleet size in a two depots system with stochastic demand.

Li et Al. (2004) already incorporated leasing considerations in their repositioning model. They have extended the problem of repositioning empty containers from one port to the other to a multiport scale, starting from "optimal pairs of critical policies" (U,D) where one port orders up to U needed empty containers or exports down to D surplus containers. The optimal solution for one port might actually not be optimal in a multi-ports network. Among other variable, they build a dynamic model incorporating the size of the fleet (number of empty containers available in each port, number of import and export containers in each port at each period), time (the model is time sensitive), costs (costs of holding empty containers in each port, costs of importing and exporting empty containers at each port, cost of leasing empty container per period), capacity (maximum import and export at each port), cost of capital (discount factor). They build a complex mathematical model to minimize the cost of repositioning considering leasing costs versus ownership costs, but they observe that the complexity of such a model makes it difficult to solve and so point out that the models might have some limitation when it comes to numerical experiments.

2.2.4. Complexity of the empties repositioning models

Jing-Xin Dong and Dong-Ping Song (2009) address both defining the optimal fleet size and repositioning policies of empty containers in a many-to-many environment (including many ports, many routes, many vessels…), which all ocean shipping companies have to deal with in a dramatically imbalanced trade system. Both problems are closely correlated. However, before Dong and Song, several papers addressed only one of these two issues. Beaujon and Turnquist (1991) developed a model to optimize the fleet size of a vehicle fleet, and highlighted the correlation between fleet sizing and fleet utilization. Du and Hall (1997) elaborated on an optimized policy to redistribute empties. Dong and Song develop a model addressing both issues simultaneously and specifically adapted to the container fleet in the ocean shipping industry. They approach the problem with a discrete, event-driven model, as opposed to a continuous model. The whole system is actually updated when a vessel arrives or leaves the port (event). Their system is built with many different variables, notably customer demand from one port to the other, penalty cost, capacities of the vessels, number of empty and laden containers on vessel and the vessel route.
The models developed in these researches are highly complex and involve a lot of relevant variables.

Much research has built complex mathematical models to define the optimal fleet size of RTIs and repositioning policies in various environments. Others have explored the financial benefits that increased visibility can generate. One condition is companies' ability to use this tracking technology and information efficiently, in order to convert this improved information into improved business efficiency. We will concur with Hellstrom and Johansson that research on asset visibility for RTI systems is still in its infancy and deserves more attention. We also want to think wider in terms of visibility and not only in terms of tracking. Especially, we want to warn the reader that the benefits The Company should expect from an up-to-date technology depend a great deal on its current practices and maturity. In addition, many optimization models have been built based on mathematical solving, but their complexity makes them hard to implement in real life operations. This is one reason why we want in the thesis to provide a wider understanding of the problem.

2.2.5. Leasing considerations

Leasing reusable transportation items is common in the ocean shipping industry, and other shipping industries as well (rail, trucks…). Container leasing has become a profitable business itself. At first sight, leasing can be an efficient solution to address high demand variability or seasonality. It is also a response to the structural imbalance of empty assets among ports. One issue would then be to define the optimal size of the leased fleet as opposed to owned assets.

Not only are the leasing companies expanding due to increasing trades, they also expand their range of services, from simple equipment leasing to consulting or software products to help ship liners to manage their fleet. Some are even taking in charge the repositioning of empty containers for customers or for themselves. In 2002, lessors would actually control 40% of the total fleet of containers operating globally, the other 60% being owned by the shippers themselves (Chris Dupin, The Journal of Commerce, October 2002).

In this thesis, we want to present a global comprehensive system for the management of a fleet of RTIs, including the leasing consideration. Using the case study of a global company, we will approach the issue as an integrated management system. This thesis will build on the existing research by questioning the benefits of a real time tracking system, identifying and quantifying some key areas of improvements regarding asset utilization and fleet cost, and providing an integrated approach embracing technology, processes and monitoring system.

3. Methods

One objective of this research is to evaluate the opportunity for a ship liner operating globally to purchase and set up a new tracking technology so it can better control its fleet of reusable transportation assets. In deciding whether to invest in a new technology or not, a company needs to weigh the costs (direct and indirect) resulting from the technology, and the expected benefits. The preceding literature review shows that these benefits should derive from The Company's being able to confidently locate and track its assets, and to improve asset utilization. In this thesis we will proceed in three steps. First, using the tracking history of the whole fleet of chassis, we will present and evaluate the activity of the fleet. Then, using sensitivity analysis, we will evaluate how higher visibility and better tracking can improve operational efficiency (including reducing the global fleet size and increasing asset utilization…). Finally, we will present different inventory and repositioning policies that could help manage the fleet more efficiently.

3.1. Historic data and process analysis

In this first section, we will use the following available data:

- Tracking history of the whole fleet, in which we use the following information over one year:
    - **Equipment identification number**, ensuring that we track each asset individually
    - **Equipment type**: we analyzed data concerning several types of chassis: 20RT (20 feet roll chassis), 30RT, 40RT, 60RT, 62RT, 72RT, 75RT, and 80RT
    - **Activity code**: this code depicts the status of an asset at a given time. For example, this code tells us if a specific equipment is loaded on ship, empty, or lost…
    - **Activity date**: this is the date of the status (activity update). For example,

ACTIVITY CODE	DATE ACTIVITY
ONLS	4/19/2011

      means that on 4/19/2011, this equipment was updated to status ONLS. We will provide below the meaning of all available statuses.
    - **Port**: is the location where this status update was recorded
- **Trailer fleet cost structure** will provide information regarding the total cost of operating a roll chassis, with a distinction between owned and leased equipment. This distinction plays a

major role in our analysis. Starting from an average cost per lift provided by The Company and broken in several cost drivers, we split this average cost to derived a cost per lift for an owned trailer, and a cost per lift for a leased trailer. Some costs, such as stevedoring or regional positioning costs are the same whether the chassis is leased or owned. On the other hand, the capital cost applies only to owned chassis, and rental costs apply only to leased chassis.

- Process analysis, based on:
  - Site visits and interviews in 2 terminals
  - Supporting tools used by the fleet management team to manage the repos and bookings

Using this tracking history of all assets in the fleet, we will provide some synthetic representations of the activity and relevant metrics. These metrics should then help evaluate the potential benefits of a new tracking technology.

The existing tracking system provides detailed data regarding the different statuses in the life span if a chassis. We found 29 activity codes used over the three years data we analyzed. In order to simplify the understanding of our results we established a correspondence between each activity code and a status we thought to be relevant to understand the life span of a chassis. We divided the life span of a chassis in six relevant possible statuses that we think are the statuses we need to monitor to optimize the management of the fleet:

- Sailing cargo: the chassis is loaded on a vessel with cargo
- Sailing empty: the chassis is loaded empty on a vessel for the purpose of repositioning
- Used by third party: the trailer is subleased out; The Company has no further details about the status of this trailer.
- Waiting in port empty: the trailer is empty in a terminal and not used by cargo
- Waiting in port to be shipped: the trailer is filled with cargo but has not been loaded on a vessel yet
- Waiting in port to be unpacked: the trailer has been unloaded from a vessel to the ground, but is still busy with cargo, waiting for the customer to come and pick it up.

We will use these correspondences to analyze the life cycle and utilization of a chassis.

The existing tracking system (detail in section 6.1) provides the date of each activity change. For example, when a filled chassis is loaded on the vessel, its status is updated in the system with the date of this change. This allows to track the time spent under each activity code for each chassis, and therefore to calculate the actual utilization of the chassis. Consolidating this data provided for each chassis, we can then evaluate the global utilization and status of the fleet. This information is critical to estimating fleet size requirements.

3.2. Cost benefit analysis

We will perform this analysis in four steps:

1- Estimate the cost of investment in the new technology and compare it to the direct or immediate (though limited) benefits we can expect from it, which is the ability to recover lost items, and calculate a break-even point at which the investment is worth.

2- What is the impact of a higher utilization of each asset on the global operating cost and fleet size? In other words, how is the fleet size sensitive to individual asset utilization?

3- How is the operating cost sensitive to the leasing policy? In other words, what is the impact of reducing the portion of leased assets in the global fleet, as we know that leasing is significantly more expensive than ownership? Based on the cost structure (cost per lift) provided by The Company, we calculate the cost of operating a leased chassis as opposed to an owned chassis. From this cost, we can simulate a new average cost per lift changing the distribution of leased vs owned chassis, the global total fleet remaining constant.

4- To what extent does a new tracking technology contribute to these operational and financial improvements? In other words, how can the new technology affect the different levers that have an impact on fleet size and operating costs? It is indeed critical to evaluate how useful a real time technology would be, in other words, how often The Company will need to use this technology to locate an asset. The Company will need this functionality when a chassis cannot physically be found where the system tells it should be. We need to identify in the data how many chassis are lost or misplaced.

3.3. Global fleet sizing and local inventory policy

3.3.1. Global perspective to evaluate potential benefits on fleet size

In order to evaluate the potential savings The Company could make regarding the fleet size, we use a basic relationship between fleet size, global demand and utilization rate.

Fleet size is actually a function of the number of lifts over a period and of the time each lift is going to utilize the asset. This simulation will provide a rough average estimate of the sensitivity of fleet size to asset utilization, regardless of cycle time variability and demand variability, which would require further study using The Company's actual data.

3.3.2. Local perspective for terminals' chassis inventory

Traditional inventory models which could be useful to estimate a safety stock in each port or terminal. Can we define a safety stock policy for globally operated reusable transportation items? In traditional inventory models, safety stock is defined as: $Safety\, stock\; = z\sqrt{\sigma L}$, where:

- Z is a safety factor, function of the customer service level (CSL)
- σ is the variability of demand. In our case, this variability would incorporate both variability in demand for empty RT requested by other ports and variability of demand for fillings (so using an empty RT available in the terminal to load cargo on the ship).
- L is the lead time: in our case lead time would be the time needed for an empty RT to be delivered at the terminal, or time for a RT to be repositioned from one port to the other.

As we know, the flows are highly imbalanced, so some port might not need to hold an inventory of empty RT. Safety inventory in each port or terminal should consider not only single supply and demand. Time constraints are critical in understanding needs for empty RTIs. Actually, the quantity needed in each port is essentially composed of the inventory actually there, the number of empties that might be currently on ship, on their way to this port, incoming cargo to be delivered and unpacked in the port, time at which RTIs are needed (when the next ship will leaving).

We will pick three representative ports (one is a net importer, one is a net exporter and the last is fairly balanced) and analyze the behavior of their incoming and outgoing flows of chassis. In order to do so, we will use average weekly demand (how many chassis are used to load cargo) and weekly supply (how many chassis are delivered). Specific behaviors should lead to defining specific inventory and repositioning policy for different profiles of ports.

4. Key sources of complexity in RTI management

4.1. General overview of a RTI life cycle

Dr Jean-Paul Rodrigue describes three types of container flows, each with a specific repositioning policy.

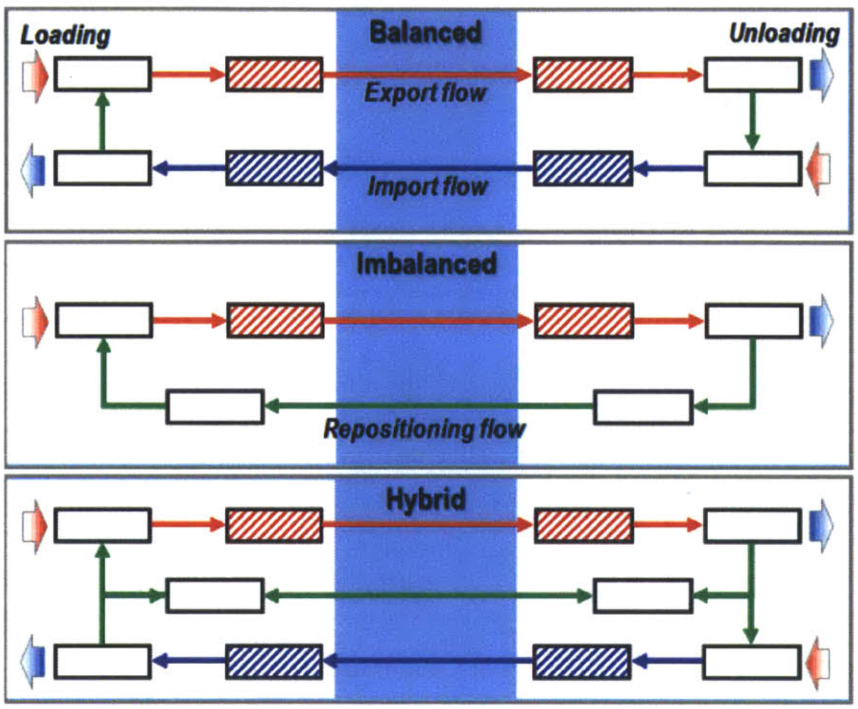
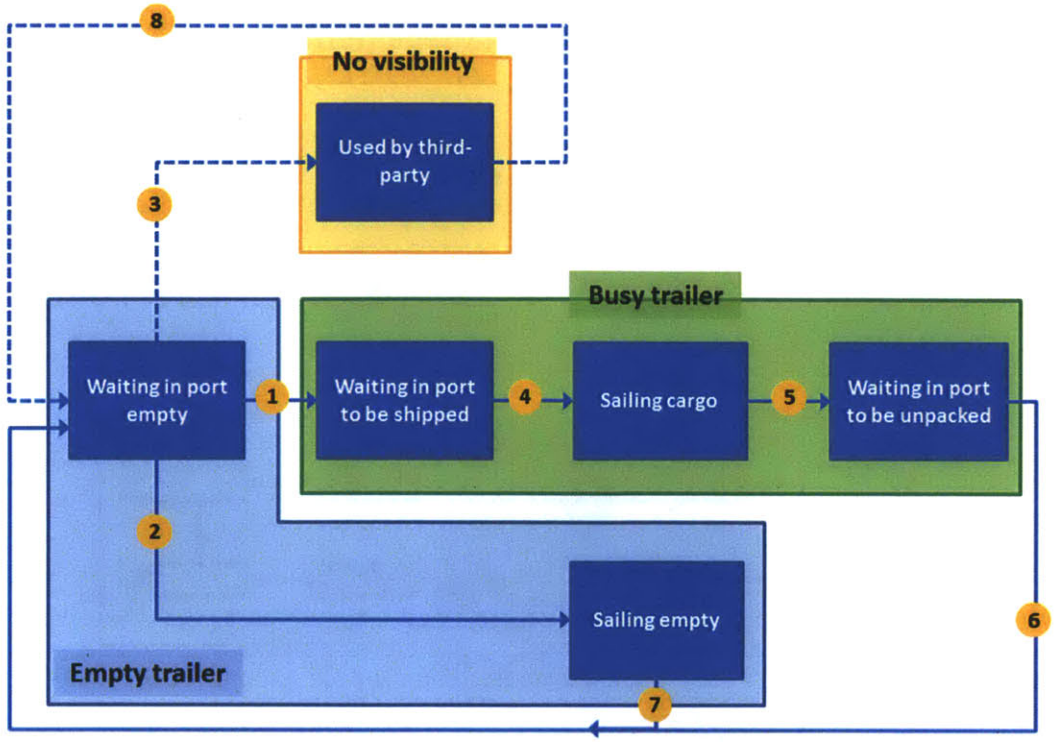


Figure 2: Types of container flows and repositioning

Source: Adapted from Alexander Kuznetsov, Admiral Makarov State Maritime Academy, St. Petersburg, Russia.
http://people.hofstra.edu/geotrans/eng/ch5en/conc5en/typescontainerflows.html

Figure 3 represents the life span of a chassis in our specific case, based on the statuses we defined earlier.



1	Trailer is filled with cargo but not yet sailing	5	Trailer with cargo is unloaded form ship
2	Trailer is repositioned empty	6	Cargo has been unpacked and the trailer is available empty again
3	Trailer is used is used by a 3rd party and leaves WWL's own network	7	Empty trailer has reached destination and is available empty
4	Trailer is sailing filled with cargo	8	Trailer is returned form 3rd party and available in port

Figure 3: Chassis life cycle

4.2. Management complexity

4.2.1. Process flaws

Through our site visits and interviews, we identified several flaws or events that make the fleet management more complex or that can lead to inefficiencies.

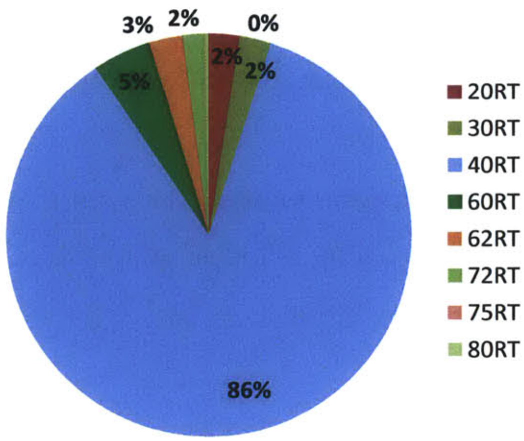
- Inventory policy and practice: all terminals are supposed to count their inventory of chassis every week and transmit this report to the central fleet management team. However, it appears that this policy is not strictly applied. Inventory physical counts are probably not performed in all terminals every week. This gap might lead to inventory mismatches between expected inventory in the system and physical inventory in ports, making the basis for repositioning moves wrong.

- All terminals do not use the same process and/or equipment to update chassis status. Some terminals are equipped with scanning devices interfaced with the system, while some other terminals update the system manually. This might:
    - Delay the update of chassis status
    - Create inaccurate data in the system
- Some erroneous data might be entered in the system, especially errors regarding the chassis identification number, resulting in the wrong chassis being updated in the system and mismatch between physical and system flows
- Some terminals ask for empty chassis because they are net exporters. To respond this need, the central fleet management team orders repositioning flows from terminals to others (with specific origin and destination). However, vessels make several stops in different ports during their journey to this destination. And it happens that empty chassis are taken in a different terminal that also need empty chassis, without notifying the central team. As a result, the destination terminal might wait for example 20 empty chassis, but will finally receive only 18 chassis, as the 2 remaining chassis have been taken by another terminal.

4.2.2. Equipment differentiation

The Company (and most of other ocean shipping companies as well) uses eight different types of chassis, even if the 40-feet chassis accounts for 86% of the fleet. In addition, there are sub-groups based on load capacity within each length family. So there are actually 19 types of different trailers to manage. This obviously brings more complexity in the management of the fleet. Specific cargo needs specific chassis. Having a significant level of inventory of chassis in a specific terminal might be useless if we don't have the appropriate chassis to handle a specific cargo.

Figure 4 represents the distribution of the different types of chassis used by The Company.



Size category (feet)	# different load capacities
20	2
30	1
40	6
60	2
62	2
72	1
75	2
80	3
8	**19**

Figure 4: Equipment types distribution

4.2.3. Leasing consideration

The Company is leasing a significant portion of its fleet. Leasing contracts range from one day to 10 years, the shorter the contract the higher the cost per day, and lessors are located in various locations. Leasing equipment (chassis in our case, but many ship liners lease containers as well) is a widespread practice, and can be used to deal with variability of demand. The price of this flexibility is twofold: first leasing is more expensive than owning a chassis; second leased trailer will have to be redelivered to a predefined location. However the contract can be extended at the end of the initial period. These time and geographical considerations bring additional constraints complexity when managing the global flows of the fleet at a given time. It also requires permanent reliable tracking and visibility of the fleet, as well as the ability to monitor time and geographical synchronization of flows for a large portion of the fleet (portion of the fleet which is leased), so as to carry the trailer back to the lessor's facility.

4.2.4. Trade imbalance

As any other ship liner, The Company's business is characterized by a significant structural imbalance. However, it is noticeable that the imbalance is structurally different from the imbalance observed in the traditional container ocean shipping business (see Figure 1 in introduction). For example, Europe is traditionally a net importer for containers, while it is a net exporter for The Company). This is probably due to the different nature of products that The Company ships.

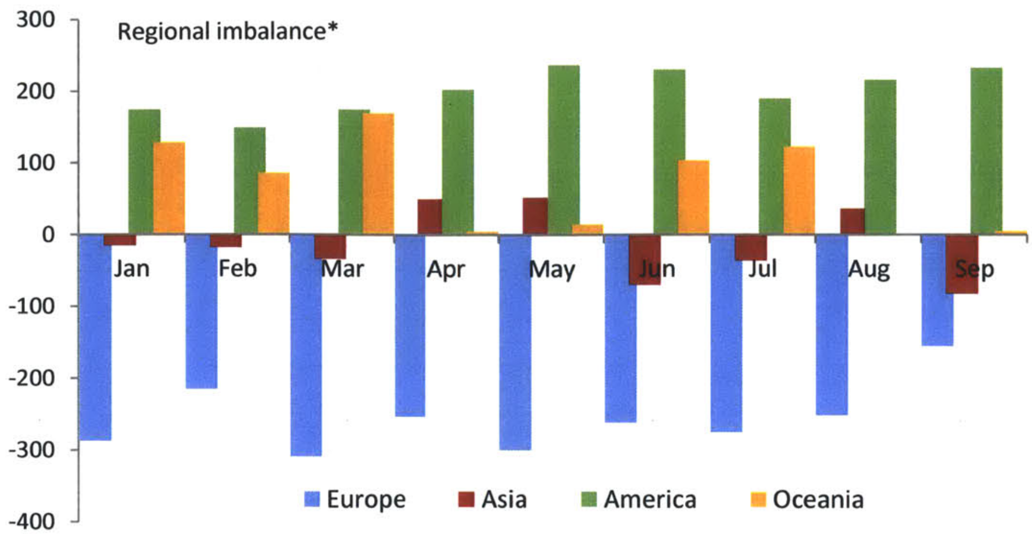


Figure 5: Regional trade imbalance

* Imbalance = Import – Export (excluding lifts in own region)
Source: The Company – Equipment Update GPS meeting Nov 2011

As we explained earlier, this structural trade imbalance is the basic reason why empty chassis have to be repositioned empty, and therefore is what makes the RTI fleet management highly complex.

4.3. Uncertainty and variability

4.3.1. Uncertainty of demand

We characterize demand as the number of loads (a chassis filled with cargo is loaded on a vessel). The number of loads of filled chassis represents the number of chassis needed at a specific time.

Figure 6 represents the global weekly demand. We analyzed demand on a weekly basis, as the week is the standard planning window in the organization (forecast and repositioning moves are made on a weekly basis).

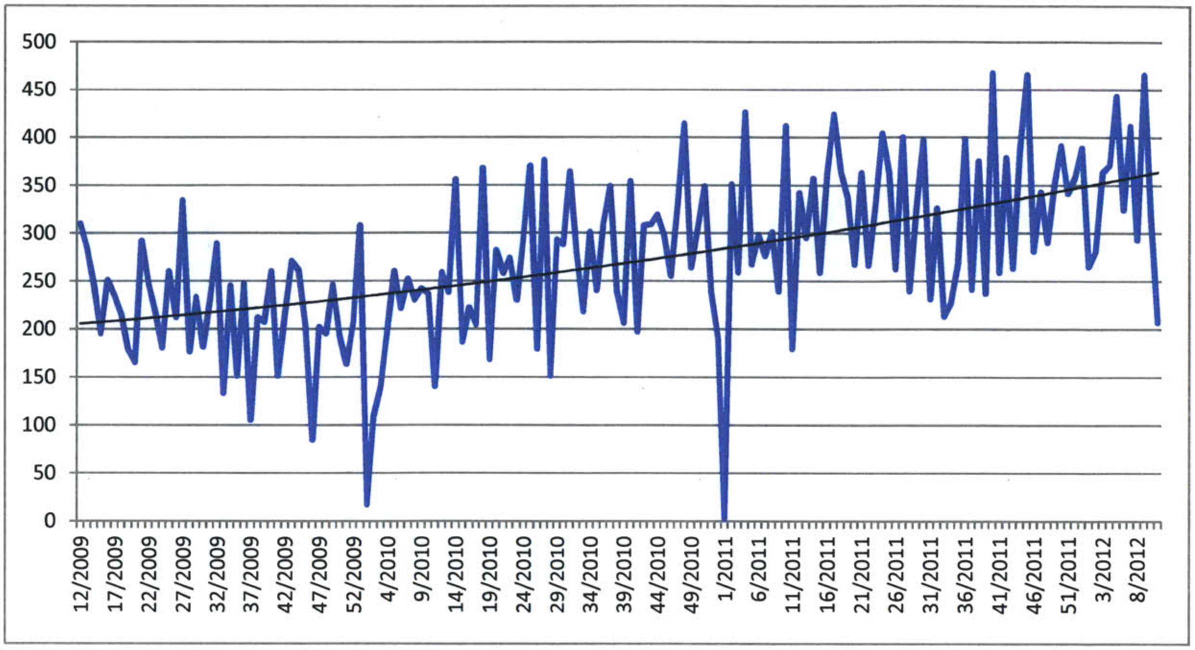


Figure 6: Weekly global demand

We can see that weekly demand is highly variable but has an increasing trend.

Table 1: Global demand variability

	Mean	Stdev	
3 years	273	84.2	31%
3/2009 - 3/2010	212	60.0	28%
3/2010 - 3/2011	276	76.6	28%
3/2011 - 3/2012	332	68.9	21%

4.3.2. Uncertainty of supply

We have described in the previous paragraph what characterizes demand for chassis. We can actually define demand as the consolidated needs for appropriate chassis to handle specific cargo.

Demand is a continuous event, as bookings and customers' request come continuously.

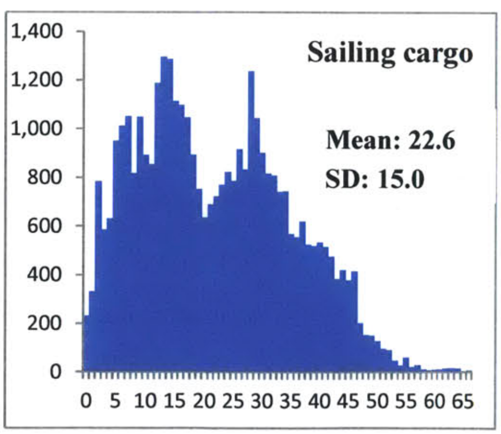
On the other hand, supply is not continuous, as terminals are replenished with chassis as vessels arrive in ports. They receive both chassis filled with cargo that will be unpacked in the terminal (so this chassis will be available for cargo leaving afterwards) and empty chassis being repositioned empty to terminals where they are actually needed.

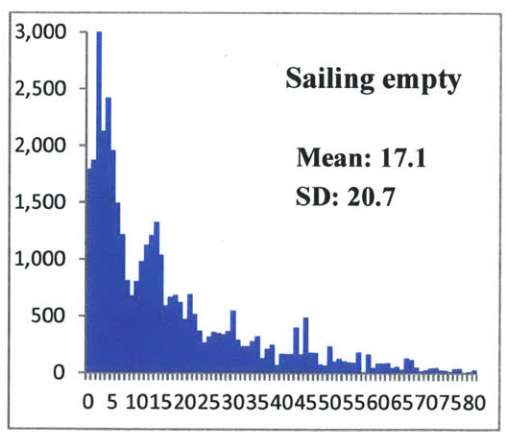
However, this supply of chassis is uncertain:

- It can happen that some chassis that are shipped empty do not reach the terminal where they were initially destined to be repositioned
- The variability of customer demand creates variability in the number of chassis terminals receive.
- All terminals don't operate with the same frequency: some are served every week, while others are served every month for example. This creates additional to the repositioning flows. Empty repositioning moves need a vessel leaving the terminal. So lower frequency might result in increasing the time the chassis is waiting empty in this terminal for the next vessel.
- There is variability in the time a chassis will be unpacked and available again for new cargo.
- The repositioning capacities are always subject to space availability on vessels. Shipping cargo is always preferred to repositioning empties. So when a vessel is already full with cargo, the empties will have to wait for the next vessel to be repositioned.

4.3.3. Representations of cycle time variability

The figures below represent the distribution of the different steps of the life cycle, based on consolidate three year data.





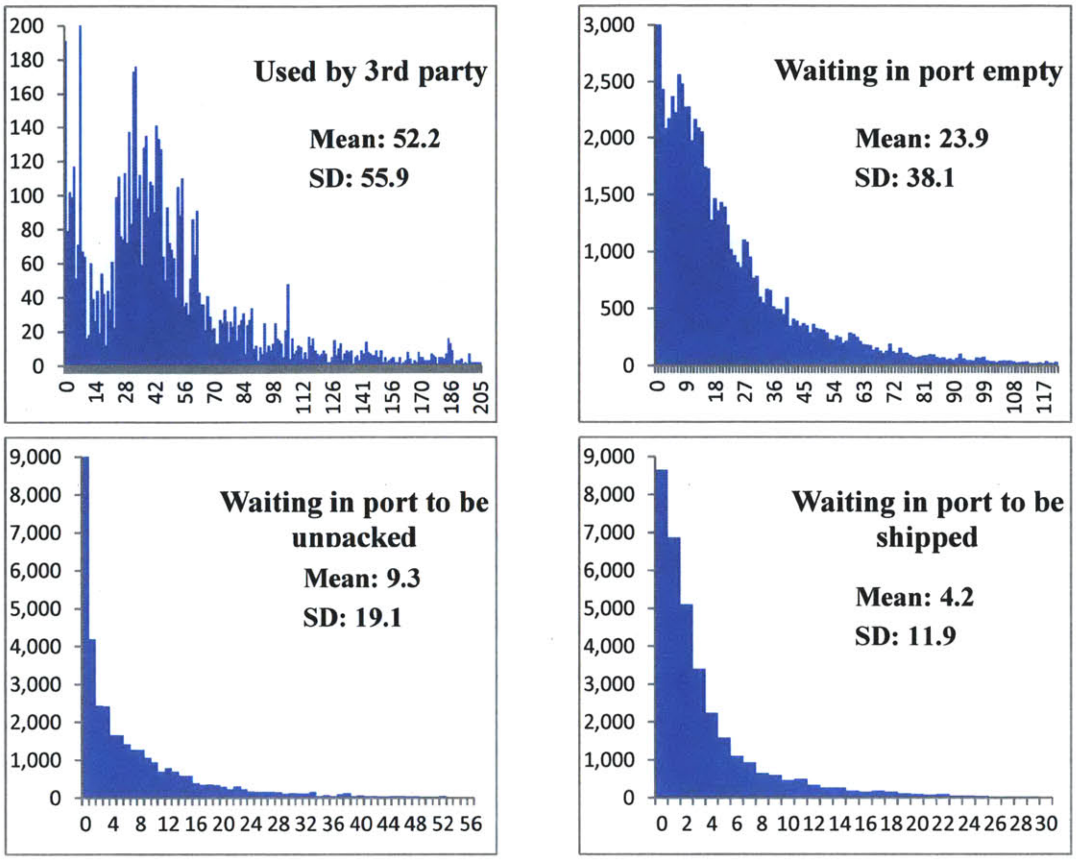


Figure 7: Cycle time distributions

Sailing times (sailing cargo and sailing empty are variables) The Company can barely leverage. The other four activities are workable and could be optimized. The Company has actually no visibility over the fleet are used by third parties, except the number of trailers that are in 3rd parties' network. We don't know how these assets are used (are they busy 100% of the time while in this external network)? There might be areas of improvement here, if The Company can also reduce the time its assets are outside its own network (we will elaborate in section 6 on the relationship between fleet size and asset utilization.

The other three idle times are also areas where the company could find some areas of improvements, especially by reducing the time trailers wait empty in ports. The distributions of these three durations are shaped like the right tail of a normal distribution. Their shape also tells us that The Company could focus both the fact that their right tail is long (with numerous very high values) and on their variability. For example, there are overall many occurrences of trailers waiting more than 30 days empty in ports.

5. Tracking technology and process

5.1. Current state

The Company is currently tracking inventories, flows and repositioning of chassis both using homemade tools and business software.

5.1.1. Planning and tracking system

The Company uses several tools to record cargo bookings and manage the fleet of chassis. We will focus here on the tools that are used to manage and repositioning the fleet of chassis and to track their moves.

- Equipment needs

Customers usually book cargo several weeks before the departure of the vessel. But it is also frequent to receive bookings just a few days before departure. Once a request is received from a customer, operational teams define the type of cargo that is needed to handle it, based on cargo weight, dimensions and other physical specifications received from the customer, and a specific chassis is then attached to this cargo (20 feet, 40 feet…). Late bookings create an operational issue, as they cannot be included in the repositioning plan elaborated several weeks in advance. Safety stock in each port is therefore important to manage this late demand.

At this stage, we know how many chassis and of which type are needed in the different terminals.

A five week equipment forecast is updated, showing, for each type of chassis and each of the five coming weeks, inventory and flows (as the difference of expected incoming and outgoing chassis). Note that this equipment forecast for each terminal is based on actual expected flows. Historical data of supply and needs for chassis in each terminal should however allow to estimate needs earlier than five weeks in advance.

- Repositioning needs

The summary of needs in each ports (five weeks view) show which terminal will need to get replenished with empty chassis from other ports, and which port will have excess inventory of chassis.

This summary is the basis of the decisions to reposition a specific type of chassis from a specific terminal to another specific terminal in a specific quantity.

- Individual asset tracking

Each asset is stamped with a unique identification number and barcode. Each time the status of the asset changes, its activity code is changed in the system. For example, loading a cargo on an empty chassis will change the status of the chassis to the new activity code FLCV ("Filled with convan cargo"), telling that the chassis is now full but has not been loaded on the ship yet, and so is waiting in the terminal.

The current activity codes provide a very consistent understanding and tracking of all different steps of the life span of a chassis. It provides information on whether the chassis is empty or filled, in port or on a ship, subleased to a third party, lost, on or off-hired.

Figure 8 presents a general planning process. The closer to execution (loading cargo or empty trailer on a vessel), the more we need actual data. While the long term forecast (based on historical data analysis) made in collaboration with customers can help define some global flows patterns and systematic repositioning from net importer regions to net exporter regions, the actual bookings can be used to adjust the these flows and get closer to actual demand, so as to ensure appropriate level of inventory in each port when it comes to execution. The last step (execution and booking of specific trailer ID to a cargo) is critical as this is where data accuracy must be controlled.

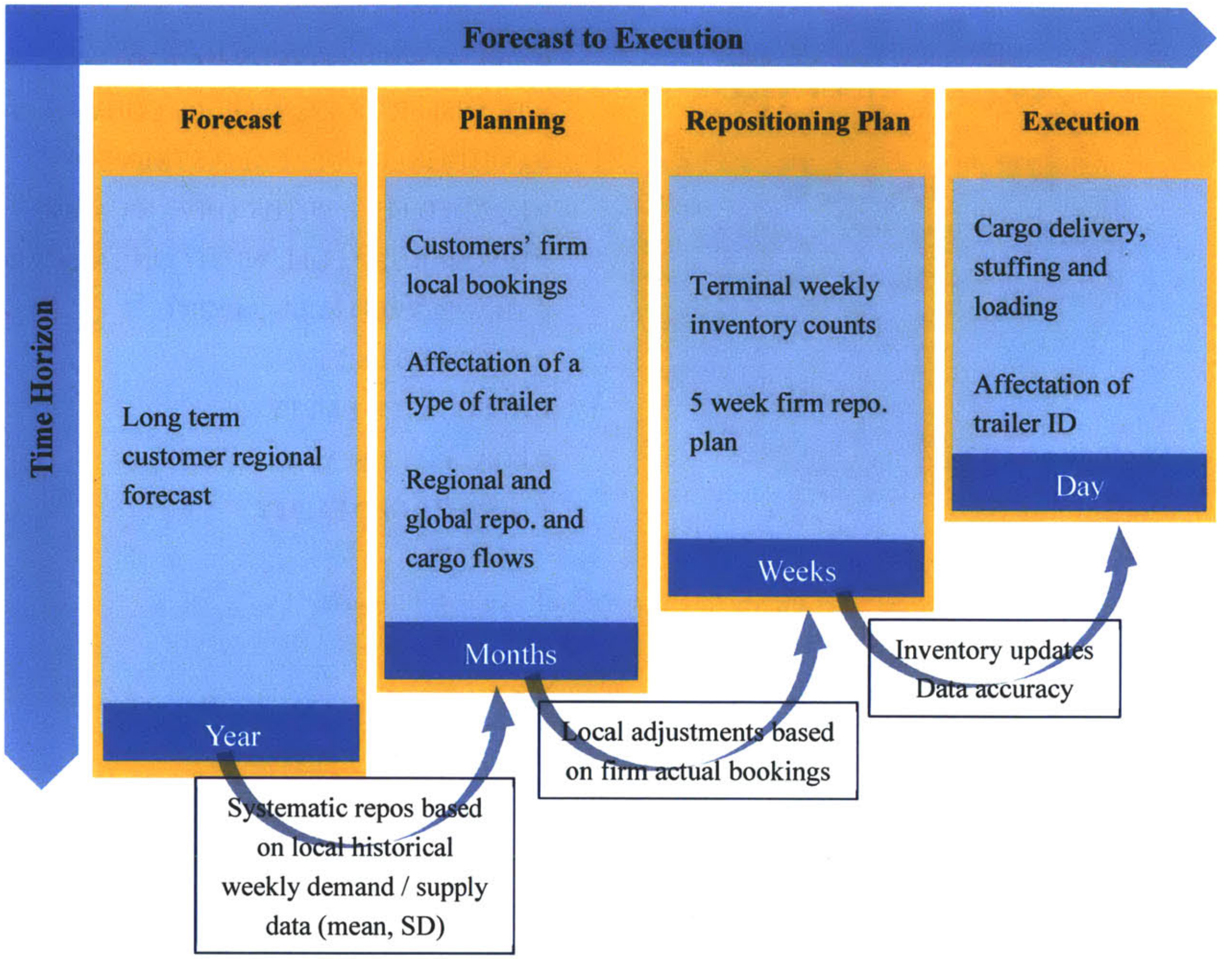


Figure 8: From forecast to execution

5.1.2. Representations of activity tracking

Figures 9 and 10 represent the activities of two specific chassis throughout a year. Each piece of the chart represents the number of days the asset has remained under the specified activity code. These two assets have a very different life span. The first one is one of the most active chassis over the year, the other one was mainly used by third parties.

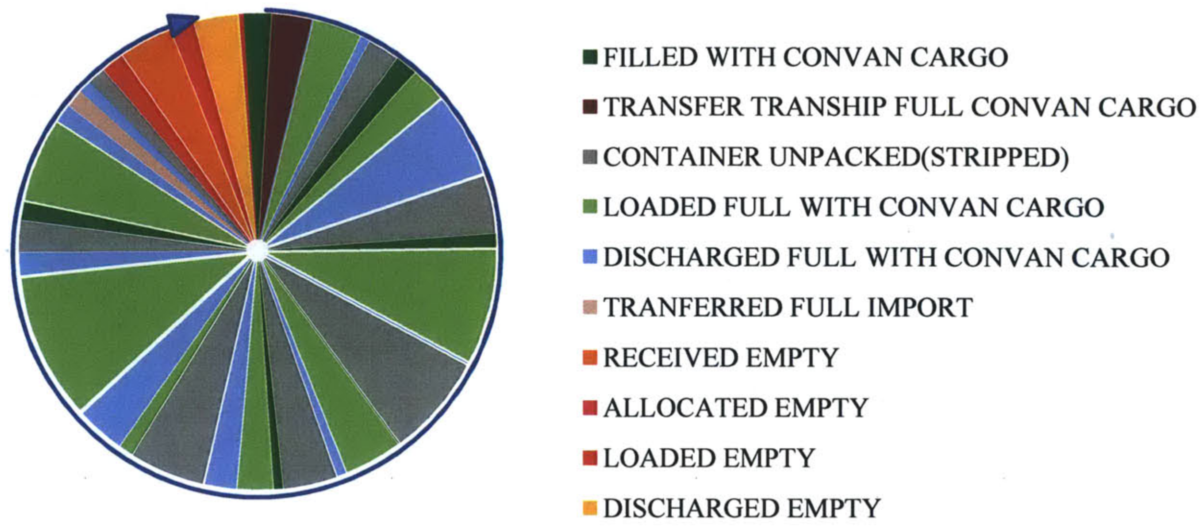


Figure 9: Example 1 of a chassis life cycle

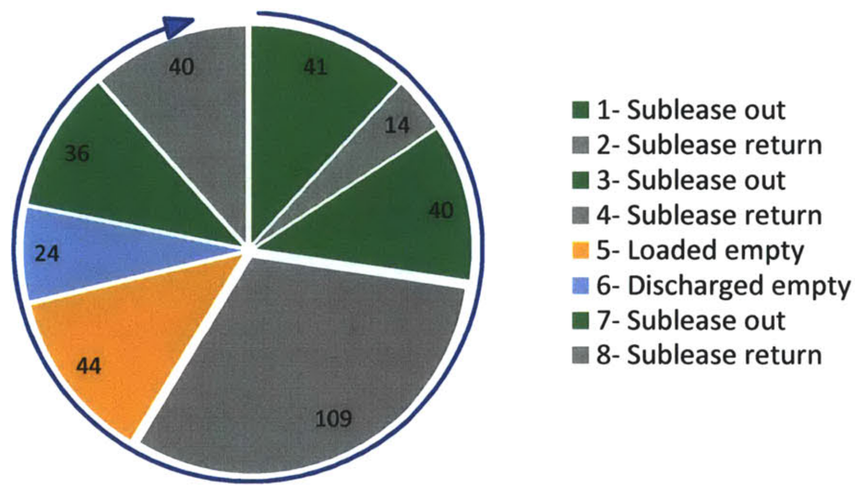


Figure 10: Example 2 of a chassis life cycle (with number of days)

These figures show that the actual tracking system provides relevant and sufficient information to track the trailers' activity and occupation efficiently. This does not mean however that the data is correct.

5.1.3. Tracking data accuracy

However, some information and updates might be not accurate, making the tracking system less efficient and complicating the management of the fleet. Errors might come from:

- **Trailer activity updates equipment and procedure gaps among ports**. Some ports use scanning devices that help filling a cargo with a specific chassis (scanning the chassis barcode) and update the activity of the chassis real time. But not all ports are equipped with such devices. Those that don't have scanning devices update the system after operations have been performed (back in the office as opposed to real time using a scanning device). In both cases (with or without scanners), as updates are manual, the data entered might be wrong. For example, the operator might enter the wrong asset identification number to the cargo. This error implies that the actual chassis that is physically loaded on the ship will not be the one that is tracked in the system. This will lead to tracking the wrong asset and to inventory inaccuracy.

- **Gaps among ports regarding inventory procedures.** Not all ports have the same inventory procedures. Chassis inventory should be performed physically every week and the system shall be updated accordingly (in case errors have been identified). Our observations on site have shown that this procedure is not equally executed in different ports. According to The Company's global fleet manager, ports across the world probably have significantly different practices in tracking and updating their inventory. This gap is an obvious cause of data inaccuracy and requires post controls and investigations by the central fleet management team.

Data inaccuracy is probably one of the main causes of asset misplacement. An asset shall be considered misplaced when its physical location does not match its location as reported in the system. Then assets are declared lost when investigations have not been able to relocate it physically. Some assets might first be declared lost, but found somewhere after several months. The activity code system tracks this event ("Located/found after being lost").

The data and tracking system does not allow to measure exactly the number of misplacements. The activity code that is used to virtually relocate a chassis from one port to the other is also used on a regular basis to easily move units that have not been correctly updated in the system on a timely basis. This activity code however represents only less than 1% of the total moves in the period, even though 20% of chassis have used this code at least once during the same period. These are the mismatches tracked by the system. However, there might other inaccuracies in the system that are not tracked, for example an activity is updated later (after the voyage and after the inventory check has revealed that a trailer is missing), and that would need to be quantified to evaluate the importance of the accuracy issue.

Methodology

We showed in this section the importance to first assess the accuracy and maturity of the existing tracking system. This will help companies to evaluate the real opportunity to invest in a new system. Data accuracy and relevance are critical to know about the fleet utilization and location and number of losses or misplacements. This data accuracy is supported by appropriate tracking system, technology and processes.

5.2. Technology improvements opportunities and risk analysis

5.2.1. Functionalities and costs of a global positioning system (GPS)

The GPS technology is mature and is largely used in logistics. It is used for example to track temperature variation in refrigerated containers, or to know if and when the doors of a container have been opened. In other words, in the container business, GPS is mostly used to ensure security. GPS utilization just to track container flows is very limited, mainly because of the relative cost of the technology to the cost of a container itself.

5.2.1.1. Decision criteria

Many different options with various complexities are available, and the decision on which equipment / system should be used is based on several criteria:

- Active / passive devices:
  - Passive devices collect data continuously, but this data is collected in batch by users

    when the equipment is back to its original location or destination

  - Active devices provide real-time tracking and continuous data transmission, whatever the location of the device.

- Frequency of transmission: systems offer a wide range of transmission frequencies, from every second to every week or even more. Chassis are slow moving items, so probably do not require highly frequent transmission. Some GPS systems might also start transmission only when the asset starts moving. This reduces battery utilization.
- Geofence: some systems allow to track if an asset is going out of an authorized area. If it does, the system sends an alert.
- Alerts: closely related to the last point, some systems are able to attach the asset to specific moves or route. Once the asset is located in a location or a route it is not supposed to be, the system sends an alert
- Life of battery: some system can tell when the battery is going low, so that you can anticipate battery maintenance
- Basic Costs: the basic cost is mainly composed of:
  - Cost of the device itself
  - Monthly subscription for the connection to GPS systems
- System integration and services:
  - To operate efficiently, the real time tracking system should be integrated with other business systems used by The Company, especially with the activity tracking system, which provides critical information about the status of each asset
  - Real time tracking technology should be provided along with monitoring tools, especially reporting the utilization of assets: how long have they been moving, how long have they been stopped in terminals, where are sailing chassis heading to… This system should provide tools to analyze the performance of asset utilization globally and in each terminal
- Additional costs must also be considered: maintenance, installation, replacement of batteries, batteries recharging, development of interfaces between the tracking system and the operational system, development of tailored monitoring tools, training…

5.2.1.2. Investment cost

If we consider only the basic costs of device and monthly subscription fee, the total cost of the investment is as follow:

$$IC = \frac{[(F * Cu) + (12 * Cs * F * T)]}{T}$$

$$IC = \frac{F(Cu + 12 * Cs * T)}{T}$$

and

$$IC\ /unit = \frac{Cu + 12 * Cs * T}{T}$$

Where:

IC is the investment cost brought to one year,

F is the size of the fleet,

Cu is the unit cost of the device,

Cs is the cost of monthly subscription,

T is the time horizon. Note T is not the amortization duration of chassis, but the horizon over which The Company would like to amortize the technology.

However this cost is only including the device and monthly subscription. It does not include, especially:

- Installation costs
- Maintenance costs
- Infrastructure costs in the location or locations where the devices would be maintained
- Software interface and development costs

Some of these additional costs are variable with fleet size (maintenance, installation), and others are fixed (not varying with fleet size, such as development costs or infrastructure costs).

So adding these costs, the total cost of the investment would be:

$$TC = \frac{F(Cu + 12 * Cs * T) + (Cf + Cd * F)}{T}$$

and

$$TC\ /unit = \frac{Cu + 12 * Cs * T}{T} + \frac{Cf + Cd * F}{F * T}$$

Where:

TC is the total cost of the investment brought to one year

Cf is the fixed cost associated with developments, interfaces or infrastructure for example

Cd is the additional variable cost for each unit installed, associated with maintenance (including battery recharging or replacements) or installation.

(Crainic, Gendreau, & Dejax, 1993; Meng & Wang, 2011)(Crainic, Gendreau, & Dejax, 1993; Meng & Wang, 2011)

In the next paragraph we will use the limited Investment Cost per unit (IC /unit) only. This basic cost will allow us to measure the sensitivity of this variable cost.

The total cost has a linear proportional relationship with F (for given T, Cs and Cu) and with Cs (for given T, Cu and F). The relationship with T is not linear. Assuming F=7,000, Cu = \$250 /u and Cs = \$7 /u/month, we get the following sensitivity. We assume these are costs The Company could get for its needs (a basic GPS device and weekly transmission).

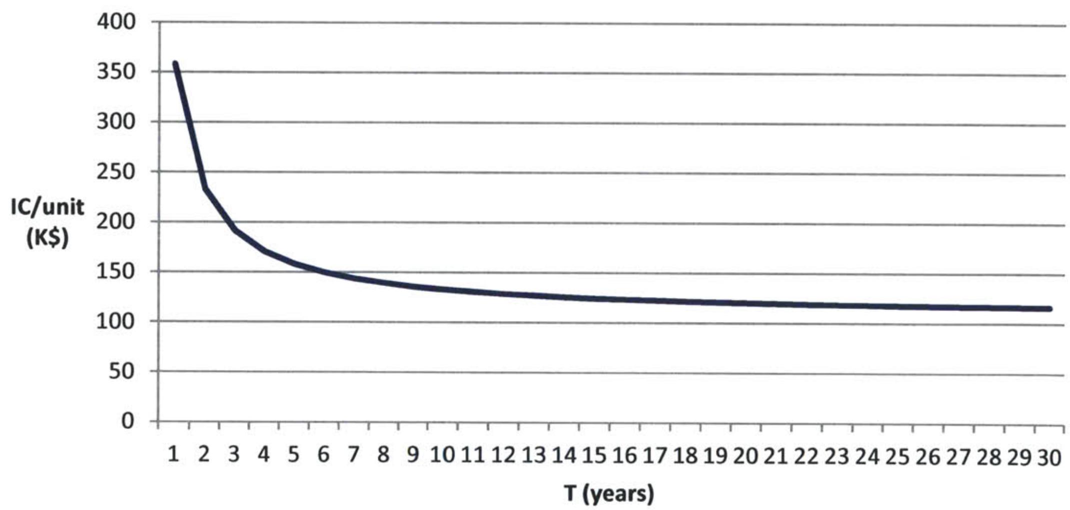


Figure 11: Sensitivity of investment cost per unit to time horizon

The time horizon is defining the time over which The Company wants to amortize the investment. We can see that the annual cost decreases rapidly in the first 7 years, but then the cost is decreasing much slower. So there is actually no real incentive to amortize the investment over more than 7 years, based on the assumptions above. Growing fleet size is simply shifting the total cost up, but the gap in costs between the smaller fleet size and the higher fleet size is reducing as the time horizon is increasing.

5.2.2. Break-even point of the investment

To evaluate the opportunity of such an investment in a technology, we need to know if this benefits we can expect from the technology will cover this investment. The first basic benefit we can expect is to recover the lost items. So we need to calculate a break-even point which would match the investment (TC) and the total value of the units lost.

Considering the initial purchasing price, the total value of lost items is equal to:

$$V = \ell F * \sigma d P * (1 - \sigma) Cl$$

Where

V is the total value of losses,

P is the purchasing price of each item,

ℓ is the portion of the fleet that is lost,

d is the actual average depreciation rate of chassis

σ is the portion of RTIs that is owned by the company (and 1-σ the portion that is leased)

Cl is the average cost of leasing

So the break-even point is matching TC and V:

$$\ell F * \sigma d P * (1 - \sigma) Cl = \frac{F(Cu + 12 * Cs * T) + (Cf + Cd * F)}{T}$$

so :

$$\boxed{\ell = \frac{F * (Cu + 12 * Cs * T + Cd) + Cf}{T * \sigma d P * (1 - \sigma) Cl}}$$

which is the loss rate for which the value of the recovered lost items would compensate for the investment. In other words, if The Company reaches this level of losses, recovering lost items will pay for the investment.

Methodology

Making first estimations based on basic costs (which are the easiest to get from suppliers) will help make a first quick analysis of the opportunity of the investment. Calculating a break-even point (which definition might vary depending on the specific needs or issue the company faces) will help assess the investment as regards to the company's current situation and improvement opportunities.

5.2.3. Expected benefits of a real time tracking technology

Recovering lost items is a quick benefit we can quantify easily. There are several other benefits The Company could expect from this technology. Most of these other benefits rely on The Company's ability to convert a pure real time tracking system into improved visibility and into an integrated monitoring system that will allow to manage the fleet more efficiently. This conversion might bring additional costs though. In section 6 below, we will elaborate deeper on other areas of improvement regarding RTI fleet management optimization.

The benefits we can expect from a real time tracking technology are the following:

1- Recover lost items, whether they are in The Company's network (in one of its terminal but not knowing which), or out of its network (used by another ocean shipping company, handled by a third party in a region not served by The Company),

2- Have a real time view of the location of each asset and inventory position in each terminal,

3- Track the flows and metrics in days to help monitor inventory and repositioning. GPS systems are able to track time and provide reports, which would be highly valuable to The Company, as we will show in the following sections. Many solutions report how many days an asset has been moving, how many it has been staying and in which location, so would be able to tell how many days a port is keeping chassis empty,

4- Reduce administrative costs due to the time spent reporting inventory counts in each terminal,

5- Help terminal operations locate chassis in the yards, which might help increase asset utilization as well, if not eliminate the manual checks in the yards.

5.2.4. Limitations and risks

A real time tracking technology like GPS will only provide the exact location of each asset. We see the following limitations in implementing this technology:

1- The Company needs to be able to recover the lost item. Stolen chassis or chassis lost or used by 3rd parties in remote locations that The Company does not operate itself might be very difficult to recover. Recovering lost chassis will incur additional costs;

2- GPS signal is weak or inexistent inside buildings, which means that each facility needs to be equipped with additional transmitters to capture the signals inside the building;

3- GPS itself will not support the activity status of the RTIs. These statuses will still be recorded in the existing software. Linking real time location and RTI status will require interfaces between the two systems, and errors in the activity tracking system will not be resolved by these interfaces;

4- The technology itself won't directly help increase the utilization or repositioning of RTIs. These improvements require management processes and monitoring tools that will need to be developed beyond the technology itself. In addition, investing in these processes and monitoring tools do not require to get a new technology: they could be implemented without it and generate significant benefits. Our analysis in section 6 will show that the biggest areas of improvement regarding RTI fleet management are not in the recovery of lost items (direct benefit) but in the ability to increase asset utilization and in the structure of the fleet;

5- The real time tracking technology won't manage the chassis activity updates, which will still require to be handled by the existing activity tracking system. GPS would provide exact location, but the existing system will provide the information about the status of the chassis. So GPS won't solve issues regarding data accuracy in the activity tracking system, it would only allow to correct location errors, but not status errors;

6- Real time tracking would reduce if not eliminate manual inventory checks in terminal. The risk here is that terminals do not have incentive to keep good records of their inventory anymore.

Locate lost items	The signal needs to be available: • Unlikely if the chassis is inside a building • Unlikely if the asset has been stolen
Recover lost items, whether they are • in The Company's own network (in one of its terminal but not knowing which) • out of its network (used by another ocean shipping company, handled by a third party in a region not served by The Company…)	• needs physical ability to get the asset back • needs benevolent cooperation of external parties • incurs additional recovery costs
Locate misplaced items quicker	• need signal availability • does not avoid system updates and physical repositioning

There are definitely opportunities for improvements in managing visibility and facilitating the global fleet management as volumes and flows are increasing, making this operation more complex. Improved monitoring tools, forecasts and performance reports will certainly be useful to better anticipate local needs and facilitate daily management of chassis. But how much will a real time tracking technology, which will basically provide only a location at a given time, contribute to improvements regarding inventory management in terminals and asset utilization through improved repositioning?

5.2.5. The importance of assessing data accuracy to evaluate expected benefits

Figure 12 shows the relationship between data accuracy of an existing tracking system and the benefits a company could expect from a new tracking system. The graph shows that a company that has currently no tracking system at all can expect high benefits very quickly. On the other side of the tail, if The Company already has a reliable or mature tracking system, the additional benefits it can expect from a new system are small. In other words, it is much more worth investing in a tracking system if The Company has bad tracking records, while the investment is relatively high if its tracking system is already reliable and mature.

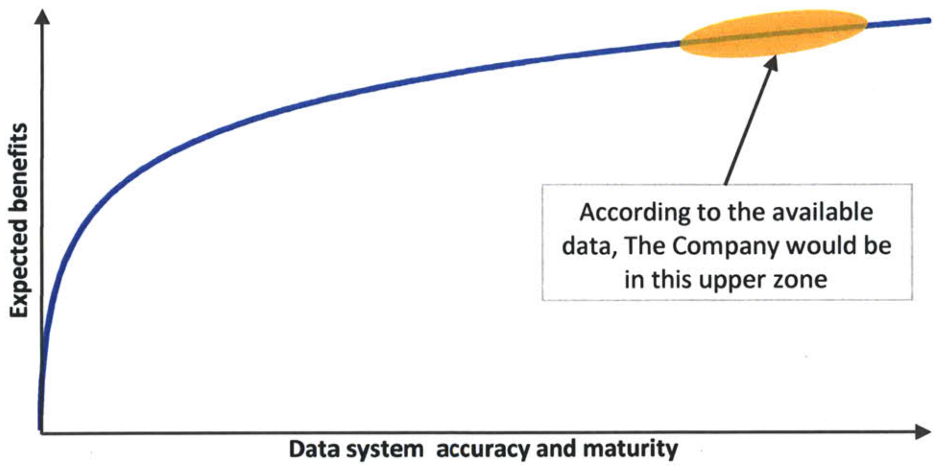


Figure 12: Relation between data system accuracy/maturity and expected benefits of a tracking system

The Company's current tracking and reporting system is apparently already reliable and contains all the necessary information to track the flows and statuses of each chassis. The data we analyzed show that the low number of misplacements and losses make the investment in an improved tracking technology relatively expensive. In their case, the cost of investment (limited to device and subscription costs) is much higher than the value of lost items.

This does not mean that there are not areas of improvement regarding fleet management. But these improvements may be not directly correlated to the implementation of a new real time technology. A great business challenge is the ability to anticipate moves (forecast) and reposition empties as quick as possible, instead of having them staying empty in port for many days. There is a tradeoff between rapidity of repositioning and fleet size. The quicker you can reposition empties, the smaller fleet you need. Tracking technology is useful when it helps improve visibility and help monitor the fleet, ultimately to reduce fleet size and reduce costs. In other words tracking technology is useful or profitable when it comes with appropriate processes and monitoring tools. We think that The Company needs first to make the most of the available data, define the appropriate metrics that will allow to monitor asset utilization, build the appropriate monitoring tools to manage the fleet globally, and secure the processes that will ensure the accuracy of the data. In the next section, we analyze business areas of improvement and key metrics that should help The Company reduce fleet costs.

Methodology

Before changing system to fix an issue, companies shall first assess their system integrity and maturity, and evaluate to what extent a new technology would help improve their system. Challenging the initial issue might also be required.

6. Fleet utilization analysis

In this section, we analyze the life cycle of a chassis, emphasizing our analysis on utilization in terms of days and not only in terms of lifts. We then analyze how fleet size is sensitive to these metrics. We finally evaluate how The Company could benefit from changing the fleet structure (or leasing policy, as the distribution of leased assets vs owned assets).

6.1. Finding the appropriate measure of asset utilization

The key variables in the definition of the fleet size are the utilization rate of each chassis and the ability and speed to reposition empty chassis to the locations where they are actually needed. The definition of utilization rate is not standardized though. The Company has been mainly tracking number of lifts per chassis to monitor asset utilization. A 'lift' is defined as a lift-on at the loading port and a lift-off at the unloading port, the chassis being filled with cargo. We could consider these as the revenue-generating lifts, as the loads for repositioning empty assets are not counted as lifts.

This indicator provides a useful indication of actual demand for chassis. However it contains a distortion, as a lift for a one day voyage is weighed as much as a ten day voyage, whereas the chassis is much more utilized in the second case. Thus, including time will probably provide a more accurate idea of asset utilization. We would then define asset utilization rate as the number of days the chassis is "busy", or filled with cargo.

However, utilization as a number of lifts and utilization as a number of busy or profitable days are not independent.

The fleet size and utilization rate probably have a correlation such as in the chart below, for a given demand:

- If the number of lifts per chassis is very high, you need fewer chassis than if this number is very low. With a given average voyage duration, we need fewer chassis to meet given demand if each chassis is used a higher number of times.
- On the other hand, given a certain level of demand (so number of lifts), if chassis are busy most of the time (high utilization rate), a larger fleet is required. We need more chassis to

meet demand if each chassis is used longer.

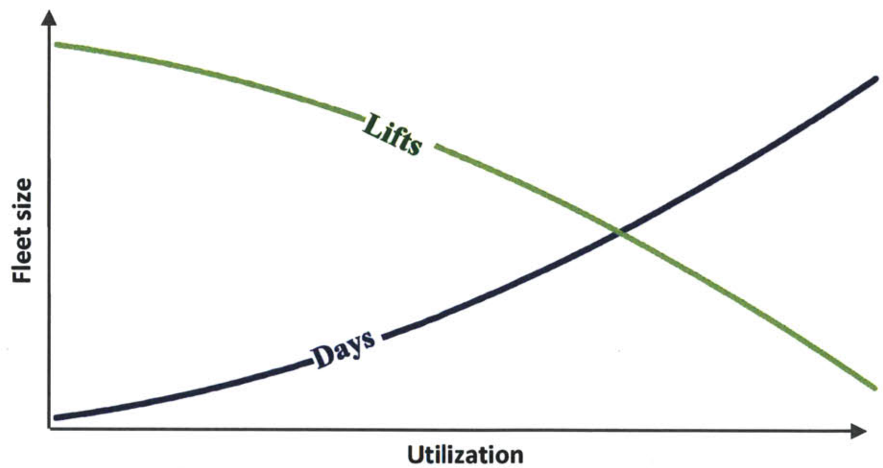


Figure 13: Asset utilization and fleet size relationship, 2 contradictory approaches

Note that we can have a high number of lifts with low number of busy days. We think that measuring asset utilization in terms of days provides a better idea of asset utilization. We could have a very high number of lifts per chassis, but use them only half the year. Would that represent a good performance as of asset utilization? Tracking data and monitoring tools should provide this measure of utilization to help manage inventory and repositioning.

6.2. Key metrics reflecting the chassis life cycle

In this section we present key metrics to measure the utilization of chassis and their life cycle.

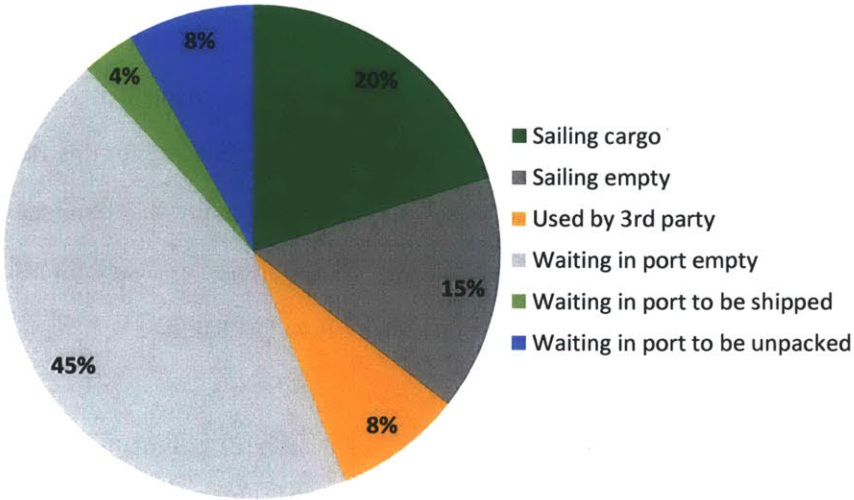


Figure 14: Distribution of days utilization of the fleet (global average over 3 years)

The major take-away of this chart is the large portion of days that chassis are waiting in port empty (45% of the total time tracked), as opposed to the number of days they are filled with cargo. This number is not only the result of managerial actions. The duration a chassis stays in port also depends on the vessels' schedules. In other words, a chassis might be staying in port simply because the next vessel has not arrived yet. In addition, there must be space available for empties on the next vessel, which is not always the case, when the vessel is full with paying cargo.

Dr Jean-Paul Rodrigue's studies on containers revealed somehow the same results, with 56% of their lifespan being either idle or repositioned empty, and 16% in terminals. Ocean transit only accounts for 16% of a container lifespan.

The table below represents the average times spent under the different statuses in one cycle. For example, on average it takes 17.1 days to reposition an empty chassis.

Table 2: Average durations in the chassis life cycle

Status	Average of Duration	StdDev of Duration
Waiting in port to be shipped	4.2	11.9
Sailing cargo	22.6	15.0
Waiting in port to be unpacked	9.3	19.1
Waiting in port empty	23.9	38.1
Sailing empty	17.1	20.7
Used by 3rd party	52.2	55.9

We see that the average time where chassis are used by 3rd parties is very high. This number includes all the time between the moment the chassis is subleased to the moment it comes back to The Company's facility and is available again. We don't have activity tracking for this fleet, so we don't know the distribution of time and how long the chassis is busy or empty, in a terminal or on a vessel. Getting more information regarding the actual utilization of subleased assets might also help identify opportunities to reduce these 52.2 days, with a direct impact on the fleet size.

Figures 15 represent the status of the fleet in terms of number of chassis. this representation is a snapshot of the fleet activity at the end of a period. We analyzed three different periods to check the consistency from one period to the other.

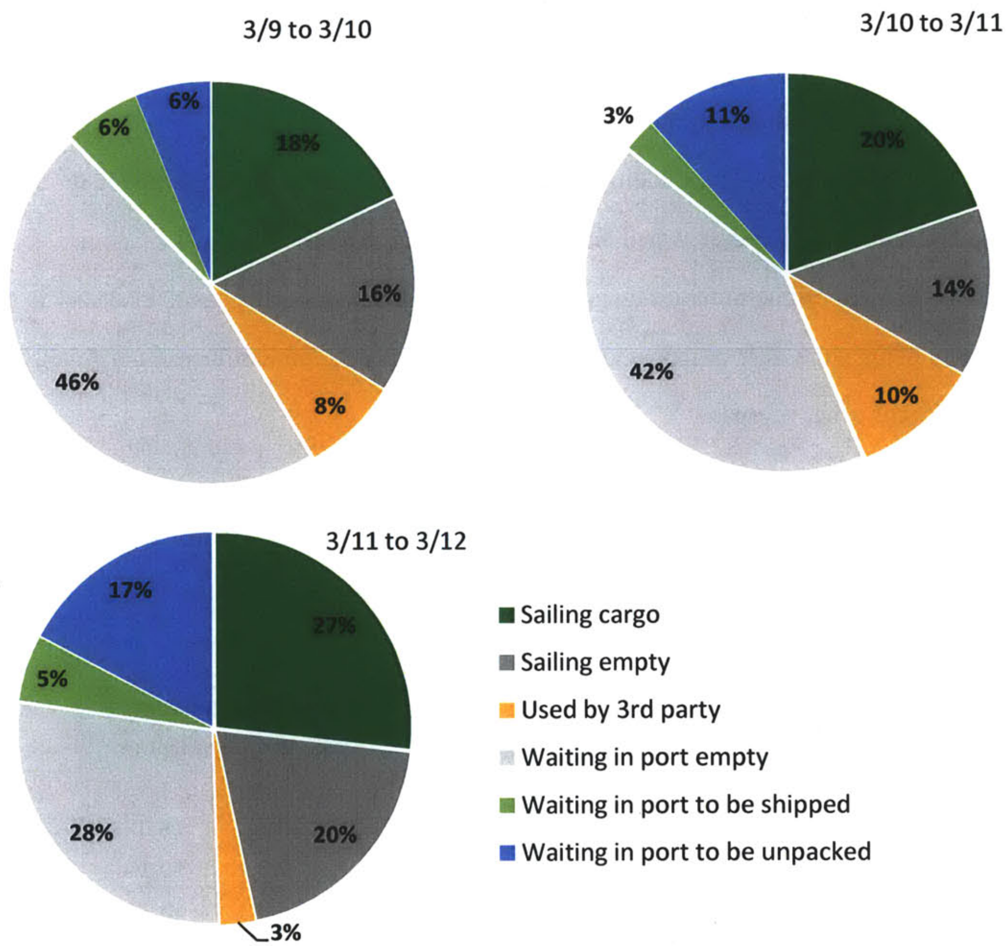


Figure 15: Activity status of the fleet as a number of chassis

Figure 16 is the average expected life span of a roll chassis throughout a year. This data is excluding the lost items.

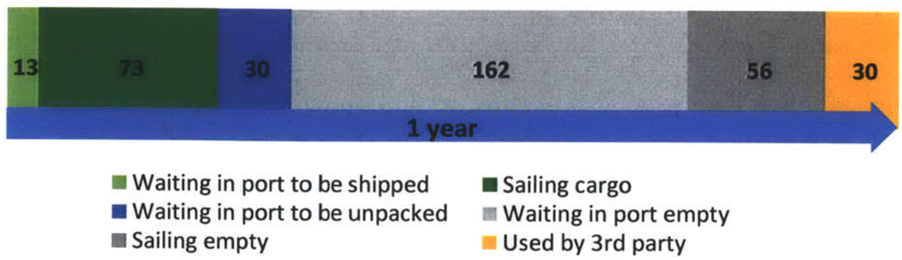


Figure 16: Representation of the cycle time of a chassis (in a year)

So, on average, within a year, a chassis spends 162 days empty in ports.

Whether it is the number of chassis, or the number of days, we can see that chassis staying empty in ports account for a significant amount of the fleet. The intuition is that the global level of inventory is too high, or not optimally allocated. Of course, repositioning empty chassis on such a global scale is highly complex.

Methodology

Choosing the appropriate metrics is key to understand asset utilization and identify areas of improvements. Securing the accuracy of data and the maturity of the tracking system are key to report this metric.

6.3. Global fleet sizing

One of the key challenge and benefit to get form improved visibility is through optimizing the fleet size of chassis needed to manage demand. There is obviously a relationship between fleet size, level of demand and the time each chassis is used. In this section, we perform a simulation to evaluate the sensitivity of the fleet size to the average times. For the purpose of this simulation, we considered that the fleet size is correlated to the time spent empty waiting in port. The current fleet size actually corresponds to these actual average times for each activity. The current fleet size is in part the result of this amount of time each chassis spends empty in ports and thus is not used for cargo in another port where it might be more useful.

The number of chassis required is a function of:

- Cycle time, which we will define as the time elapsed between the moment the chassis is filled with cargo and the time it is available for another cargo. Therefore we need to include the time for repositioning in the cycle time, as this repositioning time is necessary for the chassis to be available again. In other words, if we don't reposition a chassis, it won't available where we need it.
- Level of demand, which we will define as the number of lifts of chassis filled with cargo

$$\textbf{Fleet Size} = f(\textit{Cycle time},\ \textit{Demand})$$

Exception regarding chassis used by 3rd parties: in this calculation, we include in demand the chassis subleased to 3rd parties. We consider these moves as demand, as these chassis will be used to carry cargo and as The Company provides these chassis, even if not directly in The Company's network. However, we do not add the duration of sublease to the average cycle time, as the sublease duration is already covering times sailing with cargo or empty, unpacking or waiting to be loaded, even if we don't have visibility (or tracking) over these different steps. We observed that the average time of subleasing is approximately the same as the cycle time observed for chassis in The Company's network (54.4 days vs 53.2). So we will assume that whether they are in or out The Company's network, the cycle time is the same, and will count both lifts in The Company's network and lifts moves to 3rd parties.

We will use the following data, extracted from the 3-year data we analyzed:

Table 3: Average durations of activities of the life cycle

Status	Average of Duration	StdDev of Duration
Waiting in port to be shipped	4.2	11.9
Sailing cargo	22.6	15.0
Waiting in port to be unpacked	9.3	19.1
Waiting in port empty	23.9	38.1
Sailing empty	17.1	20.7
Total cycle time (days)	**77.1**	**10.2**

The two activities on which The Company could actually have a real action are the time chassis spend empty in ports, and time they wait before they are unpacked. Customers are allowed to leave their cargo 10 days on a chassis without additional fee; they have to pay a demurrage rate per day from the 11th day. However, if these 9.3 days could be reduced, this would help reduce the fleet size. Sailing time is hardly manageable, and time before loading is already very short. Repositioning time might be reduced by improved repositioning policy (repositioning to the closest location), but our interviews and observations suggest that the repositioning are already performed so as to reposition chassis to the closest terminal where they are needed.

Figures 17 and 18 show the relationship between the times spent empty in port (figure 17) and before unpacking, and fleet size. To simulate these savings, we just used the average weekly demand and average times of both statuses. Therefore, this simulation presents a gross estimation of potential savings that The Company might expect. We did not include in this simulation the variability of times and demand, which would require further investigation and more complex model; it does not consider constraints regarding vessels schedule, available space for empties neither and the non-substitutability of the 19 different types of chassis. This simple simulation though provides a basic estimation, given some specific parameters. Jay Jagatheesan and Ryan Kilcullen have shown how including cycle time variability improves the fleet sizing strategy.

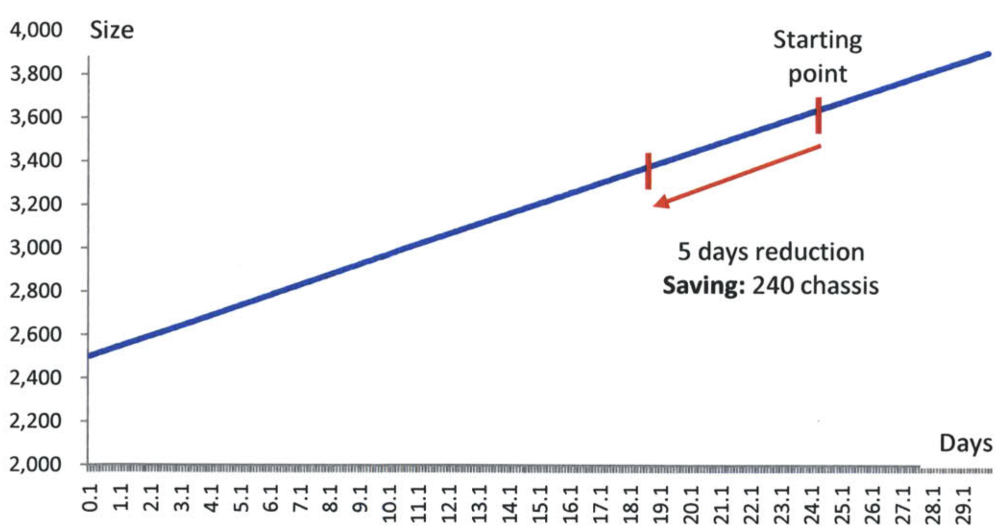


Figure 17: Sensitivity of fleet size to time waiting empty in port

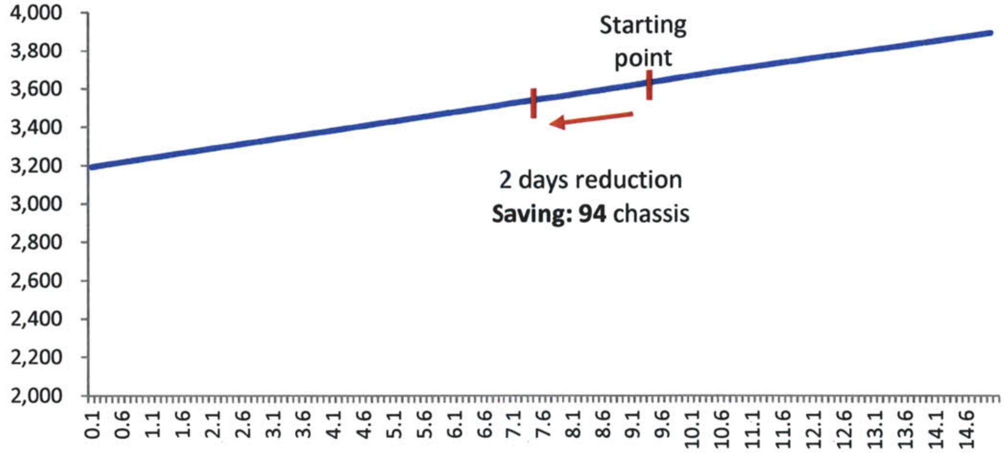


Figure 18: Sensitivity of fleet size to time waiting before unpacking

Reducing idle time allows to decrease the fleet size, and therefore the total cost of the fleet. Costs savings could be even higher if The Company could save these chassis off the leased fleet which is more expensive to operate. The benefits a company could get from these savings obviously depend on the value of the asset. Achieving new targets regarding idle times requires changes in the organization, which might represent a significant cost. The different slopes also reveal that there is much more space for improvement when the starting point is higher (23.9 days vs 9.3 days). In addition, unpacked trailers will become empty waiting in port. So savings on this activity will be realized only if the trailer is immediately used.

Methodology

Increasing asset utilization helps reducing the fleet size. The value of this saving depends on the value of the assets. These savings should be compared to the efforts required to achieve new targets regarding asset utilization. The cost of change (new processes, improved technology, improved monitoring tools…) might be higher than the savings. The effort will also be constrained by the current levels of utilization and space for improvements.

These estimates are based on reductions by 5 days and 2 days. Each company should assess its ability to meet specific targets. The more mature the visibility, monitoring system, processes and global integration, the higher these targets could be. However, there will be a threshold beyond which the total idle days cannot be reduced anymore, because in a structurally imbalanced trade pattern, companies need to reposition some RTIs empty, and they also need safety inventory to cope with demand and supply variability. In addition, this target should be precisely defined by deeper detailed investigation in each port and include some additional constraints that are not in this model, such as vessel schedules and safety stock for example. Section 7.5 below will provide additional information regarding the performance of each port, which shall be the basis for setting tailored targets for each port.

6.4. Leasing consideration

In the container business, leasing companies initially emerged to provide flexibility and manage temporal and geographical variations in demand. However, long term contracts are essentially contradictory to this initial mission, especially regarding seasonality and temporal fluctuation. After the 1990's, ocean shipping companies have tended to take ownership of their containers, with container ownership attributed to shipping companies reaching 59.8% in 2008 (Dr Jean-Paul Rodrigue). This rate is even higher for chassis ownership, with 70% being owned by shipping companies, and only 10% by leasing companies (the remaining being owned by trucking and rail companies or terminal operators).

The cost of leasing assets is higher than the cost of owning them. In the container business, this premium is approximately 60% to 70% more costly than ownership.

The leasing consideration is adding more complexity to the repositioning of empty chassis. Leased equipment should go back to their original location.

In fact, in our case, several suppliers provide chassis for leasing, contracts can vary from one to five years, lessors are located in various continents. One major lessor represents 50% of supply. The second largest represents 25% and 3 others share the remaining.

Based on actual costs provided by The Company, we performed sensitivity analysis on the cost per lift. We want to see how cost per lift figures change if we change the proportion of the leased equipment. In table 5, we assume that while the rental cost is only applicable for leased equipment and the capital cost is only applicable for owned equipment, other cost components will be the same regardless whether a chassis is leased or owned.

Table 4: Cost structure

RENTAL EXPENSES (Leased equipment only)	46%
CAPITAL COST PER LIFT (Owned equipment only)	22%
TERMINAL EXPENSES	18%
MAINTENANCE & REPAIR	7%
REGIONAL POSITONING	3%
STORAGE EXPENSES	3%
MISCELLANEOUS (incl. insurance)	1%
Average Cost / lift	**100%**

The sensitivity analysis was done on a 0% to 100% scale. One extreme scenario is the 100% owned scenario. The cost per lift would be the lowest, at 81.5%. The other extreme scenario is the 100% leased scenario, where the cost per lift would be the highest, at 115.2%. Of course, a higher percentage of leased equipment should theoretically give us a higher flexibility in terms of managing the fleet, as we could always lease more when demand is high and return the leased equipment when demand is back to normal. This is not always the case, though. One reason is the minimum leasing period, which is normally set at 1 year. This means that while we could always initiate a new lease on equipment, it's not always possible to return equipment back when we don't want them anymore. The biggest concern here is cost. As we can see, the cost per lift is 40% higher for leased equipment compared to owned equipment. This difference can quickly lead to millions of improvement opportunities if the number of lifts is high. That's why it's so crucial to reduce the percentage of leased equipment to a reasonable level, a level that balances cost and level of flexibility.

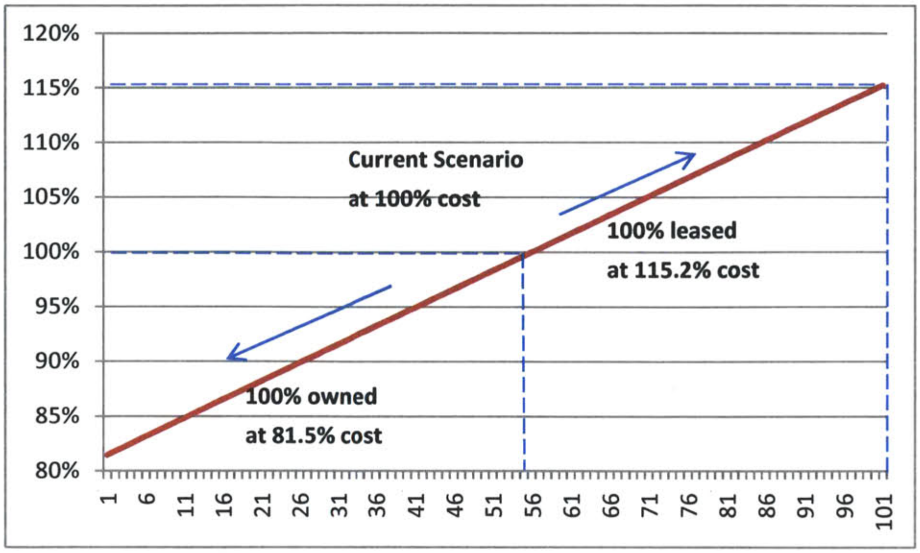


Figure 19: Sensitivity of cost to leasing policy

Table 5: Simulation of change of costs per lift as regards to leasing policy

% Leased	% Owned	Cost/Lift Change (%)	% Leased	% Owned	Cost/Lift Change (%)
0%	100%	81.5%	51%	49%	98.7%
1%	99%	81.8%	52%	48%	99.0%
2%	98%	82.1%	53%	47%	99.4%
3%	97%	82.5%	54%	46%	99.7%
4%	96%	82.8%	55%	45%	100.0%
5%	95%	83.1%	56%	44%	100.4%
6%	94%	83.5%	57%	43%	100.7%
7%	93%	83.8%	58%	42%	101.0%
8%	92%	84.2%	59%	41%	101.4%
9%	91%	84.5%	60%	40%	101.7%
10%	90%	84.8%	61%	39%	102.1%
11%	89%	85.2%	62%	38%	102.4%
12%	88%	85.5%	63%	37%	102.7%
13%	87%	85.8%	64%	36%	103.1%
14%	86%	86.2%	65%	35%	103.4%
15%	85%	86.5%	66%	34%	103.7%
16%	84%	86.9%	67%	33%	104.1%
17%	83%	87.2%	68%	32%	104.4%
18%	82%	87.5%	69%	31%	104.8%
19%	81%	87.9%	70%	30%	105.1%
20%	80%	88.2%	71%	29%	105.4%
21%	79%	88.5%	72%	28%	105.8%

22%	78%	88.9%	73%	27%	106.1%
23%	77%	89.2%	74%	26%	106.4%
24%	76%	89.6%	75%	25%	106.8%
25%	75%	89.9%	76%	24%	107.1%
26%	74%	90.2%	77%	23%	107.5%
27%	73%	90.6%	78%	22%	107.8%
28%	72%	90.9%	79%	21%	108.1%
29%	71%	91.3%	80%	20%	108.5%
30%	70%	91.6%	81%	19%	108.8%
31%	69%	91.9%	82%	18%	109.2%
32%	68%	92.3%	83%	17%	109.5%
33%	67%	92.6%	84%	16%	109.8%
34%	66%	92.9%	85%	15%	110.2%
35%	65%	93.3%	86%	14%	110.5%
36%	64%	93.6%	87%	13%	110.8%
37%	63%	94.0%	88%	12%	111.2%
38%	62%	94.3%	89%	11%	111.5%
39%	61%	94.6%	90%	10%	111.9%
40%	60%	95.0%	91%	9%	112.2%
41%	59%	95.3%	92%	8%	112.5%
42%	58%	95.6%	93%	7%	112.9%
43%	57%	96.0%	94%	6%	113.2%
44%	56%	96.3%	95%	5%	113.5%
45%	55%	96.7%	96%	4%	113.9%
46%	54%	97.0%	97%	3%	114.2%
47%	53%	97.3%	98%	2%	114.6%
48%	52%	97.7%	99%	1%	114.9%
49%	51%	98.0%	100%	0%	115.2%

Methodology

Leasing policy has a direct impact on operating costs. It is therefore critical for companies to have a clear understanding of their cost structure and find how much optimizing their leasing policy could save on the total operating costs.

6.6. Demand and Supply Analysis

In this section, we analyze the flows of chassis and repositioning patterns. In order to understand flows, we will separate incoming and outgoing flows of chassis with cargo and empty incoming and outgoing moves. Then we pick three representative ports with different demand and supply profiles to recommend different inventory policies.

6.6.1. Global flows and repositioning patterns

6.6.1.1. Global repositioning patterns

In this section, we analyze the flows of empty repositioning moves. Table 6 represents how much of the total repositioning moves are going to each port. We can see that the distribution is pretty concentrated, with 23 destination ports (out of 94) accounting for 90% of the moves. We can derive from this data that most of the repositioning flows are predictable. Using this distribution with a demand forecast based on historical data, we could define some systematic repositioning moves, before knowing the actual bookings from one port to the other. In other words, we don't need to know the actual bookings to start repositioning chassis. For each port, we could set a level of chassis to be repositioned every week systematically.

Table 6: Distribution of empty chassis' destinations

Destination port	% of flows	Cum. %
EUR1	23%	23%
ASI1	8%	31%
ASI2	7%	38%
AME1	6%	43%
EUR2	5%	49%
ASI3	5%	53%
AME2	4%	57%
ASI4	4%	61%
ASI5	4%	65%
EUR3	4%	69%
ASI6	3%	72%
AME3	3%	74%
ASI7	2%	76%
AME4	2%	78%
EUR4	2%	80%
EUR5	2%	82%
AME5	1%	83%
ASI8	1%	85%
ASI9	1%	86%
ASI10	1%	87%
EUR6	1%	88%
AME6	1%	89%
ASI11	1%	90%
Others	10%	100%

Now if we analyze the ports of origin (table 9), so which ports are ocean shipping out empty chassis, we find the same kind of distribution, with 28 ports (out of 136) accounting for 80% of the outgoing flows).

Table 7: Distribution of empty chassis' port of origin

Port of origin	% of flows	Cum. %
EUR1	9%	9%
ASI3	8%	17%
ASI11	7%	24%
ASI12	5%	29%
ASI13	4%	33%
ASI14	4%	37%
ASI1	4%	41%
AME4	4%	45%
ASI4	4%	49%
AME2	3%	52%
AME7	3%	54%
ASI2	2%	57%
EUR2	2%	59%
AME8	2%	61%
ASI15	2%	64%
AME1	2%	66%
AME9	2%	67%
AME10	2%	69%
ASI7	2%	71%
AME3	1%	72%
EUR7	1%	74%
ASI6	1%	75%
EUR8	1%	76%
AME5	1%	77%
AME11	1%	78%
ASI16	1%	79%
AME12	1%	80%
ASI17	1%	81%
Others (108 ports)	19%	100%

We can see that half of the ports of the most ports of origin are almost in the upper list as destination ports. This means that 14 ports (the most active ports) both receive and ship out empty chassis. We could conclude from this finding that some repositioning moves are redundant: why would a port that needs empty chassis ship chassis out? An inventory model might help solving this issue and limit redundant flows. However, these flows might also be the result of operational constraints: this result might be due to ports needing different kind of chassis than the ones they have in stock, or to not homogeneous vessel schedules making the synchronization of flows hard to manage.

This repositioning policy shall also be driven by a regional consideration. Priority should be given to local (meaning shorter in time) repositioning, which already how repositioning are actually ordered by the central team. Further analysis should be performed to define more precisely the regional flows as opposed to global flows.

Methodology

Data accuracy and tracking capabilities are necessary to learn about global flows and patterns. Segmenting the flows helps to identify which depots companies should focus on and will allow to determine some systematic repositioning flows from net importers to net exporters.

6.6.1.2. Detailed analysis of ports performances and profiles

Table 11 shows demand and supply at each port (total lifts over three years), and the number of idle days as regards to demand requirements, and performance in terms of speed to reposition empty chassis, where:

- Demand is the number of lifts of chassis with cargo in the specified port
- Supply is the number of chassis received with cargo (so which will be made available after being unpacked and picked up by customer)
- "Loaded empty" is the number of lifts of empty chassis from the specified port
- "Received empty" is the number of lifts of empty chassis received in this port
- "Idle before ocean shipping" is the number of days a chassis stays in the port (either empty or filled with cargo) before it is loaded on a vessel
- "Idle after ocean shipping" is the number of days a chassis is staying in port (either waiting empty or before it is unpacked) after it has been received busy or empty
- "Idle days before repositioning" is the number of days a chassis stays empty in port before being repositioned to another port. Note that this metrics is relevant only for ports which are significantly net importer and accumulate chassis (so with low demand).

These 24 ports are only an extraction of the 143 ports tracked, and represent altogether 80% of the total flows of The Company. The total flows being the sum of all moves (demand + supply + received empty + loaded empty), which provides a good idea of the intensity of flows in each port.

We can see in this table that all ports don't have the same performance, a good performer being a port which don't keep chassis too long in the port or which repositions it quickly. These gaps between ports mean that we can find some areas of improvement by setting tailored targets to each port. Note that the total demand (demand+loaded empty) should match total supply (supply+received empty), which is approximately the case in most cases. Further detailed investigation should performed to understand why some port have significant gap between total demand and total supply (a significant gap meaning that they did not get enough chassis to handle their needs).

Table 8: Detailed demand, supply and utilization per port

PORT	LIFTS (total 3 years)				PERFORMANCE		
	DEMAND	SUPPLY	Loaded empty	Received empty	Idle before shipping	Idle after shipping	Idle days before reposition.*
EUR1	9,341	3,814	3297	8553	25	26	89.79
ASI1	3,036	1,805	1566	3399	33	32	92.95
ASI3	1,322	2,859	3205	1764	19	21	25.21
AME1	3,367	2,024	764	2133	23	22	75.71
AME2	2,426	2,124	1274	1608	26	24	62.05
EUR2	2,526	1,129	900	2090	18	19	56.51
AME4	1,888	2,473	1378	727	12	23	29.37
ASI11	313	2,546	2500	320	19	21	21.28
ASI2	1,781	255	921	2529	49	46	138.64
AME3	1,874	1,466	527	965	29	28	94.35
ASI14	619	2,104	1602	209	19	21	26.50
ASI4	888	559	1338	1594	20	21	33.34
ASI12	249	1,864	1849	273	19	20	21.22
EUR3	1,827	776	272	1334	22	20	148.32
ASI13	186	1,578	1690	270	4	25	4.41
ASI6	1,101	486	465	1083	32	33	108.23
ASI5	1,416	34	70	1452	22	20	427.24
AME5	972	875	453	557	39	41	118.89
ASI7	634	660	649	721	38	35	75.42
ASI15	536	1,018	826	207	21	39	34.39
AME7	196	863	956	283	25	27	30.00
AME9	273	919	709	83	18	32	24.59
ASI10	755	512	187	465	20	24	99.25
AME8	148	906	832	32	24	29	26.79

6.6.2. Example of three representative ports

We picked three representative ports – Port 1 in Europe, Port 2 in Asia, and Port 3 in US – for our detailed demand/supply analysis. We picked them because their volumes are significant and they play important roles in balancing empty roll trailers in the entire system. Port 1 is a net export port (export > import); Port 2 is a net import port (export < import); and Port 3 is a balanced port (export = import roughly).

Data for Port 1 is shared below. The unit is number of trailers in a week. We analyzed 3 years of data to get the mean and standard deviation.

Table 9: Average demand and supply port of Port 1

PORT	Port 1		
	Supply	Demand	Net need
Mean	7.1	15.9	10.1
SD	7.1	11.1	10.6

Demand is defined as the demand on empty trailers. Supply is defined as the 'natural supply', meaning the empty roll trailers after unpacking is done. This does not include repositioning, which are empty roll trailers deliberately sent to the port for replenishment. Looking at 'natural supply' is useful as we want to know what would happen if the system is left alone without any system intervention.

As we can see, the average weekly demand is 15.9 roll trailers and the average weekly natural supply is 7.1 roll trailers. The average weekly net need is 10.1 roll trailers. This means that on average Port 1 needs a supply of 10.1 empty roll trailers to fulfill the demand. This 10.1 empty roll trailers supply is on top of the natural supply, and can only be done via system intervention.

Another point to note is that roll trailers from 'natural supply' takes time to become unpacked. So that means there is a time lag. Based on the data, it's around 10-14 days for different ports. We could use 2 weeks here. In this case we should look at the supply 2 weeks earlier for the demand of a particular week.

It takes 13 days on average to reposition empty roll trailers from other ports to Port 1. The demand during this period is 18.8 (13/7*10.1=18.8) roll trailers. This could be set as the trigger point for replenishment.

Table 10: Average demand and supply port of Port 2

PORT	Port 2		
	Supply	Demand	Net need
Mean	18.3	2.4	0.2
SD	16.6	4.1	1.2

For Port 2, it takes 26.4 days to reposition empty roll trailers from other ports. The weekly average net need is 0.2 roll trailers. So the trigger point for replenishment should be 0.8 (26.4/7*0.2) roll trailers. When inventory is below this point, replenishment should be triggered.

Table 11: Average demand and supply port of Port 3

PORT	Port 3		
	Supply	Demand	Net need
Mean	13.4	15.3	6.2
SD	10.7	12.4	10.8

For Port 3, it takes 18.5 days to reposition empty roll trailers from other ports. The weekly average net need is 6.2 roll trailers. So the trigger point for replenishment should be 16.4 (18.5/7*6.2) roll trailers. When inventory is below this point, replenishment should be triggered.

7. Conclusion: synthesis of findings and recommendations

In this thesis, we provided a methodology for transportation companies to understand RTI fleet management and optimization in a broad integrated approach, not limited to technology but embracing processes, KPIs, monitoring system and appropriate data analysis as well. Based on a case study and data analysis, we came to the following conclusions:

- **Data integrity and tracking system maturity** are the first step to visibility and fleet management optimization. Companies should first assess the maturity and accuracy of their data system before deciding on whether to invest in a new technology. The opportunity of investing in a real time tracking technology depends essentially on:
  - the value of the RTI we want to track, which is composed of both values of owned assets and leased assets
  - the room for improvement and the marginal additional visibility the technology will be able to bring
  - the real value of the investment, bringing the total investment cost to the actual use of the technology.
- An **appropriate definition of asset utilization** is key to determine the fleet size. The maturity of the data system will tell how reliably a company might report this metric. We found that for shipping companies managing RTIs, a tracking system should be able to provide detailed information regarding the activity and location of each asset as well as the life cycle (duration) of each asset and of the fleet as a whole. We found in our case study that most time in the life cycle of a chassis is spent idle, with almost half of the life cycle being assets waiting empty in ports. There is a threshold beyond which the idle time cannot be reduce, because of the structural imbalance of trade which require empty repositioning.
- **Improving asset utilization can help reduce the fleet size** and therefore fleet costs. However:
  - The financial savings a company could expect from improved asset utilization depend on the value of the assets and have to be compared to the effort that is required to achieve new targets regarding utilization

- The space for improvement is limited by operational constraints, especially moving times (either it is sailing, trucking or railing), arrivals and departures schedules in each depot and demand variability.

- **The fleet composition and leasing policy has an impact on operating costs**. Historical data may be used to determine an optimal level of leasing to cope with seasonality and demand variability. The space for improvement however is constrained by the contractual terms the company has with lessors.
- **Segmenting flows allows companies to identify global repositioning patterns** and might allow companies to define systematic repositioning flows from net importers to net exporters. Historical data regarding demand and supply in each depot should allow shipping companies to anticipate flows and design some systematic repositioning flows, regardless of actual local bookings.
- **Segmenting depots and measuring their specific performance** regarding asset utilization allows companies to identify where efforts shall be concentrated to generate most improvements. In our case study, we found that a few ports account for most of the repositioning flows, and that half of the most important ports of destination of empty chassis are also the biggest ports of origin of empty chassis. So:
  - There might be redundant flows that the company could save, which would allow the company to operate with fewer chassis
  - However, this redundancy might be the result of operational constraints (vessels' schedules constraining the synchronization of flows) or of the composition of the fleet (a port might have many trailers, but not of the right size)
- **A monitoring and reporting system is key** to understand asset utilization globally and locally. It is the critical link between efficient tracking system, visibility and managerial actions to optimize the fleet of RTIs. We think that a monitoring system should be able to report:
  - The inventory and status of different types of chassis in each terminal
  - Utilization performance metrics in days for each depot with a limited but significant chassis statuses (in this thesis we identified six statuses we think are relevant for the purpose of fleet management and optimization)
  - Globally and locally, the status of the fleet at a given time
  - Hierarchical views on terminal, port, country, region, global

o Expected flows from incoming vessels and for outgoing vessels, relying on the moving inventory and providing a projected inventory within a time period to be defined.

Tracking capability itself is certainly the first step to asset visibility and fleet optimization. However, having an integrated approach including technology, process and monitoring system is critical to obtain potential benefits. Increasing information with data is profitable if the company:

- can actually make the most out of the data
- uses the appropriate metrics to convert tracking into visibility
- has operationally enough space for converting visibility into operational change.

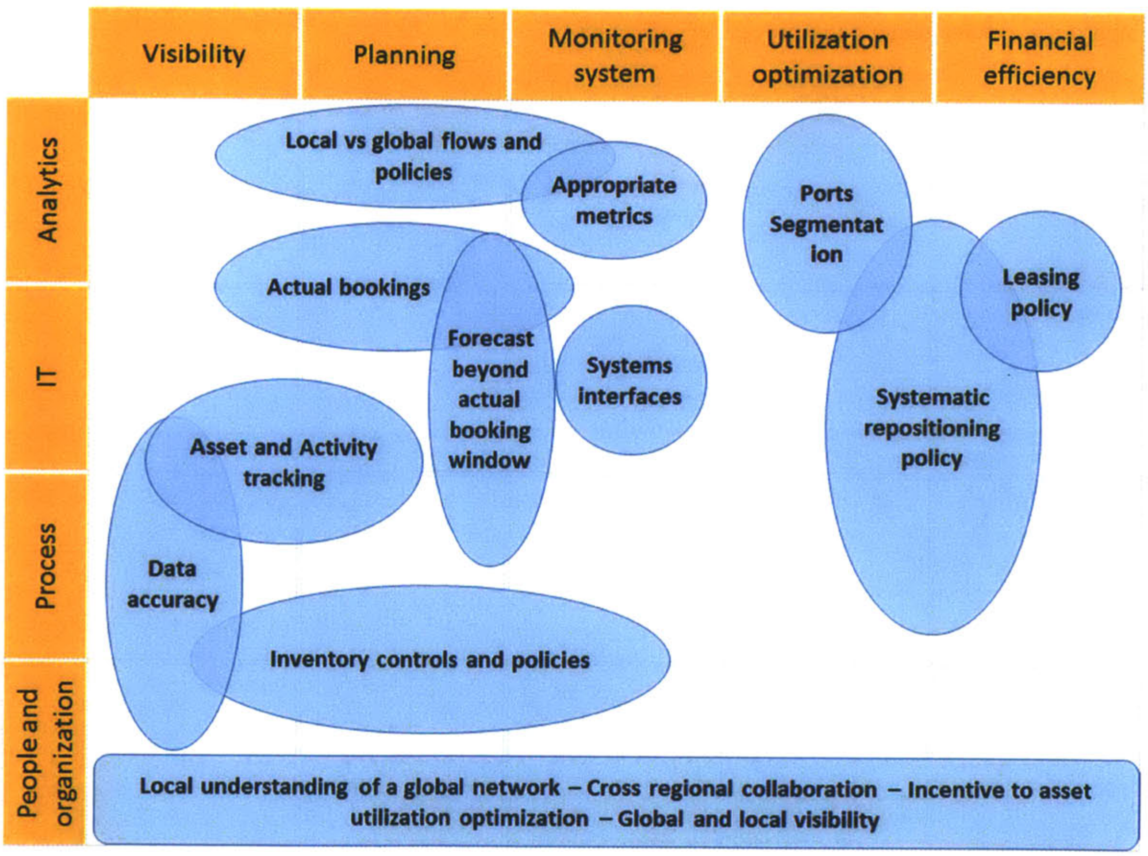


Figure 20: The integrated system for Asset Optimization

Figure 20 represents all the different components that are at stake when a company wants to optimize asset management. The path to financial efficiency starts from extended asset visibility. As stressed out by Yossi Sheffi, Director of the Center of Transportation and Logistics at MIT, planning then plays a key role as it is key to capture needs dynamically, which is critical in a many to many network of depots, vessels and types of assets. Visibility and advanced planning allow people to monitor the global and local flows of demand, supply and repositioning; these monitoring tools need specific developments and appropriate metrics to evaluate flows performance. Exactly knowing the activity and flows, The Company can work on improving the key performance drivers, to finally achieve global efficiency. We see that our initial question concerning asset tracking capabilities is key, as it is a starting point of the path to optimization: without asset tracking and accurate data, The Company can make neither tactical nor strategic decisions. But we insisted on the fact that tracking alone is not sufficient to provide business benefits. New technologies should always be accompanied with appropriate management and process improvements.

Bibliography

References

Assaf, C., & Massachusetts Institute of Technology. Dept. of Civil and Environmental Engineering. (2003). The development of a GPS enabled tracking system implemented on a web services architecture. (M.Eng., Massachusetts Institute of Technology, Dept. of Civil and Environmental Engineering). , 60.

Beaujon, G. J., & Turnquist, M. A. (1991). Model for fleet sizing and vehicle allocation. *Transportation Science, 25*(1), 19-45.

Bell, M. G. H., Liu, X., Angeloudis, P., Fonzone, A., & Hosseinloo, S. H. (2011). A frequency-based maritime container assignment model. *Transportation Research Part B-Methodological, 45*(8), 1152-1161.

Bojkow, E. (1991). Basic considerations on the calculation of the trippage number for returnable containers. *Packaging Technology and Science, 4*(6), 315-331.

Bu, X., & Wang, Z. (2010). Forwarder's shipping capacity option procurement policies with option trading and empty equipment repositioning. *1st International Conference on E-Business and E-Government, ICEE 2010, may 7, 2010 - may 9,* pp. 4061-4064.

Carrasco-Gallego, R., Ponce-Cueto, E., & Dekker, R. (2009). *A framework for closed-loop supply chains of reusable articles* (Online ed.)

Carroll, J. (2006). Performance analysis of an integrated GPS/Loran-C tracking system. *Institute of Navigation, National Technical Meeting 2006, NTM, January 18, 2006 - January 20, , 2.* pp. 615-628.

Crainic, T. G., Gendreau, M., & Dejax, P. (1993). Dynamic and stochastic models for the allocation of empty containers. *Operations Research, 41*(1), 102.

Dong, J., & Song, D. (2009). Container fleet sizing and empty repositioning in liner shipping systems. *Transportation Research Part E-Logistics and Transportation Review, 45*(6), 860-877.

Dong-Ping Song, & Earl, C. F. (2008). Optimal empty vehicle repositioning and fleet-sizing for two-depot service systems. *European Journal of Operational Research, 185*(2), 760-77.

Du, Y., & Hall, R. (1997). Fleet sizing and empty equipment redistribution for center-terminal transportation networks. *Management Science, 43*(2), 145.

Frazelle, E. (2002). *Supply chain strategy : The logistics of supply chain management*. New York: McGraw-Hill.

Hellström, D., & Johansson, O. (2010). The impact of control strategies on the management of returnable transport items. *Transportation Research: Part E, 46*(6), 1128-1139.

Hellstrom, D. (2009). The cost and process of implementing RFID technology to manage and control returnable transport items. *International Journal of Logistics: Research & Applications, 12*(1), 1-21.

Jagatheesan, J., Kilcullen, R., & Massachusetts Institute of Technology. Engineering Systems Division. Thanks for using Barton,the MIT Libraries' catalog http://libraries.mit.edu/barton. (2011). Incorporating cycle time uncertainty to improve railcar fleet sizing. (M. Eng. in Logistics, Massachusetts Institute of Technology, Engineering Systems Division). , 79.

Johansson, O., & Hellström, D. (2007). The effect of asset visibility on managing returnable transport items. *International Journal of Physical Distribution & Logistics Management, 37*(10), 799-815.

Jula, P., & Leachman, R. C. (2011). Long- and short-run supply-chain optimization models for the allocation and congestion management of containerized imports from asia to the united states. *Transportation Research Part E-Logistics and Transportation Review, 47*(5), 593-608.

Kuzeljevich, J. (2005). Thinking inside the box. *Canadian Transportation & Logistics, 108*(3), 16-20.

Lei, T. L., & Church, R. L. (2011). Locating short-term empty-container storage facilities to support port operations: A user optimal approach. *Transportation Research Part E-Logistics and Transportation Review, 47*(5), 738-754.

Li, J., Leung, S. C. H., Wu, Y., & Liu, K. (2007). Allocation of empty containers between multi-ports. *European Journal of Operational Research, 182*(1), 400-412.

Meng, Q., & Wang, S. (2011). Liner shipping service network design with empty container repositioning. *Transportation Research Part E-Logistics and Transportation Review, 47*(5), 695-708.

Pankratz, A. (1991). *Forecasting with dynamic regression models.* New York: Wiley.

Pizzagalli, J., & Massachusetts Institute of Technology. Dept. of Urban Studies and Planning. Thanks for using Barton,the MIT Libraries' catalog http://libraries.mit.edu/barton. (2001). Using bar codes to improve labor and equipment tracking in the construction industry. (S.M., Massachusetts Institute of Technology, Dept. of Urban Studies and Planning). , 70.

Schmidt, R., Gagnon, A., & Allcock, D. (2008). Trial results of a new low-cost and covert technology to trace the path of maritime containers worldwide. *42nd Annual 2008 IEEE International Carnahan Conference on Security Technology, ICCST 2008, October 13, 2008 - October 16,* pp. 102-106.

Shintani, K., Imai, A., & Nishimura, E. (2004). The location routing problem for container shipping networks with empty container repositioning among calling ports. *Journal of Japan Institute of Navigation, 111*, 273-84.

Smith, R. (2008). *Just where have all the roll cages gone?* Chartered Institute of Logistics & Transport (UK).

Som, R. (2008). Meating the need for tracking and control. *Food Magazine,* , 10-12.

Twede, D. (1997). Less waste on the loading dock. *Resource Recycling, 16*(5), 68-68.

Twede, D. (1996). Do returnable containers for large finished goods make sense? - returnable packaging considerations. *Proceedings of the 1996 Annual Fall Meeting of Council of Logistics Management,* pp. 583-583.

Twede, D. (2009). The value of shipping containers. *TAPPI Corrugated Conference 2009, CorrExpo 2009, September 1, 2009 - September 2,* pp. 20-28.

Wang, B., & Yang, T. (2012). Stochastic optimization of empty container repositioning of sea carriage. *2011 International Conference on Mechanical Properties of Materials and Information Technology, ICMPMIT 2011, September 10, 2011 - September 11, , 340.* pp. 324-330.

Yuan, Z., & Huang, D. (2008). A novel RFID-based shipping containers location and identification solution in multimodal transport. *Canadian Conference on Electrical and Computer Engineering,* pp. 267-271.

Yun, W. Y., Lee, Y. M., & Choi, Y. S. (2011). Optimal inventory control of empty containers in inland transportation system. *International Journal of Production Economics, 133*(1), 451-457.