OPTIMIZING LOGISTICS IN A LEAN INTERNATIONAL SUPPLY CHAIN

By
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B.S. 2003, Northwestern University

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ABSTRACT

Since the signing of NAFTA in 1993, North American automotive OEMs have moved final assembly and other manufacturing operations from domestic locations to international locations. Mexico provides a relatively inexpensive labor force and is within geographic proximity of the US. Tier One suppliers have also relocated some operations to Mexico, such as American Axle & Manufacturing (AAM) and its Guanajuato Gear & Axle (GGA) facility, where this study was performed.

While the proportion of GGA's inbound material sourced in Mexico has increased, this still represents a small fraction of GGA's supply base. Numerous efforts have been made at localization of suppliers to Mexico, both through existing suppliers relocating and the development of Mexico-based suppliers. For the suppliers remaining in the US and Canada, there are numerous possible transportation solutions, including FTL, stacktrain, LTL, and milkruns.

The crux of this thesis lies in the hypothesis that GGA would be better able to optimize logistics, if it had the ability to choose mode and frequency on a real time basis after having a more precise understanding of inbound material flow. A case study was then performed on the optimal manner in which to ship empty returnable containers to suppliers, which is established to be per container demand at the supplier site. Then, a model is developed and tested that takes as input the forecast of raw material shipments from GGA's entire supply base and outputs a set of packing lists that minimizes logistics cost while meeting supplier demand for empty containers. . The model outputs are tested on a limited basis, but full implementation has not been conducted at the time of writing. Based on preliminary calculations, it is expected that implementation would have a significant impact on GGA logistics expense.

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Finally I would like to thank my loving girlfriend Kim, whose patient, levelheaded demeanor gave me the strength I needed to complete this extended assignment overseas.

Biographical Note

Peter Frys was born in Prague, Czech Republic, but grew up primarily in Portland, OR after immigrating to the US with his family as a young child. He earned a Bachelor of Science from Northwestern University in 2003, majoring in Industrial Engineering and Economics. After graduating, Peter spent nine months in Thailand on an extended internship in Process Engineering at Seagate Technologies. Upon returning to the US, he took a position with Morgan Services, first as a Production Manager at their Chicago plant, and then as Plant Manager of their facility in Boston. During this time, he led held significant line management responsibilities and led numerous focused improvement initiatives aimed at improving safety, quality, delivery, and cost. In 2007, Peter somehow gained admittance to MIT as a graduate fellow in the Leaders for Manufacturing program. He expects to graduate in June 2009 with Masters Degrees in Business Administration and Mechanical Engineering.

After graduation, Peter has accepted a position as an Associate at McKinsey & Co. in Prague, Czech Republic. Outside of work and academia, Peter enjoys international travel, ice hockey, and skiing.

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GLOSSARY

AAM	American Axle & Manufacturing
API	Annual Physical Inventory
ASN	Advanced Shipping Notice
CWT	100 Pounds Freight (Hundred Weight)
DELJIT	Delivery Just-in-time (Daily ship schedule)
DGA	Detroit Gear & Axle
EDI	Electronic Data Interface
EPEI	Every Part – Every Interval
FGI	Finished goods inventory
FTL	Full Truckload
GF	Guanajuato Forge
GGA	Guanajuato Gear & Axle
GGA-N	GGA North Plant
GGA-S	GGA South Plant
JIT	Just in Time
LTL	Less than Truck Load
MRP	Materials Requirement Planning
OEM	Original Equipment Manufacturer (GM, Ford, Chrysler)
PFEP	Plan for Every Part
POP	Production Operating Plan
PPAP	Part Production Approval Process
PR&R	Problem Report and Resolution
SPMS	Supplier Performance Measurement System
TPS	Toyota Production System
TRD	Three Rivers (AAM axle & driveshaft plant)
WHQ	World Headquarters (AAM corporate office)

1. Introduction

1.1 American Axle & Manufacturing Company Overview

Axle & Manufacturing (AAM) is a world leader in the design, engineering, testing, validation and manufacturing of driveline, drivetrain, and chassis systems, related components, and metal formed products for light trucks and buses, sport utility vehicles, crossover vehicles, and passenger cars. (American Axle & Manufacturing) American Axle & Manufacturing (AAM) was founded in 1994, with manufacturing expertise rooted in 90 years of experience. Today, AAM is $3.2 billion company, one of the largest automotive suppliers in the world. Since its founding, AAM has grown from its original five North American manufacturing facilities to 29 facilities around the world. (American Axle & Manufacturing)

1.2 Guanajuato Gear & Axle Site Overview

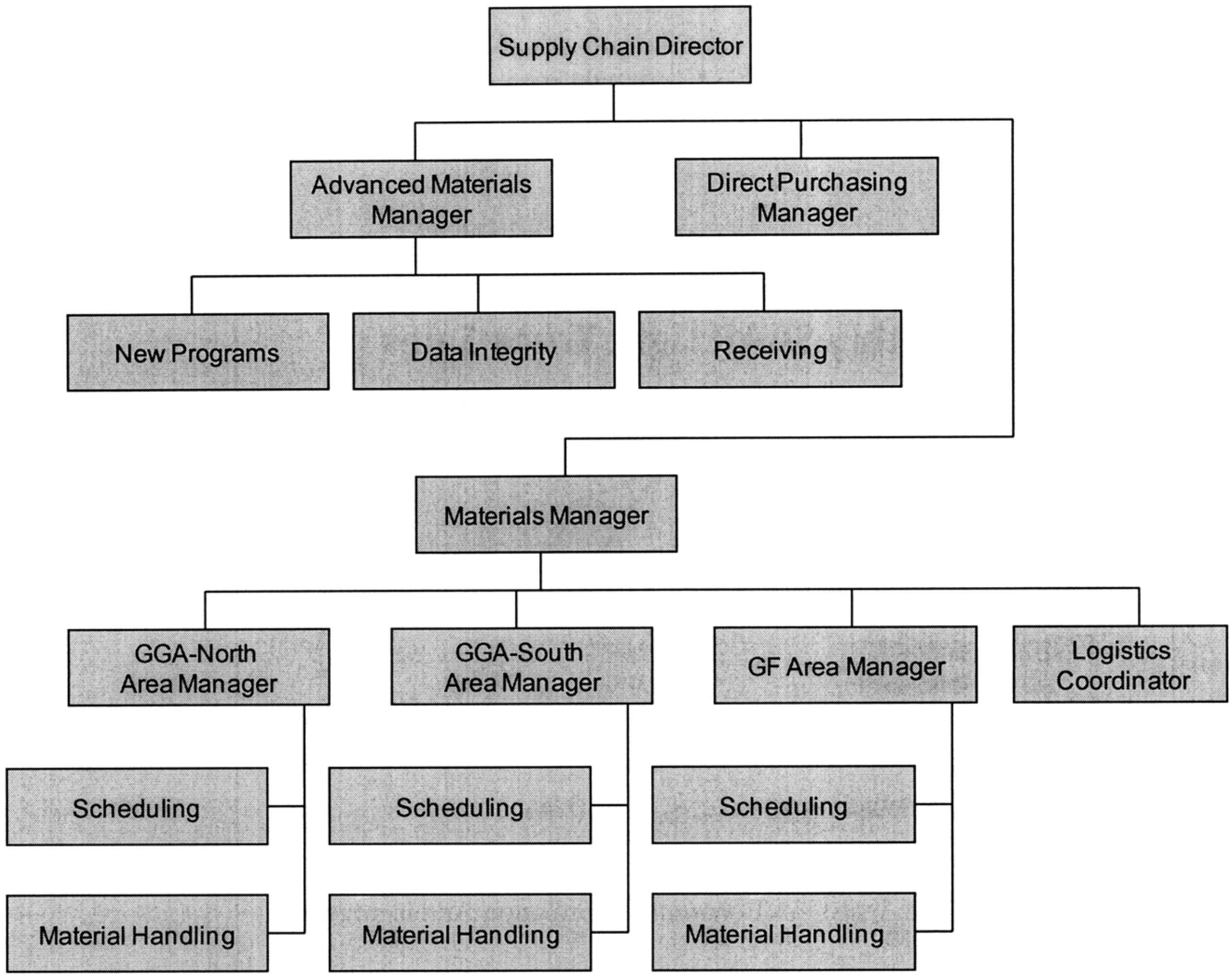
AAM's Guanajuato Gear & Axle Facility has a dedicated team of highly skilled associates working with AAM's leading-edge technology. This benchmark facility has applied the best practices from all of AAM's global facilities to manufacture rear-axle assemblies, propeller shafts, and driveline systems that are unmatched in quality and cost efficiency. Guanajuato Gear & Axle places AAM in the heart of Latin America. (American Axle & Manufacturing) Guanajuato Gear & Axle (GGA) serves as AAM's low-cost manufacturing facility for the North American OEM assembly sites that it serves. These OEM sites are spread between Mexico and the southern part of the United States. At times, GGA has also served OEM sites in the midwest. The production mix at OEM is representative of AAM's overall manufacturing mix.

GGA has expanded significantly from the original facility. It now consists of the north plant (GGA-N), which produces gears and axles, the south plant, which primarily produces axle tubes and driveshafts, and the forge (GF), which produces forgings for gears and other critical manufactured components. The manufacturing groups at GGA are organizationally divided along the lines of these physically separate facilities. However, shared resources such as materials, IT, and metalurgy are centrally managed with resources allocated to each of the three plants.

1.3 GGA Materials Department Overview

The project documented in this thesis was conducted within the umbrella of the supply chain organization at GGA. This organization consists primarily of the direct purchasing group, which manages new contracts with Mexico-based suppliers and the materials department. The materials department's responsibilities include production planning, raw material scheduling, material handling, shipping, and logistics. Additionally during the time of the project, GGA initiated a new group known as "Advanced Material," comprising of receiving, new program management, and data integrity within the MRP system. These were identified by management as weaknesses within the supply chain organization. The scope of this project focuses with the logistics group. However, truly optimizing the supply chain with regards to logistics expense requires cooperation with every group within the supply chain umbrella. Figure 1 shows a simplified organizational chart for the supply chain organization at GGA.

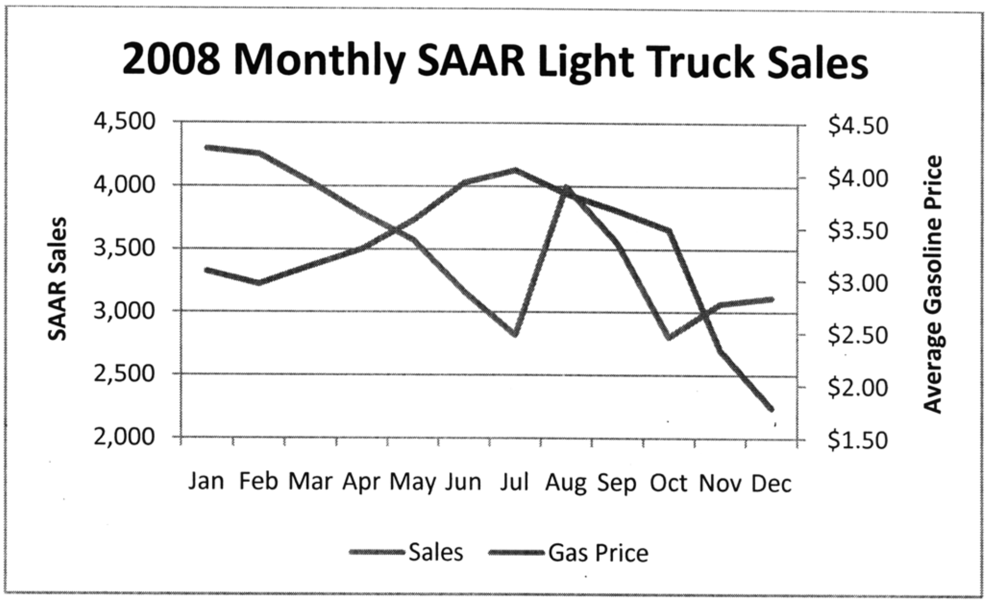
Figure 1: GGA supply chain organizational chart



1.4 Company & Industry Context

During the first half of 2008, AAM's American-based facilities in Michigan and New York State endured a 13-week strike. During this time, much of the volume that had previously been produced at these facilities was transferred to GGA, which became for this period AAM's only operating North American plant. Due to this situation, GGA produced at maximum capacity during this time period. The only priority was throughput and delivery; all concern for cost went out the window. The strike was resolved in May 2008, coinciding roughly with the beginning of the global spike in gasoline price in the summer of 2008. Although AAM had made substantial efforts to diversify its customer base, the vast majority of its business depended on the sales of light trucks and SUVs by domestic OEMs. During the first half of 2008, gasoline prices rose dramatically, which gravely hurt the sales of light trucks and SUVs. In the latter part of 2008, tightening credit markets and depressed consumer confidence depressed the sales of all automobiles. Figure 2 shows the decline in the seasonally adjusted annual rate (SAAR) of light truck sales during 2008 compared with the average price of gasoline. With exception of a blip in August, sales decreased dramatically throughout the year.

Figure 2: 2008 Sales of Light Trucks & SUVs



(US Bureau of Economic Analysis) (Economic Information Administration)

This decline in sales has forced a dramatic restructuring in the automotive industry and within AAM specifically. In the specific case of GGA, production volumes declined tremendously from their peak at the time of the US strike through the end of 2008. This project was conducted in an environment of constantly declining production volumes and busy stream of initiatives on how to improve the way in which the plant operates to cut costs.

2. Literature Review

Prior to the development of any sort of aid to help logistics needs at GGA, a vast amount of research was done examining prior approaches to the problem. Research included areas such as international supply chain design, milkrun networks, and also past studies involving returnable containers. One common theme throughout literature in the area of logistics is that manufacturing companies tend to ignore the issue of logistics as a key element in their operations.

> Logistics is a critical function for manufacturers because it's the process that links all parts of their supply chains. Even so, manufacturers often don't consider the warehouse a priority for implementing continuous-improvement initiatives. According to the 2005 IW/MPI Census of Manufacturers, 82.3% of 583 plants surveyed implemented improvement methods at the production level, while only 39.3% reported similar efforts at their shipping and logistics departments. More manufacturers might reconsider their current logistics practices if they knew the potential savings they could achieve. (Katz)

This lack of focus on logistics and logistics expense is certainly true of the case study in this thesis. Cost improvement initiatives at GGA have focused largely on work within the plant and not on the overall value chain. This fact is also prevalent in the way AAM has chosen to design its supply chain strategy, specifically in running a manufacturing facility in Mexico with a supply base largely located in the U.S. and Canada. This fact, and the issues that it creates, will be cited on multiple occasions in the thesis.

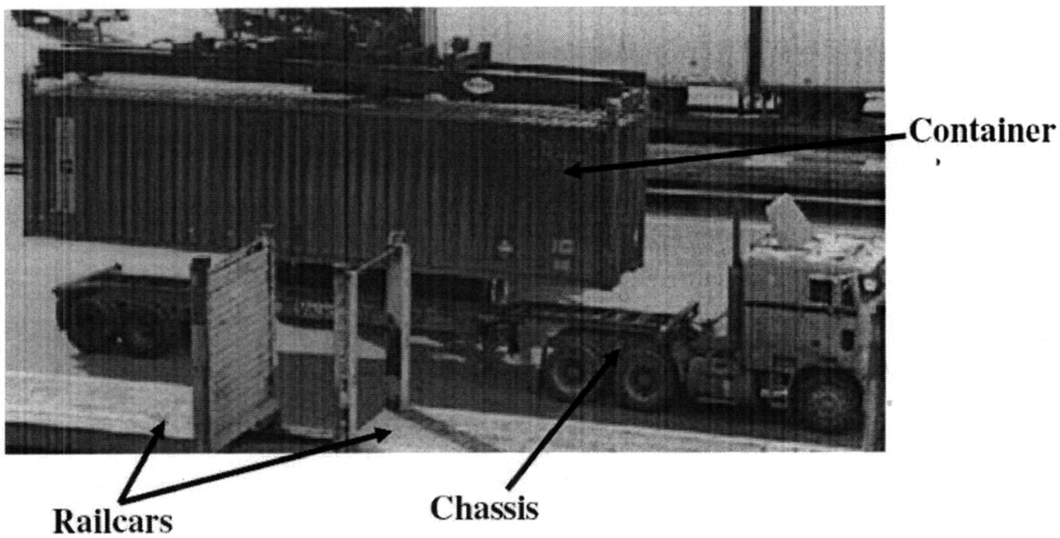
2.1 Logistics Terminology Review

The following section gives clear definitions of critical terms in logistics. These definitions are taken directly from Brooke Kahl's 2006 thesis at Eastman Kodak.

> Container – A standard-sized, rectangular metal box that can be used to transport freight by ship, truck, and rail. Containers are designed to fit in ships' holds and are often referred to as ocean containers; however, they can also be transported on public roads atop a container chassis towed by a truck. The latter scenario occurs when ocean transport is combined with truck and/or rail transport, also known as intermodal transportation. Figure (3) depicts an intermodal transportation scenario in which a container is being off loaded from a railcar and loaded onto a chassis for transportation by truck. (Kahl)

The picture below (Figure 3) shows an intermodal (stacktrain) container being moved from a railcar onto a tractor trailer.

Figure 3: Stacktrain Display & Terminology (Kahl)



Trailer – A trailer, often referred to as a semi-trailer or tractor-trailer, is an enclosed container or flat chassis that is used for freight transportation via land. It is similar to a container in size and purpose; however, the chassis and wheels are part of the trailer. Trailers can also be used for storage and, in the interest of time, often a tractor will drop off an empty trailer in exchange for a full one (and vice versa) to save waiting time and to maximize hauling time. (Kahl)

Third-Party Logistics Provider (3PL) – A company or entity that provides the outsourcing services for all or part of a company's logistics needs. A 3PL may manage inventories and reorder points, store goods, and handle consolidation and transportation, among other services. UPS Supply Chain Solutions and Penske Logistics are among the top 10 largest 3PL companies in the world. Using a 3PL may be desirable if a company has deficient logistics competencies or resources and it desires flexible logistics capacities, or it wants to take advantage of volume discounts that can be achieved by a 3PL. (Kahl)

Truckload (TL) – A shipment in which the freight completely fills the truck or trailer. This terminology applies to containers, as well, and is referred to as a container load (CL). Sometimes the terminology full truckload (FTL) and full container load (FCL) will be used and have the same meaning. (Kahl)

Less Than Truck Load (LTL) - A shipment that does not fill an entire truck or trailer. LTL shipments are often consolidated by a third-party logistics provider, known as an LTL carrier, into full truckload shipments. LTL carriers will use strategically placed hubs to consolidate LTL shipments from many sources or customers and sort these shipments into full trucks destined for a location or region. Some examples of these companies include Yellow Freight and U.S. freightways. (Kahl)

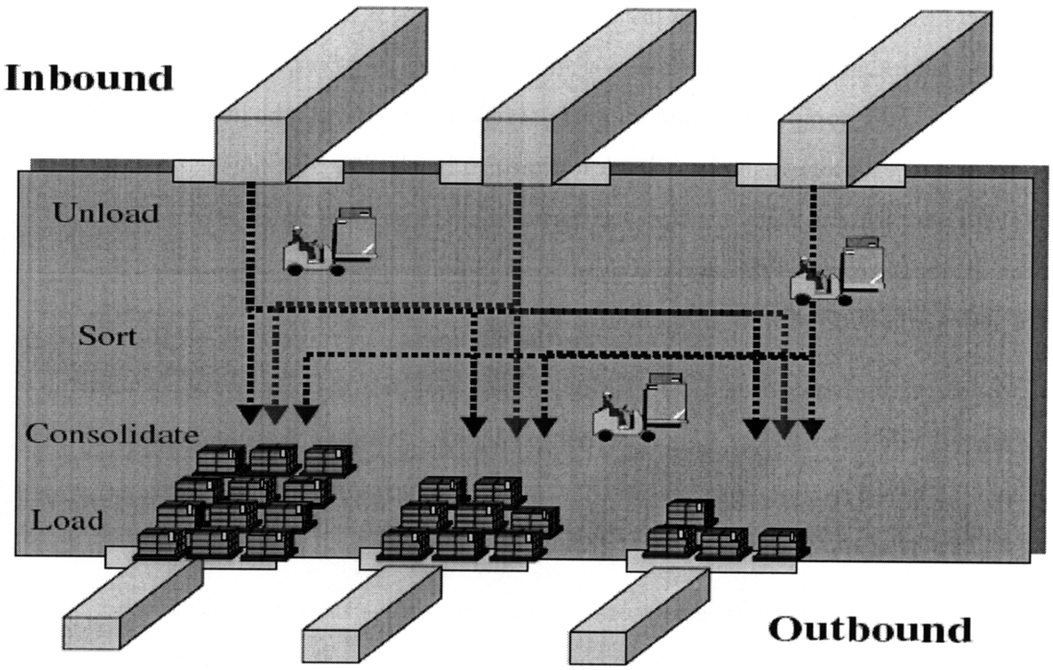
Lead Time – Lead time is the total amount of time it takes from the order point to the point of delivery where the item is available for use. This total lead time is a summation of order lead time, manufacturing lead time, and transportation lead time; however, it may not always include all three of these components, and there are several levers that can be used to affect these lead times. For example, manufacturing lead time can be eliminated if finished goods are stored at the supplier and ready for shipment upon the receipt of an order. Order lead times can be drastically reduced through electronic data interchanges and transportation lead time can be reduced by using a hub or distributor. (Kahl)

Landed Cost – A method of costing materials that includes not only the piece price, but also all of the expenses related to ordering and delivering the goods. Some of these additional costs may include transportation costs, import duties and fees, taxes, inventory holding costs, and warehousing and handling charges. (Kahl)

Milk Run – A milk run consists of a pickup or delivery route with several stops along the way which is usually run on a regular basis. In some cases, deliveries of goods or empty containers and pickup of materials may occur in the same run. Milk runs are primarily set up with local suppliers, or distant suppliers with local warehouses, that are within geographic proximity to each other; however, milk runs may be set up and function in all parts of the supply chain—inbound, internal, and outbound. The benefits of a milk run include having regularly scheduled, predictable material orders, transportation routes and deliveries, thus reducing inventories, leveling the shipping and receiving workloads, and improving communication and visibility in the supply chain. (Kahl)

Cross-Docking – Cross-docking is the activity of unloading inbound materials coming from a common region or source, sorting these materials, and immediately loading them onto outbound trucks that are headed for a common location or a regional route. The goal of cross-docking is to eliminate the need for warehouses, thus reducing transportation lead times and inventories. In some cases, it may take days or even weeks to move the material through a cross-dock, especially if consolidation is required for an outbound shipment; at this point the "cross-dock" is essentially functioning as a warehouse.30 Cross-docking is commonly used when large shipments of material are intended for multiple points of use but are originating from one supplier or region. Cross-docking is common in a hub-and-spoke network configuration such as in FedEx's network where many packages in the U.S. are routed through Memphis, one of FedEx's six U.S. hubs.34 Figure (4) illustrates the concept of cross-docking at Kodak. (Kahl)

Figure 4: Diagram of Cross-docking activity (Kahl)



2.2 Milkrun Network Literature

Milkruns at this stage are critical to the inbound supply chain of GGA. Milkruns have been adopted throughout the automotive industry as a way of realizing efficiencies in load consolidation. Robert Cook most aptly explains the benefits of milkruns and the way in which they enforce the principles of lean supply chains.

> A lean cross dock also supports JIT production by using "milk runs" to pick up materials and deliver them just-in-time and in a consolidated manner. Under this method, trucks use regular pickup routes to build mixed loads from several suppliers and return to the cross-dock. Then moving from the cross dock, trucks use regular routes to deliver mixed loads to multiple production sites. Having a cross dock that utilizes milk runs enables planners to

> realize transportation consolidation efficiencies. Milk runs also typically involve dedicated vehicles, which increases inbound-material visibility and control. These benefits, in turn, facilitate production scheduling efforts. (Robert L. Cook)

It is especially noteworthy in the case of GGA that incoming material from multiple suppliers arrives in a single consolidated load in a dedicated vehicle because of the international nature of GGA's supplier base. It is common that shipments are delayed in customs crossing the border into Mexico, and from the perspective of GGA it is much easier to track, manage, or expedite a single consolidated load crossing the border than it is to track multiple LTL loads. Furthermore as GGA moves to reduce its onsite raw material inventory, a single LTL shipment that is not manually tracked can create a shortage that stops a GGA production line or forces said line to deviate from the production schedule, causing a ripple through the supply chain.

Another benefit of milkruns is the way in which they level workload through the supply chain. Here Cook further illustrates the benefits of milkruns in their relation to heijunka.

> Finally, a lean cross dock follows the TPS principle of heijunka, which is the Japanese word for "to make level." In a cross dock, heijunka would involve leveling the load across operational hours in a manner that supports JIT operations. Heijunka is accomplished by scheduling and performing repeatable pickup and delivery routes at uniform time intervals throughout the day (for example, "pickup route 1" has scheduled departures of 8 a.m., 11 a.m., 2 p.m., and 5 p.m.). A master schedule ensures that the workload is leveled. All tasks have specific start and end times that are strictly met. The result is a level, uniform, rhythmic material flow through the cross dock as well as a level material-handling workload at manufacturing facilities, supplier locations, and the cross dock. (Robert L. Cook)

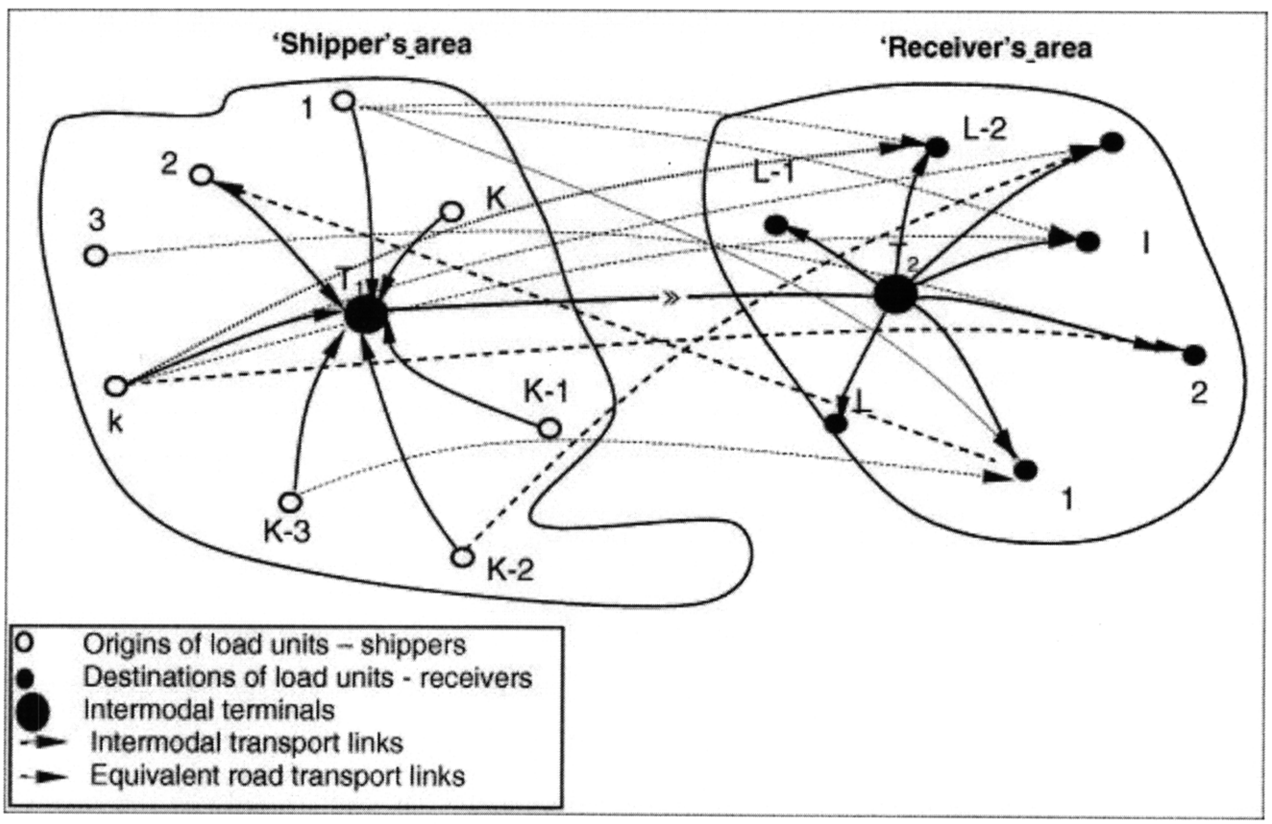
This level nature benefits the suppliers, the 3PL, and also the receiving department at GGA. Receiving is an area that has an irregular workload, and its key asset (the receiving dock) is often not optimally utilized. Consolidated loads from the 3PL at regular intervals optimize the way in which the receiving department at GGA is able to manage its labor and fixed asset resources.

2.3 Intermodal & Full Truckload Freight

In compiling this study, a certain amount of energy was devoted to the study of freight in full truckload quantities. While GGA is moving to a lean logistics model, and milkruns fit well into this strategy, certain suppliers ship a large enough regular volume to GGA that FTL is simply a more economical alternative. Therefore the economics of full truckload should be examined more closely, in addition to intermodal stacktrain, which functionally serves the same segment of freight needs as full truckload.

The essential difference in the functionality of the two freight modes is that while FTL moves directly from supplier to assembler site such as the arc from node 1 to node L-2 in the diagram below (Figure 5), intermodal moves by both truck and train. A load would move by truck from the supplier (node 1) to a consolidation point (node T_1). Then it would be loaded onto a railcar and move by rail to a second consolidation point (node T_2). Then it would be unloaded and moved by truck from the consolidation point to the assembler site (node L-2).

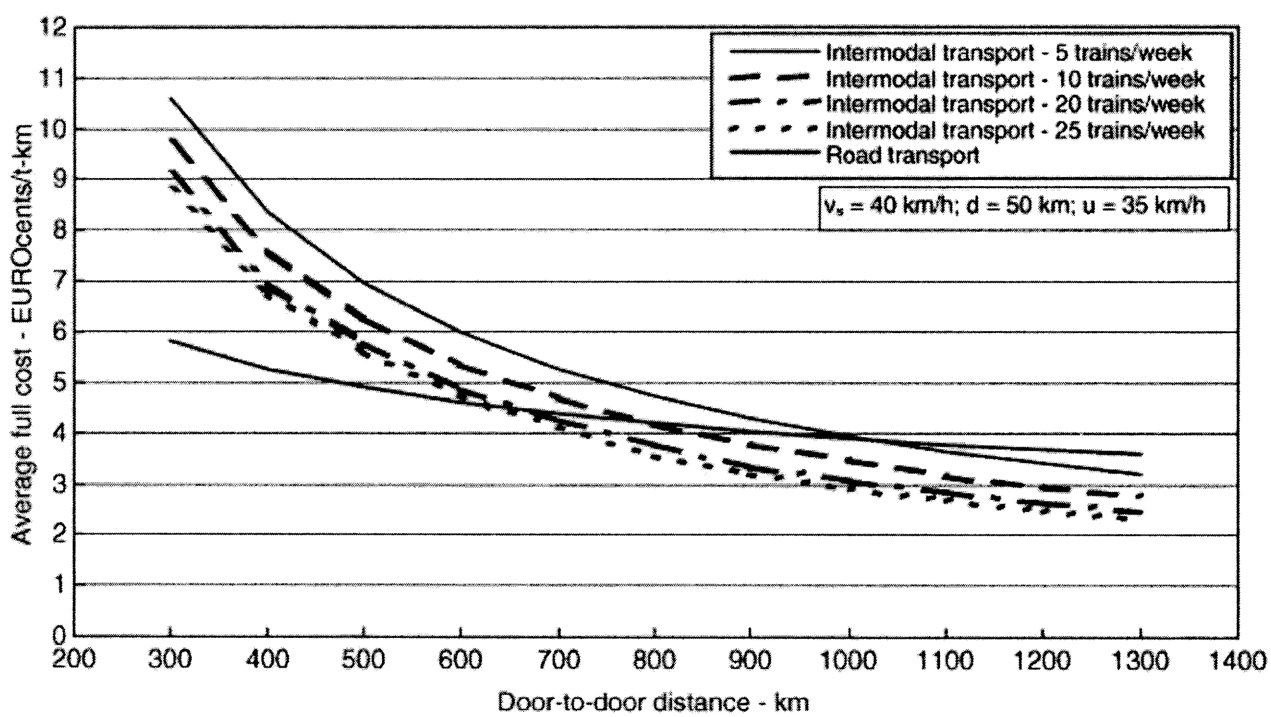
Figure 5: Diagram of Intermodal Network (Janic)



One critical difference between FTL and intermodal stacktrain is that they have a fundamentally different cost structure. Janic notes that "The results show that the full costs of both networks decrease more than proportionally as door-to-door distance increases; suggesting economies of distance." (Janic) This means that when noted in dollars per pound per mile, costs would decrease as distance increases. He goes on to conclude that "internal costs decrease more rapidly with increasing distance in the intermodal case rather than in the road transport network. Consequently, the costs of both networks equalized at a break-even distance." (Janic) This result is based on the fact that the cost of intermodal transport has a higher percentage of fixed cost (per mile) such as the infrastructure of rail networks and rail terminals. On the other hand, the cost of FTL has a higher percentage of variable costs such as labor for drivers and fuel for trucks.

Janic also concludes that while freight by truck has few economies of scale, there are economies of scale in intermodal transport. "For the intermodal transport network, the average full costs decrease at a decreasing rate as the quantity of loads rises indicating economies of scale; in the road transport network they are constant." (Janic) This is likely a result of the fact that the primary fixed assets in intermodal transit are required regardless of the volume of train traffic. The effect of these economies of scale is as follows. "Since the full costs of intermodal transport decrease and those of road transport remain constant as the volume of loads increases, the break-even distance shortens at a decreasing rate." The graph below (Figure 6) shows the relationships from Janic's study between distance, frequency of departures, and freight cost.

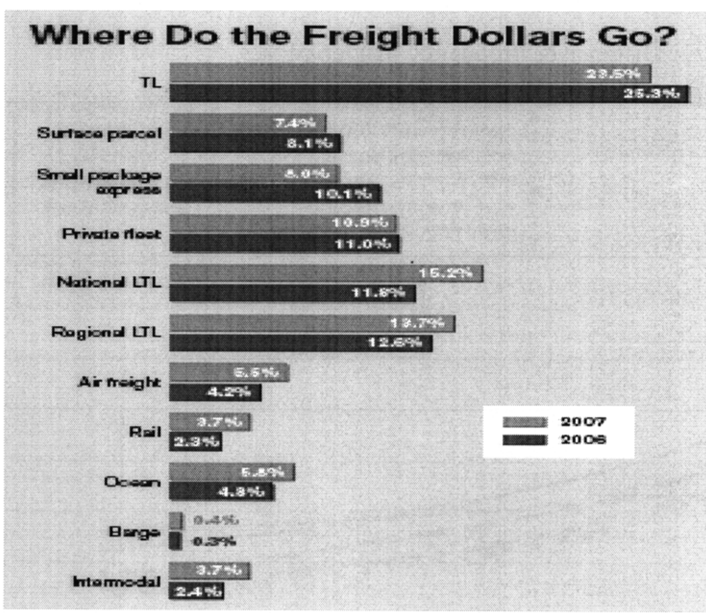
Figure 6: Dependence of Freight Cost on Distance & Frequency of Departures



In determining full truckload carriers, firms state freight cost and transit times as the two most important decision factors. (Manrodt) With regards to freight cost, intermodal has a clear advantage based on the sheer distance between GGA and its supply base. While in Janic's most conservative estimate, the break-even point is around 1000 km (621 miles), the distance between Detroit and GGA is 2,080 miles. Though Janic's model is based on empirical studies in Europe and does not reflect the North American freight market, the considerable distance between GGA and its suppliers does favor intermodal. Furthermore, market trends point to the growth of intermodal relative to other forms of transit. The percentage of total freight expense spent on intermodal grew from 2.4% to 3.7% between 2006 and 2007, while FTL decreased from 26.3% to 23.5% during the same time period. (Manrodt) In the following passage, Manrodt documents the general trend from 2006 to 2007 in moving from full truckload to intermodal stacktrain.

> The data in (Figure 7) show that intermodal continued to win this competition as shippers moved more of their long-haul freight via this mode. Unrelenting high fuel prices and highway congestion were contributing factors to the increased use of intermodal domestically; (Manrodt)

Figure 7: Distribution of Freight Expense among Modes (Manrodt)



The growth in prevalence of intermodal transit increases the frequency of departures of stacktrains, which will, according to Janic, decrease the cost of operating intermodal transit, further reinforcing its cost advantage.

In addition to freight cost, the other key factor in determining the relative desirability of intermodal and FTL is transit time. While transit time for FTL is simply a function of distance, intermodal transit time is a function of several factors. These include distance between each of the nodes, transfer time at the consolidation points, and the frequency of train departures between the consolidation points. While travel time for truck and rail are comparable, the largest gap comes from time spent at consolidation points, the sources of this time spent being queue time for transfer, and the cycle time between rail departures. As intermodal has developed and grown in North America, train departures have become more frequent and transfer infrastructure has improved, hence reducing this wait time. At the present moment, based on available figures at GGA, transit time for FTL is four days while intermodal is five days from Michigan.

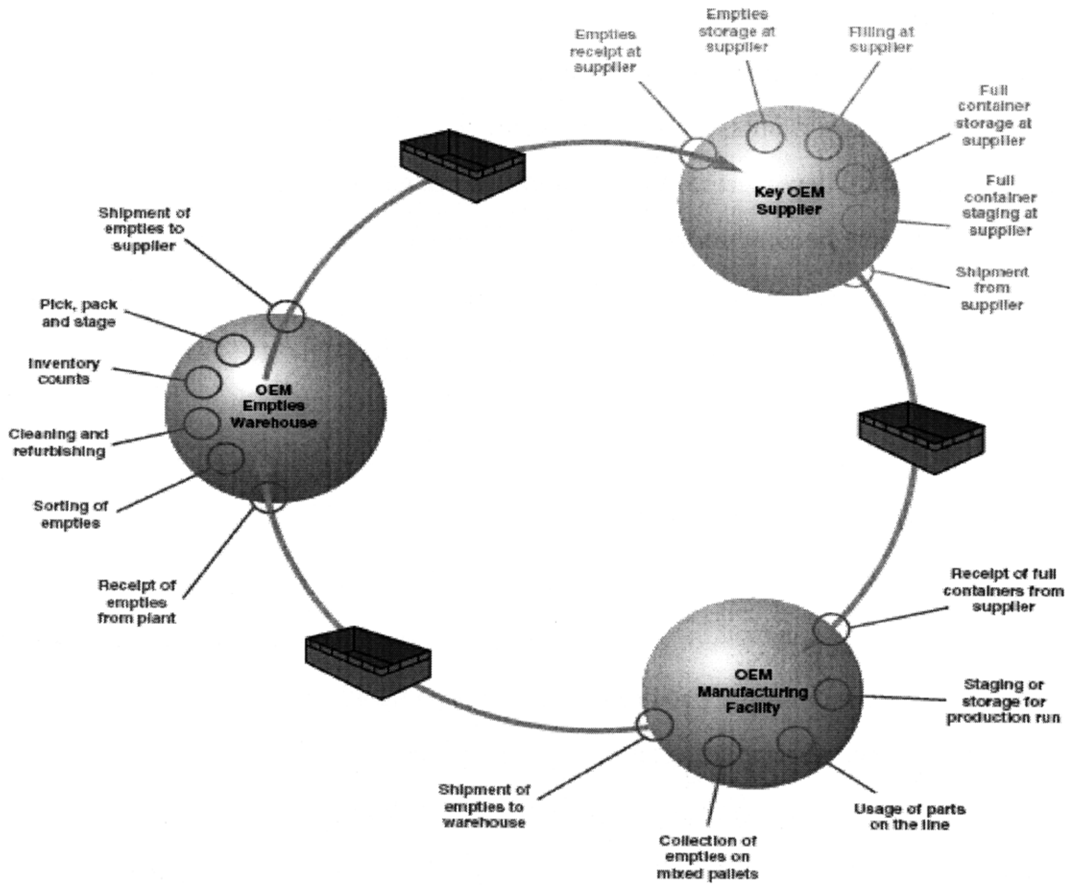
2.4 Returnable Container Literature Review

An area that needs to be studied more closely when looking at logistics at GGA, and the automotive industry in general, is the fact that 97.5% of the volume of incoming parts are received in returnable containers, which need to be sent empty back to the suppliers. The inherently wasteful process of sending empty containers back to suppliers comprises around 20% of total logistics cost at GGA. The author has therefore gone through prior research in order to find a valid framework to assess the wastes associated with returnable containers in terms of logistics, and also with regards to shrinkage, working capital, and material handling.

It is important to note that standard practice in the automotive industry is that responsibility for logistics falls on the downstream member in the supply chain. In the case of GGA, logistics for outbound finished axles driveshafts is the responsibility of the OEM customer. This study is concerned with costs directly incurred by GGA and therefore will only deal with GGA and its upstream suppliers.

In 2008, IBM Global Business Services did an in-depth study on returnable containers in the automotive industry, specifically studying major North American automotive OEMs and their suppliers. This study looks at containers from the perspective of the OEM managing its upstream supply base. Although GGA is actually a first tier supplier site, it can be compared to the OEM site in the IBM study since our project deals with the upstream supply base for GGA. The diagram below (Figure 8) shows a typical cycle for returnable containers. A key difference between the diagram below and the process at GGA is that GGA does not currently use a separate warehouse for empty containers, but rather ships containers directly to suppliers.

Figure 8: Typical Returnable Container Management Cycle (Hanenbeck and Lunani)



Regarding the costs of managing returnable containers, the study came to some alarming conclusions regarding shrinkage. "Some auto manufacturers may well have over $1 billion invested in containers, but they have neither the visibility as to where these containers are at a given time nor the certainty of whether they have misplaced $100 million or $5 million worth of containers… Our experience and research indicates that up to 30% of containers are excess in manufacturers' supply chains." (Hanenbeck and Lunani) Such conclusions correspond very closely with the opinion of a manager of a leading logistics firm, who was interviewed by the author. The IBM study concludes that the optimal solution to shrinkage is the implementation of an RFID-based tracking system, a significant capital investment. Further examination into this issue in this thesis will rule out RFID implementation as out of the scope of the study, due to the immense capital investment involved and the inability of the automotive industry to weather such an investment. However, shrinkage is a serious concern, and GGA's ability to assess the cause of shrinkage and to resolve it is critical to its success in managing returnable containers.

When assessing the effectiveness of the automotive industry's use of returnable containers, it is important to benchmark against other industries in which returnable containers are an integral part of the operating model. Palumbo notes such benchmark industries in his 2002 thesis regarding returnable containers, one of which being the milk industry. Interestingly, the milk industry suffered from a chronic problem of shrinkage, as milk crates were commonly used by people as bookshelves. After a failed campaign of printing warnings on the crates, the industry redesigned the crate in a way that it was virtually useless for any purpose other than carrying milk. Although shrinkage in the automotive industry likely isn't caused by consumer theft, a similarly clever solution may exist. The milk industry also serves as a good example due to the way that it has achieved standardization of container type. This pooling has allowed the industry to overcome short-term variability of volumes, and maximize the utilization of containers. (Palumbo)

Another good benchmark is the supermarket industry, which differs significantly from the automotive industry in that third party providers charge both buyers and suppliers for the use of the containers.

> "The durable container providers in this industry usually charge the stakeholders relativity expensive daily lease (hire) fees to discourage the stakeholders from retaining containers, instead encouraging the stakeholders to turnover containers. The strategy of "hot potato" with the containers is necessary to reinforce the desired behavior of getting the product and container to market quickly." (Palumbo)

This "hot potato" strategy is critical in ensuring good asset utilization of the containers, and more importantly, fast-flowing materials. Fast flow is extremely critical to the supermarket industry due to the perishable nature of the material, and therefore serves as a good example for GGA in its attempt to utilize lean principles in its material flow.

One industry that relies on reusable containers is the ocean freight shipping industry. In ocean shipping, one of the key metrics is to ensure that containers never be shipped empty. A 2002 study by the Tioga Group, attempts to define the reasons why containers may be shipped empty. The explanations below of situations in which it becomes difficult or unfeasible to find a suitable backhaul for empty containers actually apply accurately to GGA's returnable containers.

> There are several key factors that limit the ability of truckers and ocean carriers to reuse empty import containers for exports.

- Import/export timing or location mismatch (e.g. too slow or too distant)
- Ownership mismatch (e.g. wrong steamship line)
- Type mismatch (e.g. wrong size, wrong type, or tri-axle chassis required for heavy exports)
- Off-hiring of leased containers
- Lack of steamship line incentives (The Tioga Group)

Of the above explanations, the first three are the most relevant to GGA. The most critical in this case being type mismatch and ownership mismatch. Type mismatch essentially means that certain containers need to be used to transport certain materials due to their size, shape, and the way in which they hold a particular material. This is marginally relevant in ocean shipping, but is much more relevant in the automotive industry, where a large portion of containers are actually custom-made thermoform trays, that are molded in a way that they only can handle one type of part.

Ownership mismatch also prevents optimal container utilization in the automotive industry. Unlike the milk industry, as described by Palumbo, in the automotive industry, the owner of the containers is not a third party, but rather the assembly site that receives the material, in this case GGA. Therefore, once a container has been emptied at the assembly line at GGA, the only point to which it can go is to a GGA supplier (usually the same supplier from which it arrived), and it needs to be delivered empty. The issues of ownership mismatch and type mismatch regarding returnable containers will be expanded upon further in section seven.

3. GGA Supply Chain Current State

Historically in the automotive industry, manufacturers are responsible for incoming raw materials as soon as they leave the suppliers docks. The reason can most likely be attributed to the fact that downstream manufacturers tend to have larger scale than their upstream suppliers, and therefore have more leverage to bargain with logistics companies and more opportunity to consolidate shipments from multiple suppliers. The effect is that the focus with regards to supply chain and logistics is on the incoming raw materials from suppliers, while outbound logistics are the responsibility of AAM's OEM customers. Therefore further sections will be concerned exclusively with the logistics of incoming raw materials as well as the return of durable containers to those same suppliers, which is also AAM's responsibility.

3.1 Supply Base Overview

Currently, GGA has suppliers in the United States, Canada, Mexico, Brazil, China, Korea, and the European Union. Typically the overseas suppliers have local warehouses within 100 miles of GGA and AAM is only responsible for logistics from these local warehouses. However, most of the material from US and Canada-based suppliers is delivered by truck directly from the supplier site to GGA at AAM's expense. This large portion of the supply base will be the principal topic of focus within the thesis.

GGA's US and Canada-based suppliers are spread across a wide geographic area. There are significant concentrations in lower Ontario and eastern Michigan. However there are also major suppliers in other midwestern, northeastern, and southeastern states including Illinois, Indiana, Ohio, Pennsylvania, New York, Virginia, Tennessee, Alabama, and Georgia. The raw materials supplied from these facilities include a range from commodities such as raw bar steel, castings, forgings, and fasteners to engineered components like machined parts, assemble differential cases, brake rotors, and calipers.

3.2 Supplier Localization Efforts

When GGA began operations at GGA in 2000, essentially the entire supply base was located in the U.S. and Canada. The company made the move assuming GGA would use the same suppliers as its U.S.-based sister plants. Due to the long transit times and increased required in-transit stock and cycle stock, logistics, inventory, and supplier quality have always been a thorny concern at GGA.

It is widely understood by leadership at GGA that localization of the supplier base is the end goal, but there have been a number of obstacles that have prevented this. Within the organization, there is a widespread belief that there is a lack of capable suppliers in Mexico that can serve AAM's specific needs. It has been speculated that commodities such as bar steel are simply not available. However according to the International Iron and Steel Institute, Mexico is the world's 15th largest producer of steel and production has increased by almost 30% since 2001. (International Iron and Steel Institute (IISI)) Furthermore, GGA has recently stepped up the efforts of supplier localization by creating a local direct purchasing team, and the efforts have yielded positive results.

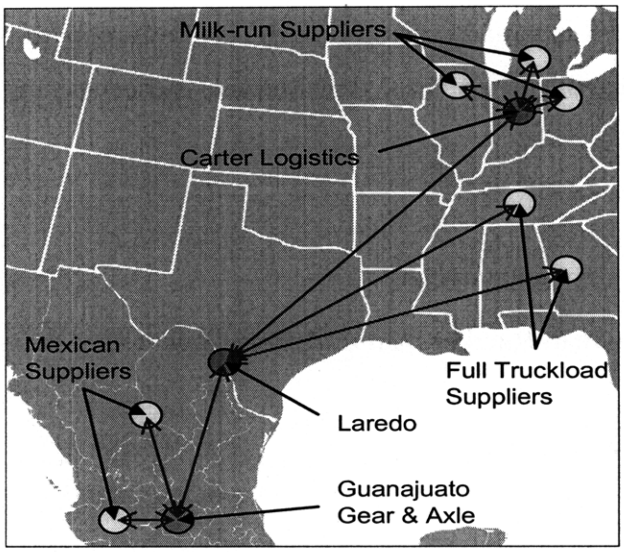
However, there exists a powerful political impediment within the purchasing organization at AAM corporate that prevents localization efforts from gaining full momentum. Essentially, purchasing associates at headquarters (WHQ) are generally assigned a particular commodity and their level of influence within the organization is derived from the total dollar spend for that commodity. Whenever material is localized to Mexico, the responsibility for that commodity is transferred to a purchasing associate at GGA, hence reducing the influence of the associate at WHQ. As a result, the purchasing organization at WHQ has been very resistant to the process of localization, and the localization of any particular part number requires an elaborate approval process.

In cooperative efforts at building up GGA's supply chain, several of AAM's key North American suppliers have built facilities in Mexico. Some of these supplier sites are largely dedicated to GGA, but most have followed the general trend of the automotive industry's move south. In 1994, GM opened its Silao assembly plant, and since that time, several large industrial parks have been developed in the surrounding area, including the park FIPASI, where GGA is located. A large automotive supply base has therefore developed, among these being some of GGA's key suppliers.

3.3 Logistics Modes Overview (U.S./Canada)

Currently GGA is using several different freight modes to transport inbound material from the United States and Canada. The modes include full truckload, less than truckload, train, stacktrain, and actively managed consolidated milkruns. There are considerable tradeoffs between the different modes and the overall advantages of each mode with regards to freight expense, material inventory, and risk are marginally understood. The map below (Figure 9) will be used as a reference for each of the freight modes to be described.

Figure 9: GGA Supply Chain Map



3.3.1 Full Truckload

Full truckload (FTL) was originally the most commonly used mode of freight for GGA. Typically full trailers are loaded at the supplier site and shipped by the AAM-designated U.S. carrier to GGA's customs broker in Laredo where the loads are inspected and transferred to the contracted Mexican logistics carrier. Total transit time from supplier to GGA averages four days.

Advantages:

- Low per-pound freight cost compared to milkruns and LTL
- Easy to track specific material
- Ideal for high-volume suppliers
- Billing is straightforward and logistics cost easy to track
- Shorter transit time than stacktrain

Disadvantages:

- Requires large quantities of cycle stock for low volume suppliers – sometimes several months of inventory
- Typically more expensive than stacktrain

3.3.2 Less than Truckload

As GGA made efforts to move to more of a lean model, less than truckload (LTL) shipments became more common. Many suppliers of low volume raw parts or physically small raw parts would ship only one time per several weeks, therefore forcing GGA to hold cycle inventories of a month or more. With LTL, selected carriers would ship partial loads to GGA's customs broker in Laredo, who would consolidate these loads into full trailers to be hauled by Mexican carriers to GGA.

Advantages:

- Allows for low cycle inventory and regular shipment intervals
- Allows GGA to bid out LTL loads on open market rather than relying on single 3PL provider
- Billing is straightforward and logistics cost easy to track

Disadvantages:

- Most expensive form of logistics per pound
- Requires GGA logistics department to track many different shipments concurrently

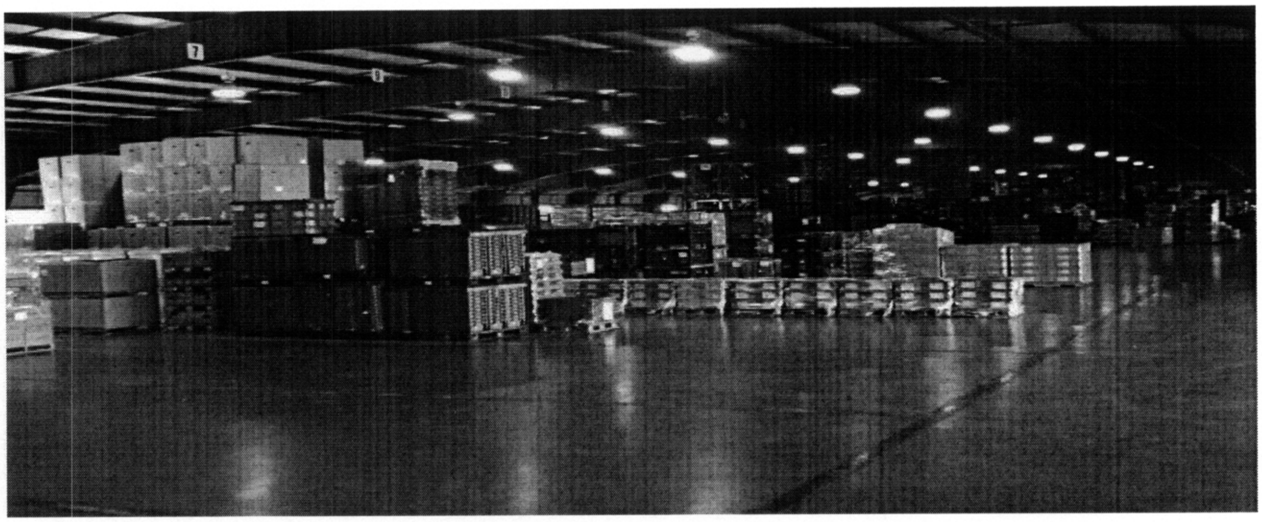
3.3.3 Milkruns

In an effort to balance the advantages of LTL with the advantages of FTL, GGA began using a 3PL milkrun service based out of central Indiana to consolidate shipments of small-volume suppliers based in the Midwest and to ship them in full truckloads from their consolidation center. Essentially the system worked in two parts:

Milkrun trucks run daily predetermined routes out of the consolidation center visiting suppliers of AAM and their other customers. They deliver returnable containers and pick up whatever materials are scheduled for delivery that day. Ideally these routes would be used to supply several of the 3PL's customers concurrently in order to pool variability of each.

At the end of the day, the material pickups from each of these milkruns are unloaded at the 3PL consolidation center, separated by customer to whom they are to be shipped, and staged for loading. 3PL-managed FTL trucks then load the materials and deliver them to the customer, or in GGA's case, to the customers broker in Laredo where there are transferred in the same manner as an FTL shipment. Figure 10 shows the layout of the 3PL cross-dock, where outbound full truckloads of material are sorted by downstream ship location.

Figure 10: GGA Partner Cross-dock Facility



Advantages:

- Allows for daily pickups, lowering cycle inventory to one day
- Flexible to accommodate day-to-day fluctuations in poundage from each individual supplier
- Lower per pound cost than LTL
- Shipments consolidated on a single truck, allowing for easier tracking of inbound materials for GGA team

Disadvantages:

- More expensive per pound than FTL or stacktrain
- Pricing scheme is unclear and difficult to audit; GGA pays for space on milkrun trucks whether it is used or not, which diminishes incentive for 3PL to pool several customers on a single milkrun

3.3.4 Stacktrain

GGA has historically used stacktrain as a substitute for FTL depending on the total cost tradeoff. In the summer of 2008, with fuel surcharges at their highest rates in decades, the tradeoff tilted more to the advantage of stacktrain, and GGA began transitioning several high volume FTL suppliers to stacktrain. Essentially full trailers are trucked from the supplier site to the stacktrain loading center in Chicago, from where they are shipped by stacktrain to San Luis Potosi, a Mexican city about 100 miles away from GGA. The total transit time averages 5 days, one day more than FTL.

Advantages:

- Similar to FTL
- Generally lower per pound cost than FTL

Disadvantages:

- One day longer lead time than FTL

3.4 AAM Materials System & Lean Efforts

The evolution of logistics planning at GGA can be largely attributed to efforts at inventory reduction and lean manufacturing. Previously, shipments from GGA suppliers were based on a forecast-based MRP system. This same basic system is still used to manage the build plan for GGA suppliers. However, while suppliers are expected to build to the forecast, they don't actually ship material until they receive a signal from AAM's electronic pull system, which is described in section 3.4.1.

3.4.1 AAM MRP System

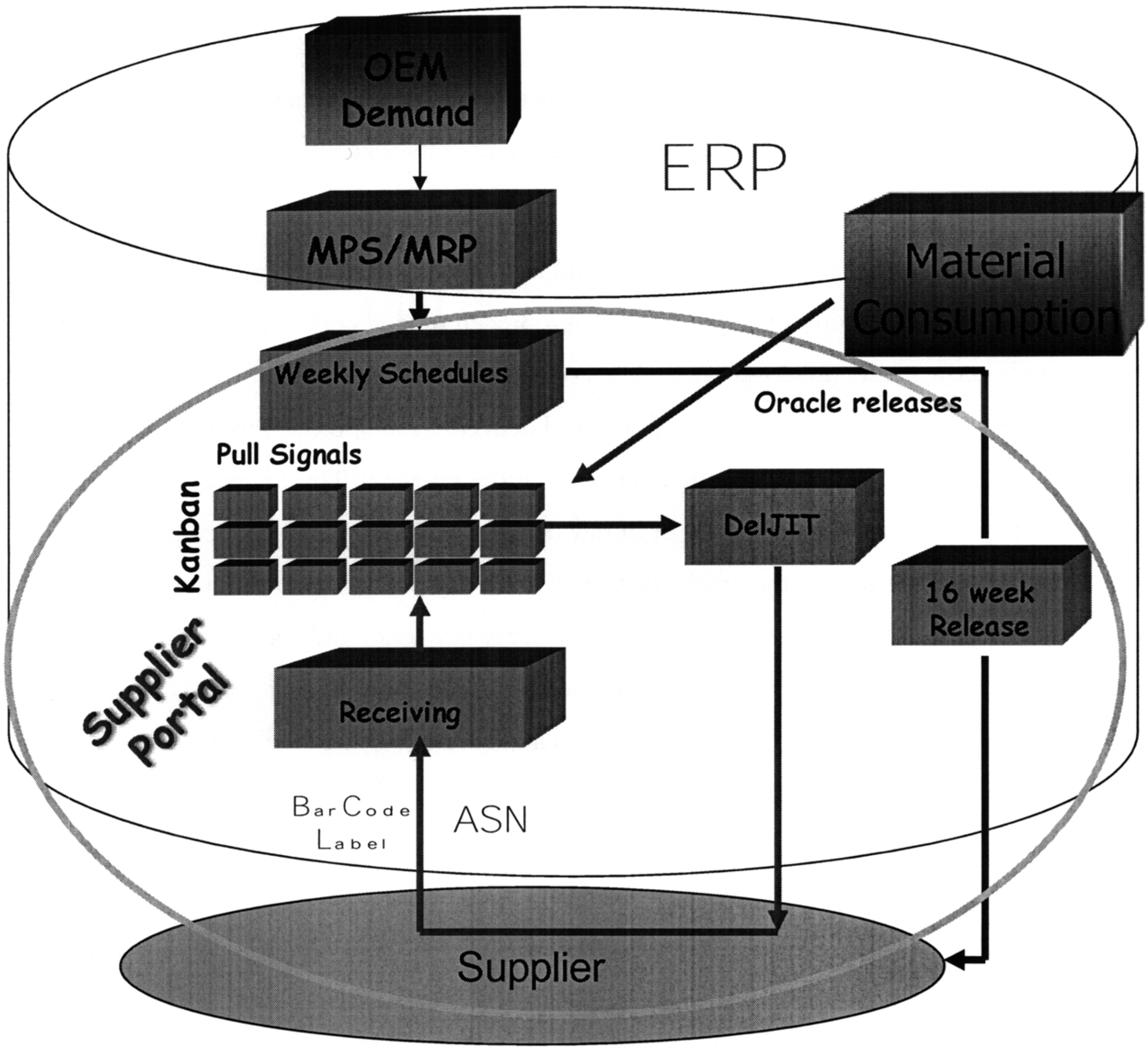
AAM uses an Oracle-based MRP system. Every week, AAM's OEM customers submit an updated 16 week production plan. This is the level that AAM is expected to have on-hand to ship. Based on this schedule, AAM then plans its production. Furthermore based on this demand, Oracle uses the Bill of Materials to determine the necessary delivery of parts from AAM's suppliers. This number is based on customer demand forecasts plus the difference between current inventory levels and target levels in both raw materials and finished goods inventory. Suppliers typically receive a 16 week forecast for parts required by AAM, and are required to have these ready to ship on each given week. Typically AAM is held responsible for the final 4 weeks of raw materials and the final 2 weeks of product built by the customer.

3.4.2 AAM Pull System

While AAM and its suppliers are required to build to a forecast plan, actual shipment is done based on a Pull System. Chrysler and GM call for shipments of axles and driveshafts (sometimes several per day) from GGA. This is based on an automated system at their facility that directly interfaces with AAM's MRP system.

The same communication is used between AAM and its suppliers. Basically for each part number that AAM stocks in raw materials inventory, there is a predetermined container or "standard pack" size and what's known as a "pull loop" size. The container size is determined by AAM and is based on an optimal size and quantity for both shipping and delivery to the production line. The loop size is determined by necessary amount of stock in the inventory pipeline. This includes containers that are at the supplier ready to ship, in transit, or in raw materials inventory. When a container is scanned empty (meaning sent to the production line), it sends a pull signal to the supplier to ship another container. For each supplier, there is a set delivery frequency and specific delivery days set in Oracle. This schedule of delivery days can be as often as daily or as little as once per month. When a pull signal is triggered, it essentially goes into a queue, and is included in the delivery-just-in-time (DelJIT) order on the next scheduled ship date from that supplier. The process flow diagram below (Figure 11) shows the interrelation between the forecast based MRP system and the external pull system.

Figure 11: MRP process flow diagram



3.4.3 Lean Supply Chain & Logistics

AAM has made a concerted effort to run their manufacturing and supply chain using Lean principles. The electronic pull in effect functions as a kanban, where the lack of raw materials in the plant triggers an order upstream. However, in order to successfully implement such a material management system, it needs to be used in conjunction with Lean Logistics.

> Lean logistics is the logistics equivalent to lean manufacturing with two main objectives
>
> 1. Delivery of the materials needed, when needed, in the exact quantity needed, and conveniently presented, to production for inbound logistics and to customers for outbound logistics.

2. Without degrading delivery, pursue the elimination of waste in the logistics process.

There are a series of lean concepts and strategies that stem from the Toyota Production (Baudin)

However GGA has one significant disadvantage that makes it difficult to implement a lean logistics system as is seen in the Toyota Production System. A core tenet of TPS is that the supply base is located within close geographic proximity of the downstream plant. Materials are delivered JIT in small incremental quantities, despite this being uneconomical from a freight cost perspective. The general theory is that the advantages of reduced inventory and greater supply chain visibility more than offset the inefficiencies in freight. "Proximity reduces cost and/or improves the quality of inter-firm coordination." (Frigant) However, in the case of GGA, where an inbound FTL shipment from a Midwest-based supplier can cost roughly $5,000, the trade-off of logistics versus inventory expense shifts so that logistics optimization becomes a greater priority.

3.5 Milk-run Networks

One of the significant efforts GGA has made in the effort to reconcile Lean supply chain with efficient logistics has been to used a 3PL managed milkrun network for incoming parts from suppliers based around the Midwest. The detailed description of the system functionality is as follows:

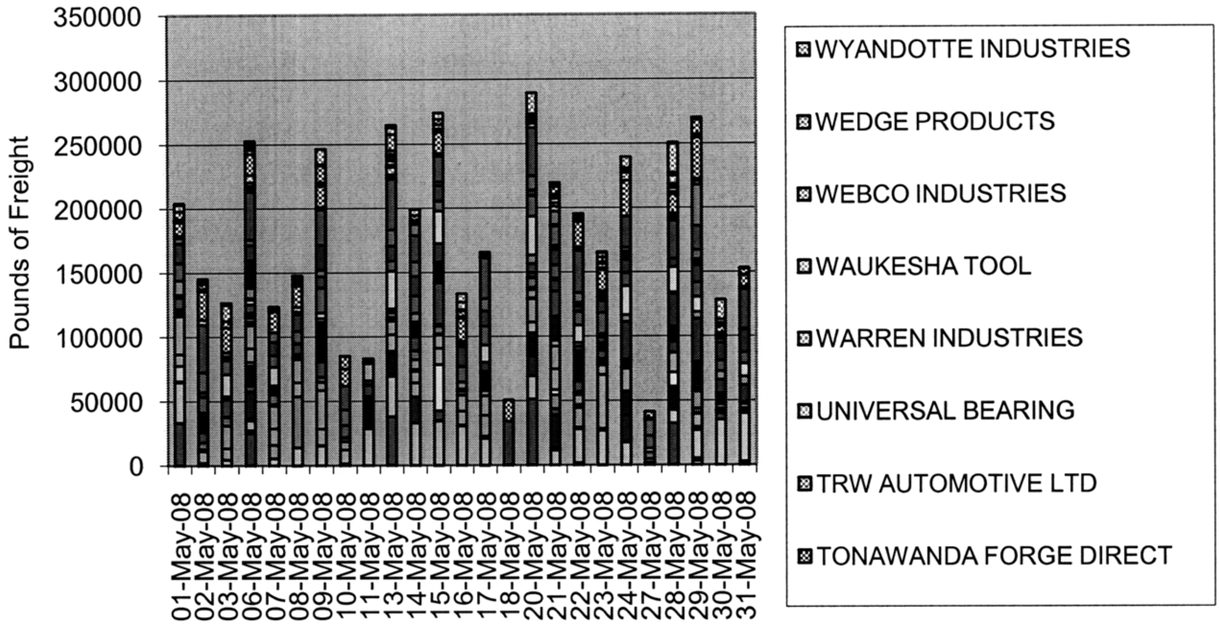
- Inbound milk runs leave early morning and return between 4 pm and midnight (Monday thru Friday)
    - Some routes same each day, some on weekly schedule, some dynamic schedule that changes depending on demand
    - Routes are shared between GGA and other automotive assemblers
    - On average 37% of each route is GGA product, but varies from 4% to 100%
    - If milkrun truck fills, 3PL tries to pick up overflow product from milk runs with another 3PL truck
    - If no 3PL trucks are available then it's typically picked up by an outside LTL subcontractor
    - Midwestern suppliers not convenient for pickup on milkruns are picked up by LTL subcontractor and delivered to 3PL cross-dock
- Outbound full trucks to Laredo leave at 3am, 6am, 9am, and noon

    - They carry product picked up from milk runs day before
    - If there is more than 4 truckloads, 3PL commissions other trucks
    - If there's half a truckload, they call GGA Logistics Coordinator in order to decide whether to ship
    - Sometimes they can combine product with other assembler's incoming raw material going to Laredo
    - Total quantities going from 3PL to GGA are very inconsistent day-to-day
    - If needed, they can do team trucking (26 hours: Anderson – Laredo)
    - Beyond border, freight is AAM's responsibility
    - Typically do a border exchange without unloading truck (AAM gets easier pass than most companies)
- Container returns are fairly manual process
    - One of every 3 trucks sent down returns with containers
    - Containers unloaded at 3PL and then returned to suppliers
    - Shippers in Mexico usually label containers with name of supplier where they go
    - Sometimes for shared containers, 3PL will call suppliers to see if they need containers
- Most routes are currently statically set
    - Routes set based on 16 week forecast coming from GGA Logistics Coordinator; if expected volumes change, they reroute

Using Milkruns has allowed GGA to reduce cycle inventories on certain items such as fasteners from over a month to as little as one day. This has decreased raw material at the plant, freeing up floor space, material handling resources and returnable containers. It has also paved the way for the materials department at GGA to use visual management methods in troubleshooting issues with the inbound supply chain.

While the overall effect of using 3PL milkruns has been very positive, there have been some definite issues. One problem is that it becomes more difficult to determine what exactly GGA is paying per pound per supplier. While a typical bill from an FTL or LTL shipment clearly outlines the poundage, cost, and distance travelled for a particular shipment, milkruns are billed as a percentage of a total truck that is reserved for GGA suppliers. This essentially means that GGA pays for a milkrun truck regardless of whether it is filled to capacity. This creates a high variability in truck utilization. The graph below (Figure 12) shows a typical distribution of daily poundage from a selection of GGA's milkrun suppliers.

Figure 12: Milkrun Daily Volume by Supplier



The graph shows a tremendous amount of variability in daily volumes from each individual supplier, as well as variability in the total poundage from all suppliers. Some of this variation is accounted for by the fact that not all routes are run on each day of the week, but there still exists a significant amount of variation week-to-week. This means that some weeks, a particular milkrun route may be filled to below capacity, while in other instances, certain material has to be left at the supplier until the next pickup. This often results in a separate LTL pickup from that supplier to the 3PL cross-dock, creating an additional cost at GGA's expense.

In a combined effort between GGA and its 3PL partner, some effort has been made to determine the exact price of shipping material from each supplier per bill of lading. This in turn gives the total freight price from the supplier dock all the way to the customs broker in Laredo, allowing GGA to determine the total price per pound separated by supplier. The chart below (Figure 13) shows the wide variation among GGA suppliers in the typical price per pound of freight delivered.

Figure 13: Total Freight Cost for Selected Milkrun Suppliers

CountOfB	shipper name	shipper city	Weigh	$	$/CW
10	ACCURATE GAUGE	Rochester Hills	24668	2386	9.67
17	THREE RIVERS	Three Rivers	384586	26344	6.85
22	AUTOMATIC SPRING	New Haven	19816	3347	16.89
1	ENGINEERED COATINGS	Plymouth	1519	139	9.14
90	ER WAGNER	Milwaukee	67198	11702	17.41
2	FORMING TECHNOLOGIES LLC	Muskegon	12000	2235	18.63
15	FREUDENBERG NOK	Shelbyville	13096	2200	16.80
118	INGERSOLL FASTENERS	Ingersoll	834125	110320	13.23
1	INTEGRATED LOGISTICS	Cleveland	1455	256	17.59
1	SOLUTIONS	Kent	3880	472	12.16
1	KAISER ALUMINUM	London	10683	735	6.88
2	METAL IMPROVEMENT CO	Fremont	3675	260	7.09
6	MICROGAUGE MACHINING	Brighton	21727	2372	10.92
91	MPT STERLING HEIGHTS	Sterling Heights	751084	85177	11.34
1	NORBERT IND.	Sterling Heights	13393	804	6.01
4	INC	Oxford	14267	1715	12.02
1	PAN PACIFIC PRODUCTS	Broken Bow	1488	259	17.39
28	PROGRESSIVE STAMPING	Royal Oak	49054	6345	12.93
21	RB&W	Kent	57715	7228	12.52

As displayed above, the price per CWT varies among suppliers in the range of \$6.85 per CWT (which is competitive with FTL) to \$18.63 (which is similar to shipping LTL from supplier site all the way to Laredo). A simple solution would appear to be to remove certain suppliers from milkruns and ship that freight by LTL from supplier site either to the LTL cross-dock or all the way to Laredo. The GGA Logistics Coordinator together with representatives from the 3PL partner regularly re-evaluate these prices and often move certain suppliers from LTL to milkrun or vice versa. However such a move has an effect not just on that particular supplier, but on all other suppliers routed on that particular milkrun. Adding or removing a supplier affects the total mileage of the route, which changes the total cost of the route, and it also changes the percentage of expected weight of that route allocated to each of the suppliers that share the route. Therefore to truly assess the cost-effectiveness of milkruns, one needs to delve deeper into the overall dynamics of the system rather than assessing one supplier at a time.

3.6 Current Logistics Initiatives

In addition to ongoing efforts at refining the milkrun network, GGA is also making steady efforts to optimize the costs of its large FTL suppliers. During the summer of 2008, when oil was approaching $150 per barrel, fuel surcharges were at record high levels. The high cost of fuel had a significant effect on the relative competitiveness of FTL and stacktrain, and the GGA logistics coordinator began the process to convert several major FTL suppliers to stacktrain. At this level of fuel cost, the savings are substantial. Below is data for one of these large-scale FTL suppliers. In this particular case, stacktrain is roughly 10% less expensive on a per truck basis. The model below also incorporates other elements of total landed cost including inventory expense for additional in-transit inventory, cycle inventory, and the additional returnable containers that would be needed to service this additional inventory. Based on forecast raw material demand at GGA, the 10% freight savings combined with the changes in inventory yield a savings of around $75,000 for this particular supplier. The table below (Figure 14) shows detailed data for this sample supplier.

Figure 14: Total Landed Cost Model FTL vs. Stacktrain

SUPPLIER	WAUPACA	MATERIAL INFO			ANNUAL LOADS	
PART NUMBER	DESCRIPTION	SALES	WEIGHT	WEIGHT/YR	SOUTHBOUND	NORTHBOUND
26046101	CASTING - DIFF CASE 8.25 GN	141,600	10	1,416,000	39	13
40004295	DIFF CASE CASTING	135,927	9	1,223,343	34	11
40028203	Case Casting	126,625	20.27	2,566,222	71	24
				TOTAL	144	48

TRUCKS		APL				
SOUTHBOUND	NORTHBOUND	SOUTHBOUND	NORTHBOUND	DEMAND WK	ILY DEMAN	TANDARD PAC
$ 169,998.67	$ 39,005.56	$ 145,887.33	$ 43,188.00	5400	900	240
$ 146,869.12	$ 33,698.57	$ 126,038.31	$ 37,311.96	2700	450	300
$ 308,089.21	$ 70,689.91	$ 264,392.15	$ 78,269.77	2400	400	160
$ 768,351.03		$ 695,087.53				

LOOP CONTAINERS				TRANSIT TIME		IN TRANSIT COST			15%
ACTUAL	ROPOSEI	PRICE	CONTAINER TYPE	ACTUAL	ROPOSEI	ACTUAL	PROPOSED	DIFFERENCE	NNUAL IMPACT
75	64	$ 9.66	Metal container	10	7	$ 86,970.96	$ 60,879.67	-$ 26,091.29	-$ 3,913.69
12	26	$ 11.09	Metal container	5	7	$ 24,956.78	$ 34,939.49	$ 9,982.71	$ 1,497.41
35	33	$ 16.52	plastic tray	8	7	$ 52,863.68	$ 46,255.72	-$ 6,607.96	-$ 991.19
				TOTAL		$ 164,791.42	$ 142,074.88	-$ 22,716.54	-$ 3,407.48

SAVINGS	$ 75,000

3.7 Returnable Containers

One critical aspect of inbound logistics at GGA, and more generally within the whole auto industry, is the outbound freight of returnable containers. Due to the heavy weight of automotive components, it is generally considered more economical to ship those using returnable rather than expendable containers, as expendable containers would generally require some kind of wooden crating in order to prevent damage to the components. The mechanics of empty container returns are such that for each full trailer of material that is moved to GGA, the local logistics team decides whether to hold the trailer. If they hold it, GGA is responsible for loading it and calling for a northbound pickup within a set time period such as one week. If not, the trailer must be unloaded, and then the logistics company will pick it up empty and GGA will not be held responsible for the backhaul of the trailer.

This thesis will not attempt to investigate whether overall the use of returnable containers makes sense within the context of the auto industry. AAM top management has made a commitment to returnable containers by mandating that no cardboard be allowed in any manufacturing area. The reasons for this are primarily because of potential safety issues resulting from collapsed cardboard containers and the overall "unsightliness" of cardboard in the plant. Why "unsightliness" in a manufacturing setting is such a high priority for top management is also outside the scope of this thesis.

Instead of questioning the need for returnable containers, this thesis will attempt to establish an optimal management system for said containers under the conditions present within the GGA supply chain. The topic of returnable containers will be investigated in thorough detail in section four.

4. Container Returns – Issues & Current State

4.1 Why Container Returns

Beyond choosing an optimal logistics plan for GGA, there are significant opportunities on the operational level. While freight planning is done based on forecast releases, the actual authorization to ship specific pieces is driven by material pull, which in turn is driven by the consumption of product at the line. The design of this pull system was driven single-handedly by the goal of inventory reduction, as it was designed under the assumption of a Midwest-based supply chain where inbound logistics is a small percentage of total cost.

Since the pull system diminishes the ability of the logistics department to plan individual shipments, the opportunity for a real-time piece-specific logistics planning is diminished. The benefit of real-time logistics planning can therefore be tested using the outbound shipment of returnable containers. The decision of how, when, and how often to ship returnable containers is entirely within the control of the materials team at GGA and is in no way reliant on the pull system.

Furthermore, the opportunity for savings with regards to returnable containers is significant. A preliminary study was performed involving a group of five major FTL suppliers based in the US and Canada. In the study, we took six months of data of return container shipments moving from GGA to these select suppliers. We assessed each shipment based on the actual weight, cost, container quantity, and container type that was shipped. We then aggregated the results to essentially determine the container demand that the particular supplier needed during the six month period. Then for each supplier, we determined the optimal container type, container loading, and the minimum total number of FTL loads to fill that demand. The results show a total savings in US freight (from supplier to Laredo) of $250k for the six months, which annualizes to about $500k per year. We then added an allotment of $113k for customs and transport from Laredo to GGA for this freight, yielding a total annual savings of over $614k. The data from this study is displayed in the table below (Figure 15).

Figure 15: Savings Assessment – Returnable Containers

POTENTIAL SAVINGS - RETURNABLE CONTAINER LOGISTICS

Supplier	Carrier	# Loads	Total Weight	Total Cost	Average Weight	$/Load	$/Lb	Optimal Cost	Potential Savings
TUBBY'S TUBES	Lou's Logistics	35	480,000	$ 97,884	13714	$2,797	$ 0.20	Ropack max @ 32k lbs	
	Total	35	480,000	$ 97,884	13714	$2,797	$ 0.20	$ 41,950	$ 55,934
AL'S ALUMINUM	Lou's Logistics	16	213,476	$ 44,460	13342	$2,779	$ 0.21	Ropack containers max @ 32k lbs	
	Lilly's LTL	3	27,200	$ 2,358	9067	$ 786	$ 0.09		
	Total	19	240,676	$ 46,818	12667	$2,464	$ 0.19	$ 20,899	$ 25,919
CALLY'S CASTINGS	Stacktrain	19	231,376	$ 51,955	12178	$2,734	$ 0.22	CC544440 max out at 78 pieces & 40k lbs	
	Lilly's LTL	1	38,808	$ 1,843	38808	$1,843	$ 0.05		
	TOTAL	20	270,184	$ 53,798	13509	$2,690	$ 0.20	$ 18,169	$ 35,628
STEVIE'S STEEL	Lilly's LTL	1	3,784	$ 526	3784	$ 526	$ 0.14	Collapsable Metal & Some trays: 30k lbs	
	Lou's Logistics	37	379,779	$110,401	10264	$2,984	$ 0.29		
	TOTAL	38	383,563	$110,927	10094	$2,919	$ 0.29	$ 38,149	$ 72,778
GRENVILLE CASTINGS	Tim's Trucking	33	442,446	$123,072	13407	$3,729	$ 0.28	Trays max @132 pallets	
	TOTAL	33	442,446	$123,072	13407	$3,729	$ 0.28	$ 74,589	$ 48,483
TIBBY'S TUBES	Tim's Trucking	32	1,131,726	$103,923	35366	$3,248	$ 0.09	CC544440 max at 40k	
	TOTAL	32	1,131,726	$103,923	35366	$3,248	$ 0.09	$ 91,884	$ 12,038

MAXIMUM POTENTIAL 6 MONTH SAVINGS	$ 250,780
MAXIMUM POTENTIAL ANNUAL SAVINGS	$ 501,560
SAVINGS IN CUSTOMS & MEXICAN FREIGHT	$ 113,353
TOTAL POTENTIAL SAVINGS	*$ 614,912*

The reasons for this savings lie largely in the attitude at AAM (and in the automotive industry in general) regarding returnable containers. When planning for logistics expense, a simple 3:1 ratio is always assumed. This means that for every three trailers that move material with inbound freight, one trailer will return northbound with empty containers. In reality, there exist many cases in which it is possible to outperform this 3:1 ratio, and in looking at the data, often 3:1 is not even achieved.

The causes for waste and opportunity in returnable containers are from a variety of sources. These shortcomings and costs are documented in detail in section 4.3. From a preliminarily assessment, the problem appears to stem from an inability to forecast container demand at the supplier, and then to preemptively plan shipments to fulfill this demand in a way that optimizes trailers. To assess the sources of these shortcomings, we closely studied the mechanisms in the current system.

4.2 Current System

The current system in theory functions as a fixed return schedule. Figure 5.3.1 below is a sample section of the current schedule. It shows a fixed set of containers, which are shipped to a fixed set of suppliers each Monday, and so on throughout the rest of the week. The quantities are determined by the new programs group in the materials department, when a new supplier, finished part, or raw part number is initiated. The quantities of containers to ship are loosely based on sales forecasts for the particular part number for which those containers are to be used. Sales forecasts in this environment have minimal accuracy. Actual shipments of parts vary week-to-week, and the overall trend was significantly downward during these six-months, resulting in quantities that were nowhere near the original sales forecasts. Once quantities are set on the weekly returns schedule, they are rarely revised to reflect changing demand for containers, which is driven by changing demand for raw material parts at GGA. The only time that the container returns schedule is changed is when a supplier contacts GGA to complain about either a shortage of containers or an overabundance. Resultantly, no problem is brought to light until there is a threat that a supplier will not be able to ship, creating a constant state of fire-fighting. Figure 16 shows a sample of the weekly container ship schedule that is currently used. The schedule includes the supplier, the container type, ship quantities, and logistics provider.

Figure 16: Current Fixed Container Returns Program

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PROGRAMA RETORNOS PLANTA SUR

PROVEEDOR	DESCRIPCION DEL CONTENEDOR	CODIGO DE CONTENEDOR	PESO KG	TRANSPORTE	CANTIDAD A EMBARCAR
EPTEC	Trays slip yoke / damper 15 pz.	20218	4.4	Este embarque esta sujeto a seguimento	Este embarque esta sujeto a seguimento
ARCELO MITAL-TUBULAR CAN (DOFASCO)	Contenedores abatibles (código 475316 MBACO)	WB 544840 COLAPSABLE	208	CAJA COMPLETA CELADON	85 Contenedores
ER PROCESOS	Trays para weld yoke color negro /franja azul base 30x32	DH-DC WELD YOKE	3.54	Transporte Montes	25 bases 30x32 / 90 charolas weld yoke
HALDEX	Tote azul / base y tapa 48x45	Caja de color azul/tapa gris 16x24x8.5	6	Transporte Montes	Lo que se genere
SG AUTO (PTI)	1/4 de Gondola	WB 1/4 GONDOLA	86	TRANSP. GONZALEZ	20 contenedores 1/4 gondola
	Trays slip yoke 18 pz.	85905	4.3	TRANSP. GONZALEZ	Falta
	Trays para slip yoke color negro / franja azul blanca basae y tapa 30x32	3R3032SY	3.52	TRANSP. GONZALEZ	76 Trays 38 Base/Tapa 30 x 32
	Trays slip yoke / damper 15 pz.	20218	4.4	TRANSP. GONZALEZ	Falta
ROBIN - BOTA	Ropack negro 30x32x34	ORPK30X32X34	39	CARTER	3 Ropack
UNIVERSAL BEARINGS INC.	Bote naranja / ropack 30x32x25 color café	Unibersal Bearing	.125GRS	CARTER	120 botes naranjas / 60 botes por ropack
	Ropack 30x32x25 color café	ORPK30X32X25 café	35	CARTER	2 Ropack
AAM-3 RIVERS	Trays slip yoke color negro/ franaja naranja Base y tapa 30x32	3032SY	3.46	CARTER	35 Trays / 10 bases 30x32
	Trays weld yoke color negro/ franaja naranja blanca /base 30x32x34	WELD-YOKE	3.4	CARTER	96 Trays / 24 bases 30x32
	Trays spline yoke color negro/ franaja blanca Base y tapa 30x32	SPLINE-YOKE	3.24	CARTER	35 Trays / 10 bases 30x32
	1/4 de Gondola	WB 1/4 GONDOLA	86	CARTER	4 contenedores 1/4 gondola
	Trays slip yoke damper 15 pz	20218	4.4	CARTER	24 Tryas/ damper
JR ENG (B&C)	1/4 de Gondola	WB 1/4 GONDOLA	86	CARTER	7 Contenedores 1/4 gondola

Ideally, schedules could be adjusted on a more proactive basis. This, however, would require manual calculations involving someone checking the material releases for each part number for a supplier and then aggregating actual container demand. It would be unreasonable to expect someone to perform these manual calculations for each supplier, each time material forecasts change.

Once a schedule is set by the new products team, it is the responsibility of the receiving teams in each area of the plant to execute the actual material returns. The systems for the actual execution vary widely. In GGA-S, the schedule has traditionally been followed literally, regardless of changing volumes. Essentially, the specified container types get shipped to the specified supplier on a particular day, regardless of the quantity of that container available at the plant.

GGA-N has historically been more conscious of freight costs, and has deviated from the set daily schedule, by holding trailers until they've accumulated enough containers to send the truck relatively full. They've also established a primitive system for handling common container types, tracking the number that suppliers send, and sending them back using a one-for-one policy.

4.3 Shortcomings & Costs of System

The system as it stands has several key shortcomings that will be described in greater detail. In summary the most critical issues are:

- Regular shipment schedule result in sub-optimized trailers: trailer is not full by weight or volume
- Common generic containers over-shipped to certain suppliers & under-shipped to others suppliers, resulting in shortages & overstocks at suppliers
- Container/Supplier combinations on outbound shipments not optimized: some fill on volume; others on weight
- Freight mode for specific suppliers not chosen optimally based on current demand level for that supplier (i.e. supplier is on LTL and should be on FTL)
- Suboptimal containers used; underutilization of more compact collapsible containers

4.3.1 Regular Shipment Schedule Leads to Sub-optimized Trailers

As mentioned in Section 4.2, the fixed schedule of container returns means that trailers leave from GGA on specified days with containers for a specified set of suppliers. If volumes are down and not a sufficient amount of containers have accumulated in this time period, the trailers leave the plant less than full.

An example of system inefficiency is a major component supplier that we'll call Supplier G, which is scheduled to ship containers twice per week FTL. Both anecdotal evidence such as the photo (Figure 17) and historical data in the table (Figure 18) show that there is tremendous waste in the shipments of this supplier. The table essentially shows that the average weight of actual outbound shipments to the supplier was 13,407 lbs. A full load for this supplier fills up with 132 container sets, equaling 21,069 lbs. Using this ratio, it can be determined that based on container shipment volumes in the first six months of 2007, Supplier G would have optimally required 21 rather than 33 outbound trucks, resulting in a savings of almost $45,000, not including the Mexico portion of the outbound freight.

Figure 17: Sample shipment of containers to major component supplier

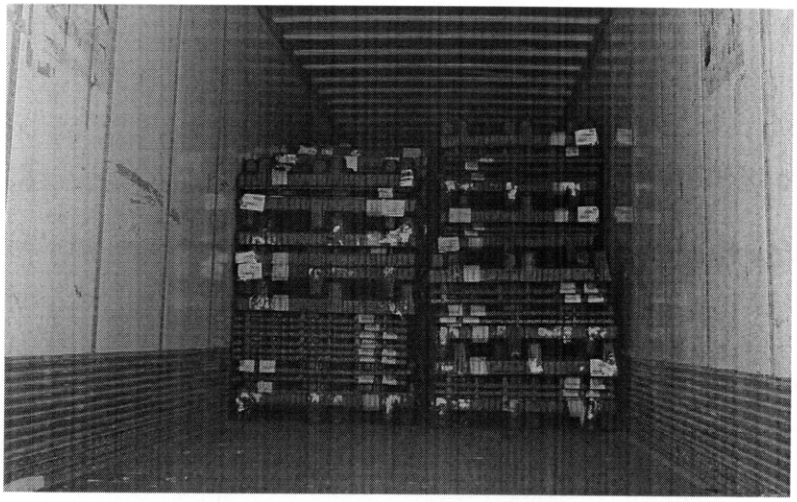


Figure 18: Historic Data & Opportunity

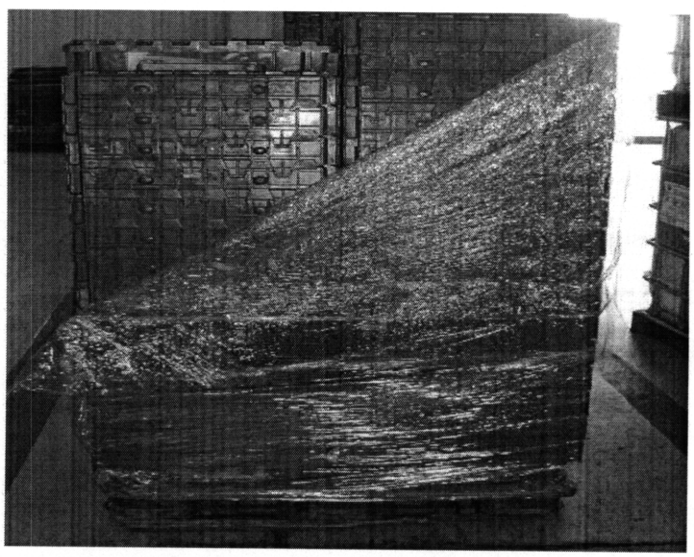
Supplier	Situation	# Loads	Total Weight	Total Cost	Average Weight	$/Load	$/Lb	Potential Savings
GRENVILLE CASTINGS	Actual	33	442,446	$ 123,072	13407	$ 3,729	$ 0.28	
	Optimal	21	442,446	$ 78,319	21069	$ 3,729	$ 0.18	$ 44,753

4.3.2 Fixed Schedule Leads to Incorrect Shipping of Shared Containers

As mentioned previously, the current container returns system has a fixed schedule of container shipments. This schedule is based upon the initial expected demand of the particular raw part number that uses that container. For specialized containers only used by one supplier, this doesn't cause an issue, since the full stock of that container type is typically sent back to that one supplier. However, 75% of the total weight of shipped containers is common, meaning they're used for a number of different suppliers. The most common of these containers is the 15"x8"x7" nested bin, most commonly used for fasteners and other small parts. The bin is typically shipped by suppliers on a reusable plastic pallet in packs of 18 bins (Figure 19) and returned to suppliers in stacks of 90 on a single pallet (Figure 20). Additional pallets are sent in large batches when a supplier specifically requests them, on average once every three months.

Figure 19: 15"x8"x7" bins w/ material

Figure 20: 15"x8"x7" bins – return



There are significant issues with this system. First is that the schedule requests that each supplier receive containers on each given week. However, the return shipment quantity is in packs of 90, and many suppliers only need a few bins per week. Therefore the receiving department has to choose to which suppliers to send these containers, alternating between suppliers week-to week. The table below (Figure 21) Compares shipment quantities from the returns schedule against actual demand for containers from the suppliers. In several cases the differences are in orders of magnitude and in one case, GGA ships this container to a customer that does not even use this particular container.

Figure 21: Shipment vs. demand of 15"x8"x7" bins

Supplier	Ship Schedule	Actual Demand	%Over (Under)
Brighton	10	12	-17%
Dajaco	40	10	300%
General Plug	12	36	-67%
GKN Conover	4	36	-89%
GKN Menonomee	48	1	4800%
MNP	108	144	-25%
Newcor	90	324	-72%
Palmer	90	64	41%

The result of this issue is that certain suppliers are under-stocked and have to ship in cardboard, which under some contractual agreements, results in an extra charge. Also when these items arrive at GGA, they have to be repacked into plastic bins before being moved to the line, resulting in non-value-added labor expense.

On the other hand, other suppliers are overstocked, hence resulting in unutilized container capacity. In one case, a supplier actually refused to accept a full-truck shipment of large wire baskets, forcing the truck to return from the supplier site to Laredo, hence wasting an FTL round trip costing approximately $5000. Over-shipping and under-shipping common containers costs GGA in freight, container inventory, supplier charges for using expendable containers, and labor at GGA in repacking material from expendable to reusable containers.

4.3.3 Sub-optimization of Weight/Volume Ratio

When optimizing outbound trailers, a key aspect is the weight/volume ratio. While on average, empty containers fill trailers by volume rather than weight, there are certain container types that fill a trailer by weight. The table below (Figure 22) gives an example of the benefit of combining two containers, a rigid wire basket that fills truck on volume, and a collapsible wire basket, which due to greater density, fills up on weight. When loaded separately, one truckload can contain only 44 of the rigid basket, while the other can hold 82 of the collapsible basket. When combined into two mixed truckloads, two trucks can contain 58 and 112 baskets respectively, an overall capacity increase of around 35%

Figure 22: Benefit of Combining Containers of High/Low Weight/Volume Ratio

	Separate Trucks		Combined Trucks	
	CR544440	CC544440	CR544440	CC544440
Capacity (Vol)	44	154	60	112
Volume Used	2420	3176	3300	2310
Capacity (Wgt)	94	82	58	115
Weight Used	39668	39524	24476	55430
Pct. Increase			32%	37%

4.3.4 Suboptimal Outbound Freight Mode

Since the current system gives the logistics department very little visibility as to the volume of outbound containers, there is no opportunity to make real time changes in freight mode based on changing volumes. In the second half of 2008, volumes to several suppliers that had traditionally been shipped FTL, have decreased to where it is more economical to ship LTL or milk-run. However, due to this lack of visibility, changes in freight mode were made considerably later than would have been optimal. For example, we refer to Supplier M located in Ontario, for which container returns were shipped using full truckloads until the end of August. Supplier M uses a 30"x32"x30" collapsible wire basket, which fills a trailer from weight at 160 units. During August, several truckloads were shipped with only 78-80 units, filling the truck to 50% capacity on weight and 34% capacity on volume. The photo below (Figure 23) shows a loaded trailer ready to ship containers to Supplier M.

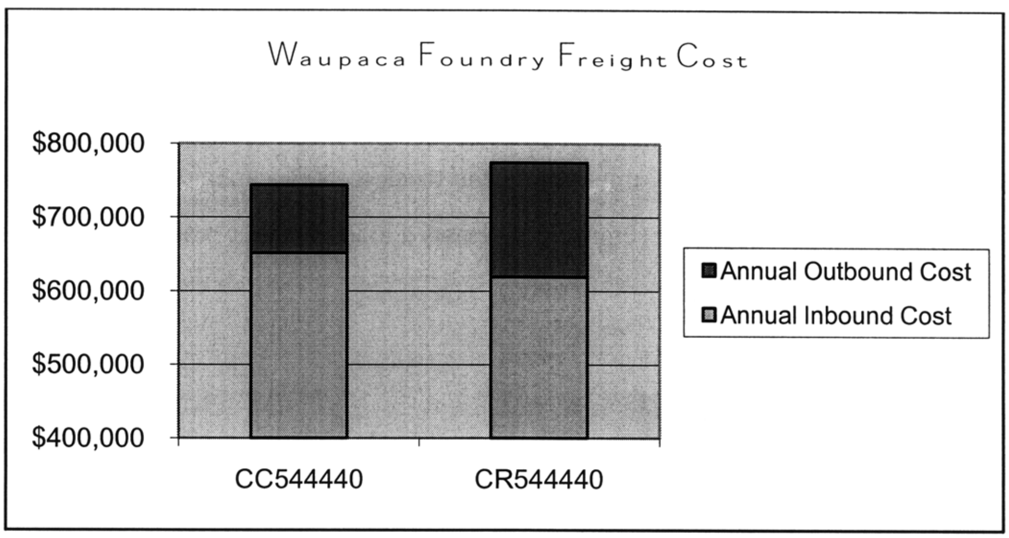
Figure 23: Container Shipment to Supplier M

In September, Supplier M was moved from FTL to milkruns to account for the decreased volumes. However, if the logistics department had had more visibility into the quantity of containers actually being shipped and the resultant loading of the truck, they could have made the change earlier and saved substantially.

4.3.5 Sub-optimization of Container Choice for Specified Suppliers

Another source of waste in container returns is the suboptimal choice of container types for particular suppliers and the inconsistent use of specific container types. The goal when choosing container types should be for suppliers with high per-pound logistics cost to find the container that is lightest and most compact subject to the constraint that it is durable and stable enough to safely transport that particular product. An example is Supplier W in Wisconsin, the largest supplier of differential case castings for GGA. These castings are currently being shipped using a rigid 54"x44"x40" rigid wire basket. If instead, the plant used a collapsible basket of the same size, they could fit 82 rather than 44 empty baskets in a trailer, saving approximately $30,440 per year. See graph below (Figure 24) for summary.

Figure 24: Potential Savings from Using Collapsible Containers for Supplier W



4.3.6 Organizational Issues with Returnable Containers

Another issue under the current system is organizational. The team responsible for setting up the returns program is the new programs group, which only deals with the initial ramp-up of new products, new model years, new suppliers, and new design changes. This organizational design was chosen since the new programs group is responsible for the design coordination and initial order of containers for new raw part numbers. However, once something is no longer a "new program," the responsibility of the new program group ceases, as they move on to other projects. At this point, the day-to-day responsibility for that raw material moves to the supplier scheduler responsible for that product line. The supplier scheduler has the overwhelming priority of making sure that their GGA line does not run out of parts. Hence as pertains to returnable containers, their priority is that the supplier does not run out of containers. The responsibility for storing and shipping of returnable containers belongs to the receiving department. Their top priority is typically to keep their area as clear of inventory as possible, so they generally opt to ship out any empty containers, even if the truck is not full.

So in conclusion, the only department that is deliberately judged by their performance regarding returnable containers is the logistics department, since container returns are currently 20% of their total cost. However, the execution of container returns rests across three other groups within materials: new programs, supplier scheduling, and receiving. None of these three groups is judged by their performance regarding container returns, and each of the groups has goals and priorities that are either unrelated or directly opposed to the logistics department's goal of minimizing transport cost.

5. Container Returns – New System

5.1 Approach & Goals

In the above section we have established a set of faults with the current returns system and its negative impact on logistics cost and other operational issues at GGA. In order to solve the above issue we need to approach the issue of container returns with a set of broad objectives and constraints that will define the potential structure of the model/tool. In choosing this structure, it must first be established what are the primary goals of the container returns system.

The first goal must be to ensure that suppliers have the containers that they need in order to ship parts when they need them. From the perspective of this goal, it is not important how, when, or how many containers suppliers receive, but rather simply that they receive them. Furthermore, this goal is not a goal in terms of something that can be maximized or minimized, but rather a standard to be met. Hence, as it pertains to an optimization model, the requirement that suppliers have the containers they need when they need them functions more as a constraint and will be treated so in the container returns model.

The second goal is to minimize total costs in the process of shipping containers. These costs are all those associated with the forms of waste described in section 4.3, and include freight costs, material costs, container inventory costs, and material handling costs.

5.2 Program Parameters

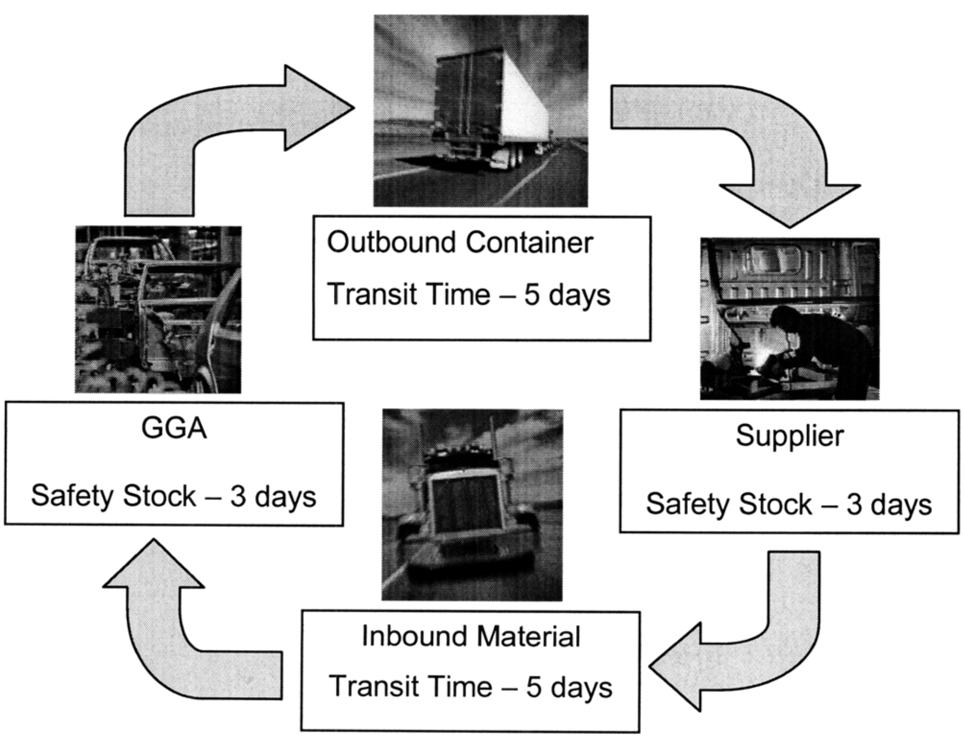
Based on the above goal, an ideal way to look at the problem is in terms of an optimization model. In order to ensure that the model functions in a realistic way, corresponding to actual container returns, it is important to correctly set parameters. These parameters essentially establish the framework for setting up constraints within the optimization model. Two critical parameters are the characteristics of the container loop and the mechanism that determines how many containers need to be shipped to the suppliers

5.2.1 Target Container Inventory & Container Loop Timing

One of the most critical parameters is the target inventory of containers in the system. This target inventory is based on the weekly consumption of material, the quantity of raw material that fits in each container, and the target "weeks of inventory" of containers required in the system. The first two inputs can be easily calculated, but the target "weeks of inventory" requires some study. Drawing on relevant literature, in analyzing Ford's European container pool, it was determined that the average cycle time for a container was 31.2 calendar days (Palumbo) However in the Ford system, all containers used at the Ford assembly line were immediately shipped to a third party container management service that then sent the containers to Ford's suppliers. We will assume that this process causes extra lag in the system.

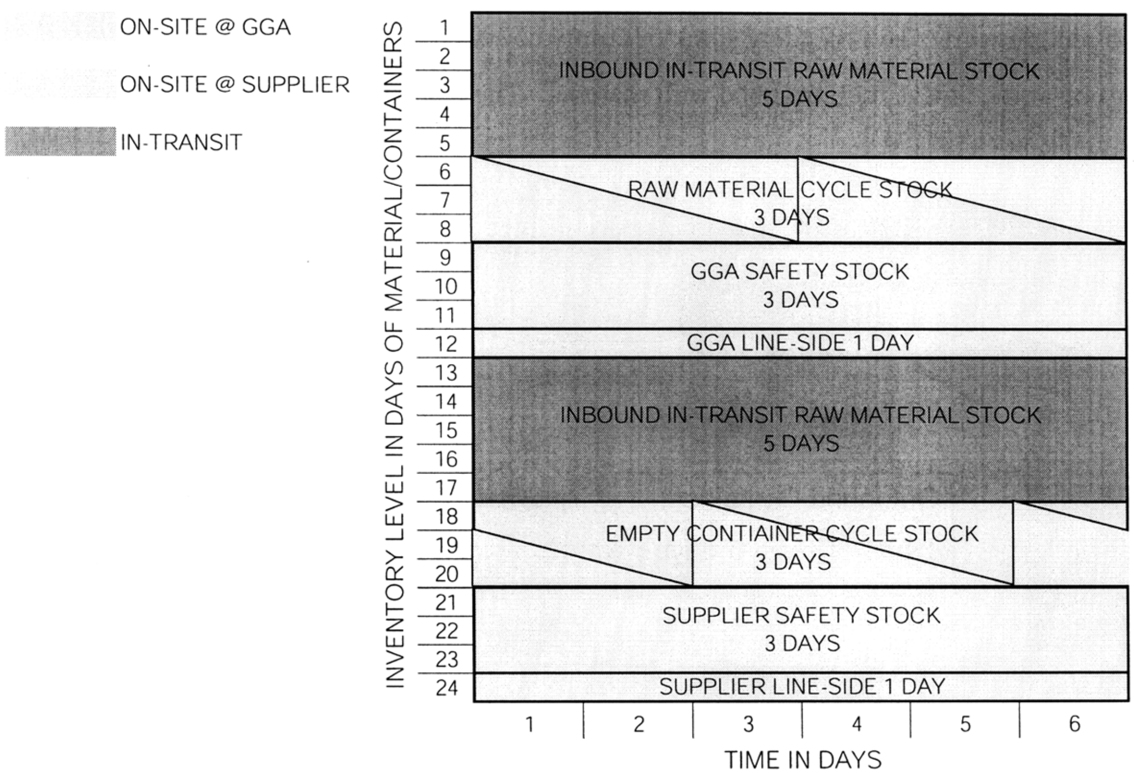
In designing GGAs container supply chain we assume that GGA will continue to handle the shipping of containers to supplier in house. The process starts with an inbound shipment of containers full of raw material from the supplier. Transit time for shipment varies, but since the bulk of the supply base is still based in the Midwest US or Ontario, a transit time of five days can be assumed. The same transit time applies for the return trip. We can also assume that GGA requires on average three days of safety stock and that material spends around one day line-side. The supplier also requires three days of safety stock of empty containers and one day for those containers to be at the line as they are filled with material. The diagram below (Figure 25) shows the container flow cycle.

Figure 25: Container Flow Cycle



In summing up the total number of days of inventory required, one of the more difficult concepts to consider is that of cycle stock. Traditionally in a p/p/n reorder system, the average amount of inventory is equal to the reorder point plus one half of the reorder quantity. However in this case, empty containers at the supplier are being used as fast as they are being generated by the production line at GGA, and essentially as soon as the cycle stock of containers is consumed, another shipment of empty containers arrives in the pipeline. This way, assuming a constant amount of inventories in transit, the sum of cycle stock at GGA and at the supplier is essentially constant and equal to the daily use times the order period. The total container inventory required in the system is more clearly diagramed below (Figure 26), and with the above assumptions, the total required equals 24 days. Since GGA and most trucking companies operate 6 days per week, this can safely be equated to four weeks. WHY CAPS?

Figure 26: Container Inventory Allocation Diagram



5.2.2 Determination of Container Shipment Quantity

Another primary concern when designing the container returns program is how to determine the weekly quantity of containers shipped to each supplier. The broad-based goal is to ensure that each supplier has the number of containers they need to ship required raw material parts to GGA, assuming a set cycle order quantity and period. Another goal is to optimize the cost of shipping returnable containers. This cost is the total of outbound container return logistics, container inventory capital charge, container material handling labor, and cost of floor-space for storing empty containers.

For establishing this logic there are three distinct options. The logic behind the three different options is also illustrated in the diagram below. (Figure 27)

1. **"Current static system:"** fixed shipments of containers to each supplier based on sales forecasts, as described in section 4.2

   Pros: System is currently established, does not require additional training, coordination

   Cons: See Section 4.3

2. "**One-in, one out system:"** receiving department tracks incoming containers with material by individual supplier and ships out equal number of empty containers the following week to the same suppliers

   Pros: Has already been implemented on an ad-hoc basis for certain shared containers; easy, simple system

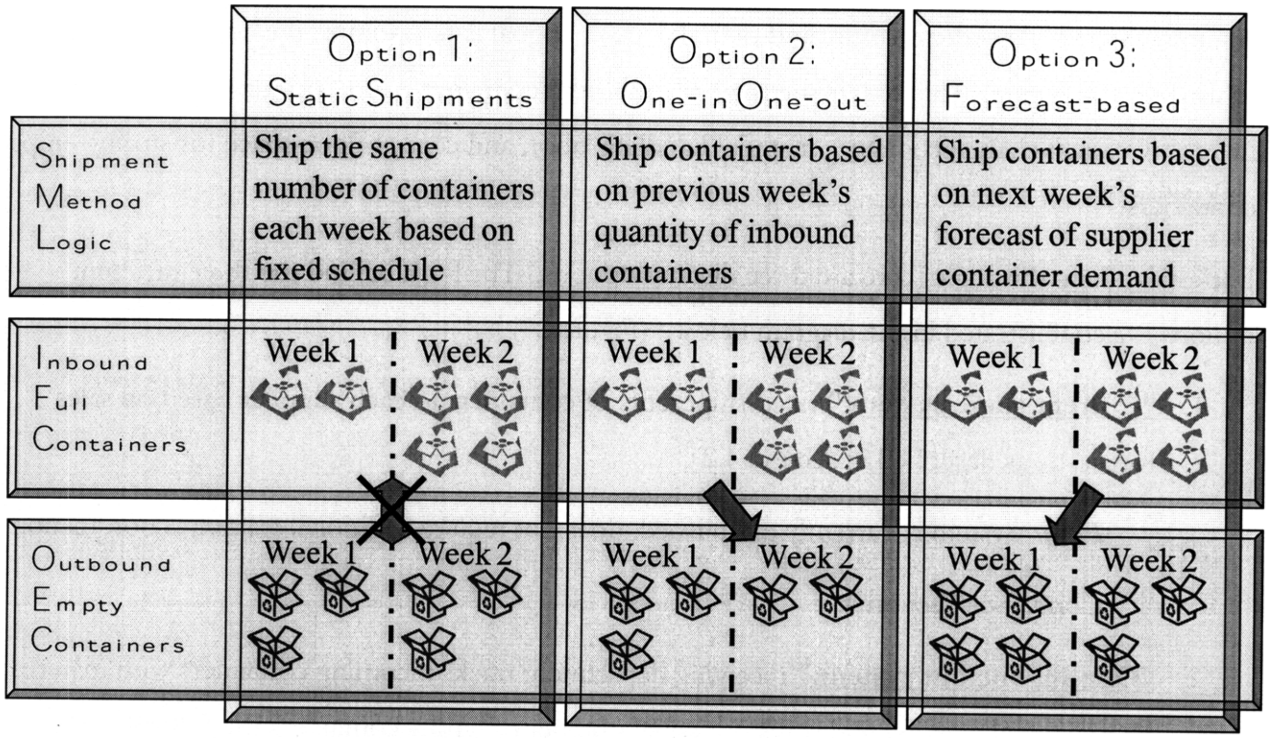
   Cons: Ships Based on past consumption, rather than future demand; receiving staff needs to track each individual container manually

3. **"Forecast-based system:"** Ship based on forecast: forecasted raw material demand is translated into exact number of containers needed by suppliers and then that quantity is shipped two weeks in advance

   Pros: Ships exact number of containers that suppliers require; minimizes necessary inventory in system to fulfill requirements; gives GGA forward visibility of required outbound shipments, allowing GGA to optimally choose logistics

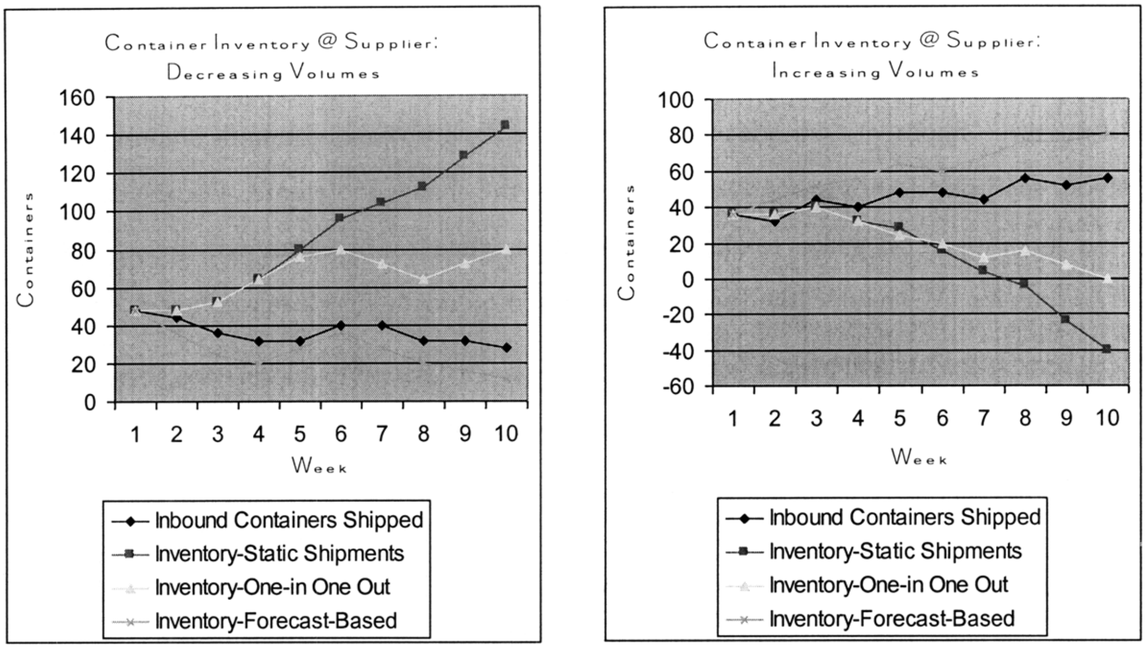
   Cons: Requires complex system; retraining of staff; must maintain accurate data; what if demanded containers aren't available?

Figure 27: Options for determining container return ship quantities



In analyzing the pros and cons of each system, it may be useful to diagram some hypothetical systems of container demand, and see how shipments would be affected in each situation. The graphs below (Figure 28) show two scenarios of changing demand for raw materials. The first blue trend line shows the actual shipments of inbound containers full of raw materials. The quantity of these shipments is irregular, while generally trending upward in the graph on the left and downward in the graph on the right. The other three trend lines show the resulting container inventory at the supplier (assuming an initial on-hand inventory equal to one week's demand) using each of the three methods of computer shipments.

Figure 28: Supplier container levels at decreasing & increasing volumes



From the data, the current static system performs the worst. In the scenario where demand is increasing, inventory at the supplier drops at the same rate as the demand for containers increasing, in this case running out at week eight. Furthermore, in the scenario with decreasing demand, the container inventory at the customer rapidly increases, to the point that by week ten, there are four weeks of container inventory at the supplier, far above the one week target.

The one-in, one-out system performs significantly better regarding supplier inventories; specifically there is some responsiveness to the change in container demand from suppliers. However, there is essentially a two week delay in the response to changing volumes. If the supplier ships a reduced container volume in Week One, those shipments will be in inbound transit for one week and arrive in Week Two, during which the GGA receiving team can collect this information about the new container demand level and ship at said level in week three. This two week delay means that during the transition period, inventory will rise or fall at a level equal to the change in shipment volume, and when shipment volume stabilizes, inventory will stay at this new increased/decreased level. Hence sharp increases in volume can result in stock-outs of containers.

The forecast-based system performs by far the best of the three methods. Since it ships containers based on the expected demand for them at the supplier, it is able to anticipate shifts in shipment volume and ensure that the supplier has sufficient supply of containers to handle these shifts. The result is that the container inventory at the supplier tracks very closely with the demand, meaning that the inventory level when measured in terms of "days of inventory" stays consistent and close to the target. The table below (Figure 29) shows the ending days of container inventory at the supplier for each of the three shipment methods in both scenarios. In both cases the static shipment and one-in one-out methods do not properly compensate for the change in volume. For the decreasing volumes, container inventory spikes to close to three days, while for increasing volumes, suppliers run out of containers. Meanwhile, the forecast-based method maintains close to one day of container inventory at the supplier in each scenario.

Figure 29: Ending days of inventory of containers at supplier

	Decreasing Volumes			Increasing Volumes		
Shipment Method	Static Shipments	One-in One Out	Forecast-Based	Static Shipments	One-in One Out	Forecast-Based
Ending Days of Inventory	3	2.5	0.78	-1.11	0	1.43

In Ford's European container strategy, they also chose to drive container shipments based on future demand. "The component suppliers make requests for containers from the Durable Container Provider seven days in advance." (Palumbo) Although in this case the driver for container shipments is a specific request from the supplier rather than expected container demand based on forecasted part demand, the principle is the same. Essentially container shipments are driven by expected container use in the next period rather than actual container use in the past period, as it is in a one-in, one-out system.

In conclusion of section 5.2.2, tests that our team performed at GGA, in accordance with past industry projects, confirm that the best way to determine many containers to ship to a supplier is based on forecast demand. Furthermore, section 5.2.1 established that the time period to be used in the system needs to be one week.

5.3 High-level Program Logic

Now that it is determined that the container returns system needs to be driven by the forecast materials shipments from suppliers, program logic needs to be established. Below are the primary objectives, required outputs, and program logic that has been chosen.

- Objective

  - Ensure suppliers receive demanded quantity of required containers JIT
  - Maximize volume & weight of each outbound trailer with returnable containers
- Output
  - Exact number of trailers of each freight mode to be sent each week
  - An optimized packing list of container to go on every truck
  - A level daily schedule to shipments to maximize use of dock resources
- Program Logic
  - Based on GGA supplier material forecast, GGA will ship exactly the required containers for supplier shipments 2 weeks ahead
  - Based on container demand, freight mode, and current milk-run consolidation plan, program will calculate how many trucks are needed
  - Mix of containers on each truck will be proportional to demand, and distributed so as to maximize weight and volume on each truck

5.3.1 Container Returns as an Optimization Model

One of the ways in which to model the container returns problem at GGA is to treat it as an optimization model. This model puts in mathematic terms some of the key elements of the program logic established in section 5.3. As listed in section 5.1, the fundamental objective of this problem is to minimize cost, including freight, inventory, and material handling. For example, logistics cost can be looked at as a function of the variable X, which signifies the number of containers k that are shipped to a supplier i using freight mode l in any given week.

Dimensions:

i = Supplier (GGA: i = 0)

j = Raw Material Part Number

k = Container Type

l = Logistics Mode (essentially one iteration for each truck/train)

t = 1 week

Variable:

X_{iklt} = The number of container k sent to supplier i using logistics mode l in week t

Parameters:

I_{ikt} = Inventory at supplier i of container k in week t

D_{ijt} = Demand of raw material part number j from supplier i in week t

T_{jk} = Number of container type k required to ship 1 unit of raw material part number j

w_k, v_k = Weight and volume of each container

W_l, V_l = Weight and volume capacity of each logistics mode

Objective:

$$Minimize: \sum_{i,k,l,t} Logistics\ Cost + \sum_{j,t} Material\ Inventory\ Cost\ \{for\ i = 0\}$$

$$+ \sum_{i,k,l,t} Container\ Inventory\ Cost$$

$$+ \sum_{j,k,t} Material\ Handling\ Cost\ \{for\ i = 0\}$$

Subject To:

$$I_{ikt} = I_{ik(t-1)} + \sum_{l} X_{ikl(t-1)} - \sum_{j} D_{ij(t-1)} \times T_{jk}\ \ \{For\ all\ i, k, \&\ t\}$$

This constraint establishes that inventory of each container at each supplier each week equals the inventory from the previous week plus whatever shipments of that container were made from GGA minus the shipments of those containers back to GGA, which is established as a function of the raw part numbers that correspond to those particular containers.

$$I_{ikt} \geq \sum_{j} D_{ijt} \times T_{jk}\ \ \{For\ all\ i, k, \&\ t\}$$

This constraint establishes that inventory of each container at each supplier each week has to be sufficient to meet the demand for those containers, which is established as a function of the raw part numbers that correspond to those particular containers.

$$\sum_{k} w_k \times X_{iklt} \leq W_l\ \{For\ each\ logistics\ mode\ l\}$$

$$\sum_{k} v_k \times X_{iklt} \leq V_l\ \ \{For\ each\ logistics\ mode\ l\}$$

These two constraints ensure that the sum of the weight and volume for all containers that use a particular logistics mode don't outweigh the capacity of that particular mode.

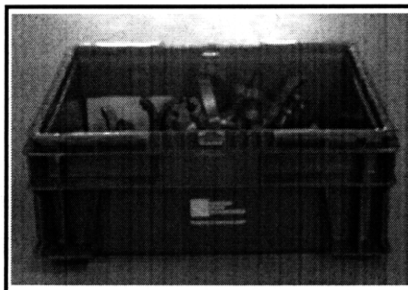
5.4 Data Collection

One of the key activities in making the model functional is to gather the proper data by which to define the parameters in the model. This part of the project was supposed to be readily available in a file known at AAM as a PFEP (Plant for every part). This file theoretically contains each raw material part number, its typical line usage quantities, and all relevant information about the part including the appropriate container type. However, very early we discovered that this data was out-of-date and much too unreliable to run any sort of planned container returns system. Most of the data had to be researched from scratch. GGA logistics intern Alejandra Briseño was critical in finding this data.

5.4.1 Updated Container Catalog

One of the key issues was an accurate container catalog. On the PFEP, most containers had names such as "estiba negra" or "bin gris," meaning "black pallet" and "grey bin," names that could be generically applied to any number of containers used at GGA. How would GGA and its suppliers be able to communicate about container shipments, when there was no clear way to identify containers? Early on, the team established a numbering system for containers based on the types of containers and their measurements. The table below (Figure 30) shows a cross-section of the visual aid for this container numbering system.

Figure 30: Sample of container code system

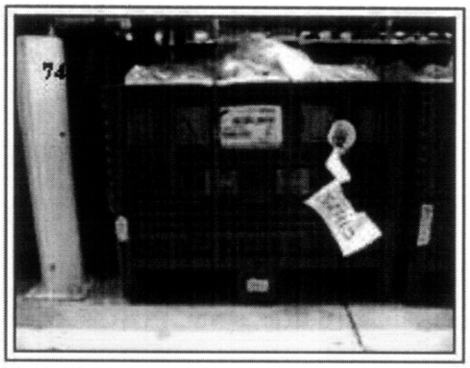


BIN - RIGIDO (BR)

BR151205	15L x 12W x 5.5H
BR151207	15L x 12W x 7.5H
BR151209	15L x 12W x 9.5H
BR161507	16L x 15W x 7.5H
BR241505	24L x 15W x 5.5H
BR241507	24L x 15W x 7.5H
BR241509	24L x 15W x 9.5H
BR241209	24L x 12W x 9.5H

The system was set up on these lines for all 142 container types used at GGA, including all standard and custom containers. In order to create a master container list, we had to take photos of each container in order to ensure it was properly identified. Furthermore, the team had to confirm the proper weight and volume (w_k, v_k) of each container. This data was compiled in the Master Container Catalog, part of which is displayed in the figure below (Figure 31).

Figure 31: Example from container catalog



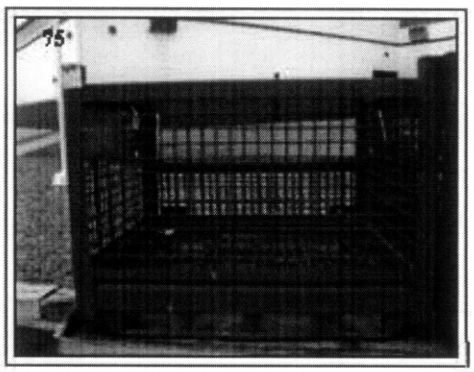
***DESCRIPCION*:** **Ropack para Baleros**

CÓDIGO: KY323025

PROVEEDOR: Koyo.

PESO: 66 Lb.

CONTENEDORES METALICOS



***DESCRIPCION*:** **Canastilla metálica rígida.**

CODIGO: CR544440

PROVEEDORES NORTE: **Colfor Malvern, Bing Metal, Detroit Forge, Waupaca, Motodiesel**

PROVEEDORES SUR: Arcelo Mital (Marion).

PESO: 366 Lb.

5.4.2 *Establishing Container to Part Number Relationship*

One of the critical pieces of data is establishing the matrix T_{jk}, which is essentially the transfer matrix that establishes the number of parts that fit in a container, or as the linear algebra of the program works, the fraction of a container that is needed for each raw material part shipped. This data was supposed to be included in the PFEP, but was also inaccurate and not up-to-date. The project team therefore took on the daunting task of compiling this information linking each part number to the corresponding container and including all the relevant information. Using this we built an updated PFEP document that, while focused on the application of container returns, would be useful for other applications within the plant The diagrams below (Figures 32 & 33) document this container PFEP.

One of the challenges was that there were different combinations of packaging used for each type of container. Figure 32 below shows a side gear, which is simply shipped in a bulk collapsible basket (canastilla in Spanish). However the machined axle shaft comes in a set of packaging where 42 axles are placed on a thermoform tray and each set of five trays required a specialized base and lid.

Figure 32: PFEP Part 1

Part No.	Part Description	Std. Pack	LOCATION	Tray/Bin/ Seperador	Base/ Canastilla	Tapa	Tray/ Std Pack	Base/ Std Pack	Lid/ Std Pack
26058813	SHAFT MACHINED - 8.25 G	210	NORTH AAM DETROIT	TFFFAAMD	BSCM4848	BSCM4848	5	1	1
40048045	Gear, Diff. Side	1008	NORTH AAM TONAWANDA	0	CC303230	0	0	1	0
3977326	LOCK DIFF ADJUST	14,400	NORTH ADVANCE WIRE ADD	BC150807	BSCM3032	0	18	1	0
40040992	TUBE&LINER4.00X.075SW	45	SOUTH ALCOA LAFAYETTE	0	RK844834	0	0	1	0

Basic Part Data

North or South & Supplier Site

Container Types Used for Part Number

Quantities per Standard Pack

Therefore, for each standard pack of 210 machined shafts, the required set of packaging was five trays, one base pallet, and an additional pallet to be used as a lid. For this particular set, the "Pack Contents" that would need to show up on a packing list so that the receiving team knows exactly what to ship would be "(5)TFFFAAMD (1) BSCM4848 (1) BSCM 4848 as shown in Figure 33.

Figure 33: PFEP Part 2

H	W	L	Total Weight	Total Volume	Pack Contents	Piece Demand	Std. Pack Demand
36	48	48	156.2	48.0	(5) TFFFAAMD (1) BSCM4848 (1) BSCM4848	6144	29
18	32	30	249	10.0	(1) CC303230	4032	4
0	0	0	170.24	15.6	(36) BC150807 (2) BSCM3032	0	0
15	48	84	240	35.0	(1) RK844834	0	0

Demand for Containers

Container Pack Weight & Volume

Standard Pack Contents

Imported Forecast Part Demand

5.5 Model Description

The model as developed included the basic elements that were described in the model above. As the project team worked with GGA staff, it became apparent that in order to successfully implement, the project had to make the process of managing container returns easier. Therefore we decided that the output of the container returns model would have to be an explicit packing list for each truck that could simply be handed to the receiving department, who would be responsible for shipping based on the packing list. This meant that each value of logistics mode (subscript l) would represent not just a freight mode, but an individual trailer, and the variable matrix X_{iklt} would represent each container on each truck going to each supplier each week.

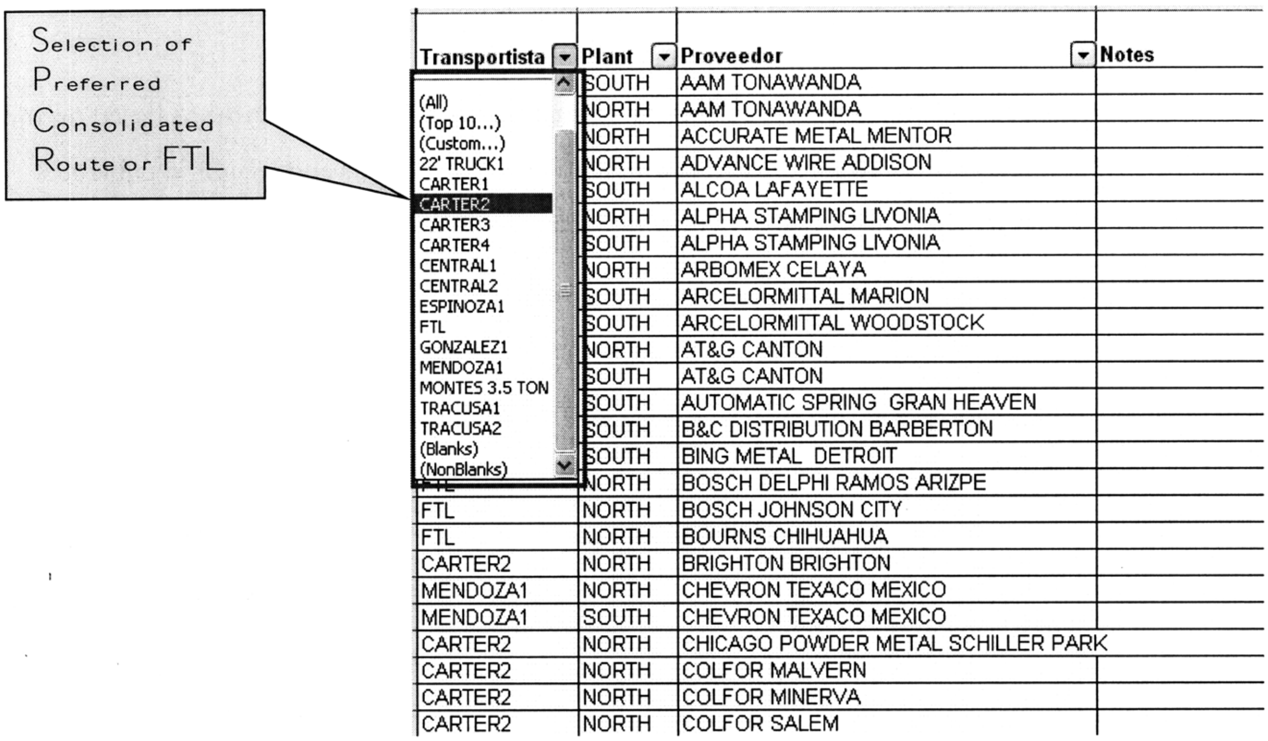
5.5.1 Optimization Model vs. Heuristics & Metrics

When we built the initial model using an optimization format based around the decision variable matrix X_{iklt}, the extreme complexity became apparent. The initial model used a mock set of test data involving only 10 suppliers and 10 container types. Even with this limited set of data, the mixed integer program became extremely large, and it was clear that an optimization program would be unfeasible on a large scale.

Another issue using an optimization model was the accuracy of determining cost of certain logistics solutions, specifically milkruns. As described in section 3.5, the cost of delivering to a particular supplier on a milkrun is based on the total costs of that milkrun. In a model that dynamically makes freight decisions for multiple suppliers, it would be impossible to determine the cost of any one supplier without statically fixing the makeup of the rest of the route. Furthermore, there was risk that the model output would be too dynamic week-to-week, meaning that the optimal logistics solution for any individual supplier would vary too widely week-to-week. This would completely negate the value of working relationships and familiarity between the logistics companies, the supplier, and the GGA logistics team.

Based on the factors above, it was decided that it would be better not to implement an across-the-board optimization model. Instead it would be better to create a system that starts with a preferred set of combinations matching suppliers to logistics solutions, and predetermining logical combinations of suppliers for consolidated trucks. These initial combinations would serve as a sort of default. Then once the logistics needs are determined for a particular week, the model would provide a set of metrics, by which the user could use heuristics to change logistics solutions and consolidation combinations to optimize the capacity utilization of the outgoing trucks. Figure 34 shows a sample of the tool used to select freight mode. Note that when a particular freight provider has several options listed, those represent the individual trucks that are expected to go out in that particular week. The metrics and heuristics used to then go back and change freight providers per supplier will be described in section 5.5.6.

Figure 34: Freight determination spreadsheet

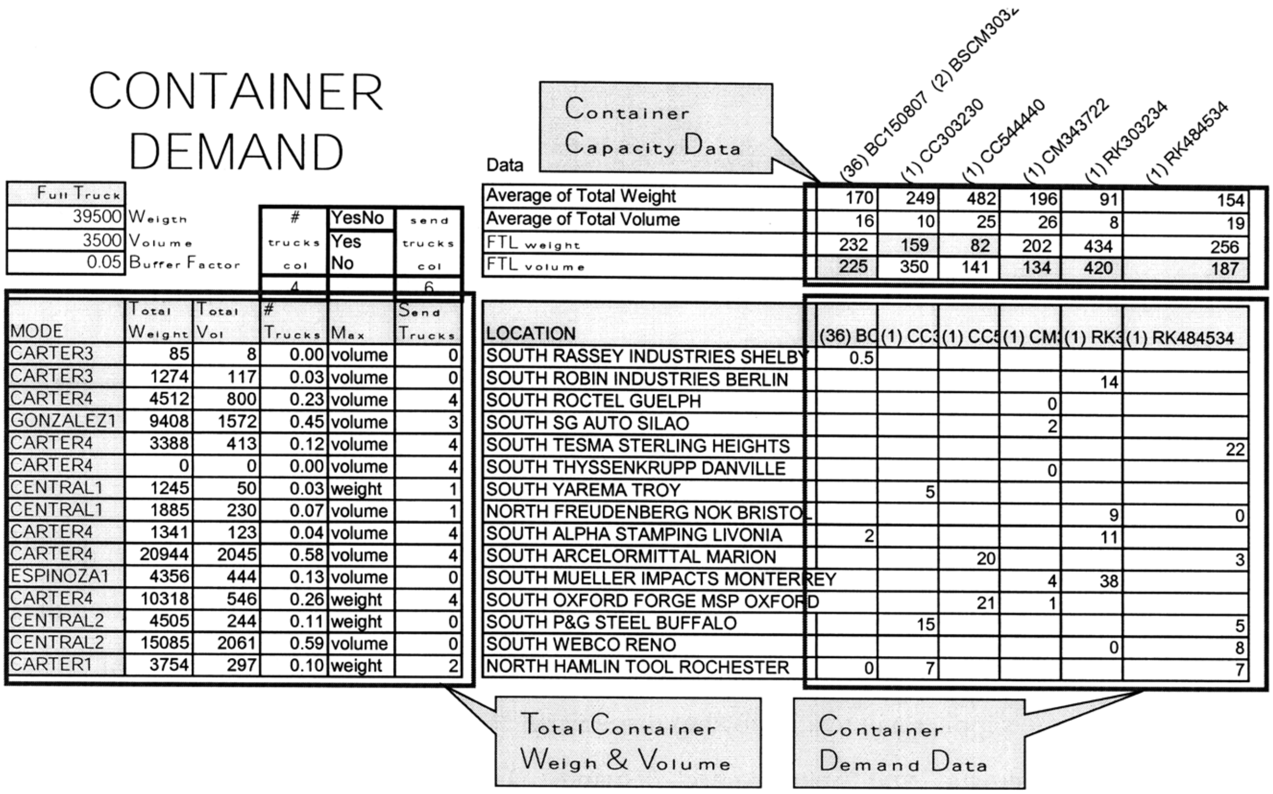


5.5.2 Importing demand model into model

A key element of the model is ensuring that the correct container demand be imported into the system. As mentioned in section 5.5.2, the container PFEP spreadsheet maintains the relation data between the number of raw part numbers to be shipped from a supplier, and the number of containers that the supplier will require to ship those parts. In figure 33, the last two columns are labeled as "Piece demand" and "Standard pack demand." The piece demand is imported from the actual material forecasts for two weeks ahead, and it is translated into the "Standard pack demand" using the containers required per part. This number represents the number of container required for that part number. However, since often suppliers use the same container for multiple part numbers, the total number of containers is then aggregated in the actual container returns model. A small sample of the first tab of this model, which represents container demand, is shown in Figure 35. Container combinations are displayed on the horizontal axis while suppliers are on the vertical axis. The matrix on the lower right hand side of the model represents the total container demand for one week for each supplier and each container ($\sum_j D_{ij(t-1)} \times T_{jk}$). The data on the upper right hand side represents relevant data for each container, specifically the weight, volume, (w_k, v_k) max quantity per trailer by weight, and max quantity per trailer by volume $(\frac{W_l}{w_k}, \frac{V_l}{v_k})$. The number highlighted in yellow represents whether the container loaded on its own maxes out a trailer on weight or volume.

The set of data on the left represents data specific to a particular supplier. This means based on the supplier demand for a particular container, how much volume in pounds and weight in cubic feet that the containers would consume, and to how many trucks that would equate.

Figure 35: Container returns model – Container demand tab



Full Truck	
39500	Weigth
3500	Volume
0.05	Buffer Factor

# trucks col	YesNo	send trucks col
	Yes	
	No	
4		6

MODE	Total Weight	Total Vol	# Trucks	Max	Send Trucks
CARTER3	85	8	0.00	volume	0
CARTER3	1274	117	0.03	volume	0
CARTER4	4512	800	0.23	volume	4
GONZALEZ1	9408	1572	0.45	volume	3
CARTER4	3388	413	0.12	volume	4
CARTER4	0	0	0.00	volume	4
CENTRAL1	1245	50	0.03	weight	1
CENTRAL1	1885	230	0.07	volume	1
CARTER4	1341	123	0.04	volume	4
CARTER4	20944	2045	0.58	volume	4
ESPINOZA1	4356	444	0.13	volume	0
CARTER4	10318	546	0.26	weight	4
CENTRAL2	4505	244	0.11	weight	0
CENTRAL2	15085	2061	0.59	volume	0
CARTER1	3754	297	0.10	weight	2

Data	(36) BC150807 (2) BSCM303	(1) CC303230	(1) CC544440	(1) CM343722	(1) RK303234	(1) RK484534
Average of Total Weight	170	249	482	196	91	154
Average of Total Volume	16	10	25	26	8	19
FTL weight	232	159	82	202	434	256
FTL volume	225	350	141	134	420	187

LOCATION	(36) BC	(1) CC3	(1) CC5	(1) CM3	(1) RK3	(1) RK484534
SOUTH RASSEY INDUSTRIES SHELBY	0.5					
SOUTH ROBIN INDUSTRIES BERLIN					14	
SOUTH ROCTEL GUELPH				0		
SOUTH SG AUTO SILAO				2		
SOUTH TESMA STERLING HEIGHTS						22
SOUTH THYSSENKRUPP DANVILLE				0		
SOUTH YAREMA TROY		5				
NORTH FREUDENBERG NOK BRISTOL					9	0
SOUTH ALPHA STAMPING LIVONIA	2				11	
SOUTH ARCELORMITTAL MARION			20			3
SOUTH MUELLER IMPACTS MONTERREY				4	38	
SOUTH OXFORD FORGE MSP OXFORD			21	1		
SOUTH P&G STEEL BUFFALO		15				5
SOUTH WEBCO RENO					0	8
NORTH HAMLIN TOOL ROCHESTER	0	7				7

It is of note that with regards to the set of suppliers displayed above, none are of a quantity that can be shipped FTL, and all are currently set on consolidated routes. The column on the far left represents the settings for each individual supplier on the freight determination spreadsheet. For all consolidated loads, the Demand worksheet includes a section at the bottom which sums up all weight and volume for that particular load (Figure 36). As an example, the consolidated supplier set of "Carter 4" sums up to 114847 lbs and 15828 cu ft, which equates to 4.52 tucks. Section 5.5.5

explains how this container demand data is used in heuristics, and then how actual truckloads are set up.

Figure 36: Container returns model – Consolidated route total demand

Total Truck Weight & Volume

Total Container Demand Data

CONTAINER DEMAND

Full Truck	
39500	Weigth
3500	Volume
0.05	Buffer Factor

			# trucks col	YesNo	send truck col
				Yes	
				No	
			4		6
CARTER1	46822	7656.7	2.19	volume	2
CARTER2	32262	5113.9	1.46	volume	1
CARTER3	24017	2760.3	0.79	volume	0
CARTER4	114847	15828	4.52	volume	4
CENTRAL1	35068	4716.5	1.35	volume	1
CENTRAL2	24222	2797.4	0.80	volume	0
ESPINOZA1	5084	510.21	0.15	volume	0
MENDOZA1	22060	4206	1.20	volume	1
MONTES 3.5	1338.9	160	0.05	volume	0
TRACUSA1	15061	3243.5	0.93	volume	0
TRACUSA2	11167	1031.1	0.29	volume	0
22' TRUCK1	1689.4	162.92	0.05	volume	0
GONZALEZ1	91500	13228	3.78	volume	3

Data	(36) BC150807 (2) BSCM303	(1) CC303230	(1) CC544440	(1) CM343722	(1) RK303234	(1) RK484534
Average of Total Weight	170	249	482	196	91	154
Average of Total Volume	16	10	25	26	8	19
FTL weight	232	159	82	202	434	256
FTL volume	225	350	141	134	420	187
CARTER1	4	7	16	4	6	7
CARTER2	58	0	0	0	0	35
CARTER3	3	1	1	0	14	0
CARTER4	2	34	41	52	11	133
CENTRAL1	0	5	0	0	9	5
CENTRAL2	0	26	0	0	0	13
ESPINOZA1	0	0	0	4	46	0
MENDOZA1	0	0	0	0	0	16
MONTES 3.5 TON	0	0	0	0	0	0
TRACUSA1	0	0	0	0	0	0
TRACUSA2	65	0	0	0	0	0
22' TRUCK1	0	0	0	0	18	0
GONZALEZ1	0	0	0	2	0	0

5.5.3 Program Calculations

At this stage it is critical to understand the calculations taken by the container returns model to determine how many trucks it will ship for each consolidated load and then how many of each type of container it will ship. Let us refer to demand quoted in terms of trailer loads for each FTL or consolidated truck as TD_l or trailer demand of l. Let us also define a manually determined binary variable in this case Y_{iklt} that represents whether or not a particular container from a particular supplier will be shipped on a particular supplier group combination l. Therefore:

$$TD_{lt} = \sum_i \sum_j \sum_k D_{ijt} \times T_{jk} \times Y_{iklt} \times \max\left(\frac{W_l}{w_k}, \frac{V_l}{v_k}\right) \{For\ all\ l, t\}$$

This variable TD_{lt} represents actual container demand for the time period in terms of exact truckloads. From this we determine number of trucks shipped of l (TS_{lt}) which equals TD_{lt} rounded down to the full truck quantity.

$$TS_{lt} = Rounddown(TD_{lt}, 0)$$

The meaning of TS_{lt} is that the mode of transport or consolidated load l will ship containers for the set of suppliers manually determined by the binary variable Y_{iklt}. From here, the next logical question is what actual containers will be shipped on each truckload within the one, two, three, or actual trucks that are to be shipped from that combination of suppliers that represent TS_{lt}. The ideal answer in terms of practicality of both the model and the real-life procedure is to make each of these trucks homogeneous, meaning that each time that during the course of the week, GGA would ship three trucks with the same packing slip of containers. In reality, this may not be practical. It may be the case that all the suppliers included in this consolidated load ideally would receive containers two times per week. The solution then would be for the program user to split this group of suppliers into two consolidated combinations so that the total quantity for each load would call for only two shipments per week. This can be done manually using the freight determination spreadsheet from section 5.5.1

At this stage, we've established a quantity of homogenous truckloads for each supplier group l each week t. The next question is to determine how many of each container will be placed on this truckload. This quantity for each container will be based on the total number that is demanded by the set of suppliers included on that truckload. Looking at figure 36, the consolidated group "Carter4" requires two of the container set "(36) BC160807 (2) BSCM3032", 34 of "(1)303230" and so on. In this case, demand adds up to 4.52 trucks. Therefore, to find the amount of each container that can ship during the week we can multiply the demand for each container by the ratio of 4/4.52, and the quantity that can be loaded on each individual truck is 1/4.52. This logic is applied to the shipment of all individual containers using the following equation:

$$X_{iklt} = rounddown(\textstyle\sum_j (D_{ijt} \times T_{jk})/TD_l, 0)$$

5.5.4 Issue of Rounding Container Quantities

One of the primary issues faced in determining container ship quantities is the issue of rounding down the number of containers demanded to the number that are actually shipped. For example, if a supplier demands one container each week and their particular container is shipped on a truck with a TD_{lt} value of 1.9, the quantity of that container that can be shipped will be 1/1.9, which will round down to zero. By this logic, the ship quantity each week for that container to that supplier will be zero. For this reason, the container returns program has a built-in "remainder" feature. Through this feature, all demanded containers that are not shipped in a particular week are stored in a remainder file and added on to the next week's demand. This ensures that in the long run, all suppliers will receive exactly the number of containers they require. Fluctuations can be accounted for by a small amount of buffer inventory at the supplier. However this buffer inventory will be significantly smaller than the container build-up that has historically occurred.

Another key element of the "remainder" feature is the ability to choose minimum economic order quantities for certain containers. The feature ensures that container demand at any particular supplier builds up to the point where the supplier requires a quantity of containers that can be feasibly shipped in an economical manner, as per the EOQ formula:

$$Q^* = \sqrt{\frac{2CD}{H}}$$

- Q^* = optimal order quantity
- D = annual demand quantity of the product
- C = fixed cost per order (*not* per unit, in addition to unit cost)
- H = annual holding cost per unit (also known as carrying cost)

In order to illustrate, let us return to the example of the most standard container: the 15"x8"x7" bin. This bin, when full of material, is shipped on a standard 32"x30" returnable pallet, with 18 bins stacked 2x3x2 as displayed in the picture below (Figure 37).

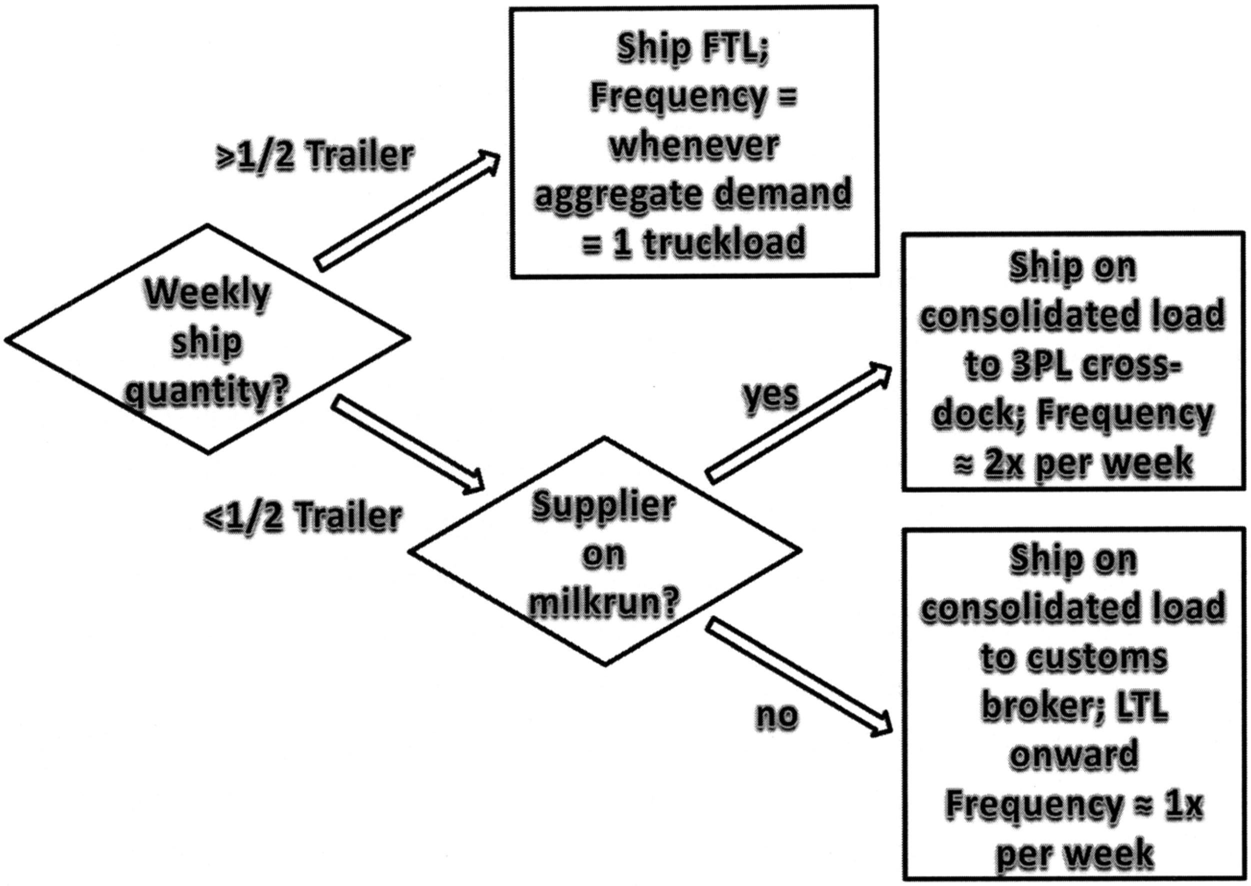
Figure 37: Standard 15"x8"x7" bin with material

For small items that are typically shipped in this bin, the "standard pack," as defined by the material pull system, can be a full pallet or just a single bin, depending on the daily usage of that particular part number. In the case that the "standard pack" is only a single bin, the container requirements per standard pack are (1)BC150807 (.067)BSCM303. Clearly one bin and 1/18 of a pallet is not a very economical ship quantity for empty containers. Therefore, we have determined that the optimal tradeoff between LTL/Milkrun freight charges and the value of the bins is to ship them in a pack of two pallets and 36 bins stacked and nested. So in using the "remainder" feature, demand at a supplier accumulates until it reaches 36 bins. This pack may entail 10 pallets per week or one pallet every three months. The result is a good tradeoff of low freight cost and a proper allocation of common container inventory amongst GGA's suppliers.

5.5.5 User determined heuristics

Minimum EOQ as described above is one way that the user can modify and optimize the program. Another way is on a weekly basis to make changes to how each supplier will be shipped. At this stage, specific logistics costs have not been built into the system. This is because of the complicated dynamics of milkrun costs. However, generally logistics costs would be minimized using the following set of rules that are also diagramed in the decision tree below (Figure 38).

Figure 38: Logistics decisions heuristic



1. For all suppliers where weekly quantity amount to one half of a trailer or more, FTL is cheapest. Whenever aggregate container demand reaches a full truckload, a truck will be shipped. This may be several times a week or as little as once every other week.

2. If weekly container quantity is less than half a trailer, the decision rests on whether that supplier can be economically placed on a milkrun route. This determination is typically made by the 3PL.

    a. If the supplier cannot be placed on a milkrun, the material is placed on a consolidated truck to the customs broker in Laredo, where the individual shipments are sent LTL to the supplier. Since LTL has a relatively high fixed shipping cost (C in the EOQ model), ship frequency is optimally only once per week. However, zero containers will ship in that week unless that supplier's demand exceeds the minimum EOQ as defined in section 5.5.4

b. If it can be place on a milkrun, then the containers need to be placed on one of the consolidated trailers that go directly to the 3PL. Since these milkruns run daily, regardless of the quantity of return containers, the fixed shipping cost (term C in EOQ formula) equals zero. Therefore ship frequency is twice per week rather than once.

5.5.6 User ship decisions

As described in section 5.5.5, the user makes decisions as to the optimal freight mode and frequency for suppliers. These decisions are typically based in more long-term trends in container demand quantity for each supplier. Typically, suppliers will not be moved from FTL to LTL and back on a week-to-week basis. However, a decision that would be made on a week-to-week basis is the consolidation combinations for suppliers shipped by LTL or Milkruns. Figure 39 shows a small cross section of a sample container ship output. Particularly of note are the consolidated loads at the bottom labeled as "Carter 1" and "Carter 2." These represent the consolidated loads that will be shipped to the 3PL and then go out on milkruns. From the demand data in Figure 36, we know that the combination "Carter 1" amounts to 2.19 truckloads and the combination "Carter 2" adds up to 1.46 truckloads, both maxed out by volume. Once the model applies proportional reduction and rounding algorithms, the result is that the combination of containers for "Carter 1" will be shipped twice and "Carter 2" will be shipped once. Both groupings are left with a quantity of containers that cannot be shipped. In order to optimize truck loading and ensure that the maximum supplier container demand is met, the program user has the option to move certain suppliers in between the two combinations, or consolidate everything into one combination to be shipped three times during the week and essentially eliminating "Carter 2."

Figure 39: Container returns model – shipment quantities

FULL SHIPMENTS

Full Truck	
39500	Weigth
3500	Volume

	(36) BC150807 (2) BS	(1) CC303230	(1) CC544440	(1) CM343722	(1) RK303234	(1) RK484534
Data	(36) BC	(1) CC3	(1) CC5	(1) CM3	(1) RK3	(1) RK484534
Average of Total Weight	170	249	482	196	91	154
Average of Total Volume	16	10	25	26	8	19
FTL weight	232	159	82	202	434	256
FTL volume	225	350	141	134	420	187

MODE	Load Weight	Load Volume	% Weight	% Volume	Send Trucks	LOCATION	(36) BC	(1) CC3	(1) CC5	(1) CM3	(1) RK3	(1) RK484534
FTL	39042	2005	99%	57%	1	SOUTH ARCELORMITTAL WO	0	0	81	0	0	0
CARTER2	3542	431	9%	12%	1	NORTH RADAR WARREN	0	0	0	0	0	23
CARTER4	2618	319	7%	9%	4	SOUTH L&W BELLEVILLE	0	0	0	0	0	17
CENTRAL1	1234	150	3%	4%	1	NORTH FREUDENBERG NOK	0	0	0	0	6	0
CARTER1	2892	149	7%	4%	2	NORTH DETROIT FORGE DET	0	0	6	0	0	0
CARTER4	980	131	2%	4%	4	SOUTH B&C DISTRIBUTION B/	0	0	0	5	0	0
CARTER2	1021	93	3%	3%	1	NORTH NEWCOR CORUNNA	6	0	0	0	0	0
CARTER4	1743	70	4%	2%	4	SOUTH MATCOR BRAMPTON	0	7	0	0	0	0
CARTER1	18562	3098	47%	89%	2	CARTER1	1	3	6	1	2	3
CARTER2	20174	3171	51%	91%	1	CARTER2	37	0	0	0	0	23
CENTRAL1	24614	3319	62%	95%	1	CENTRAL1	0	3	0	0	6	3

Percent Capacity by Weight and Volume

Trucks per Week

In looking at the above data, it is also noteworthy that none of the utilization is at 100% for either weight or volume. Most consolidated loads average 50% weight utilization, as a function of the average weight/volume ratios of empty containers. In terms of volume, the loads average between 89% and 95%. This inability to achieve 100% is a function of the rounding issue described in section 5.5.4. This may be difficult to overcome within the model, and true optimization may require some on-the-floor flexibility with regards to the implementation of the model.

One opportunity for improvement over the solution given in Figure 39 pertains to the first supplier displayed. Note that this is the only FTL supplier on the list, and that it uses only collapsible wire baskets that actually max out on weight with only 57% of volume utilized. In this example, it may be worth investigating combining this supplier with another FTL supplier within close geometric proximity. This would help eliminate the "Sub-optimization of Weight/Volume Ratio" issue described in section 4.3.3.

5.6 Model Output

The above sections describe the functionality of the model and the ways in which the user can modify this functionality as well as the week-to-week output. In this section we will describe the actual output that results. A key requirement of the system that was reiterated by numerous managers within the materials department was that the system outputs something practical and usable. From this we deduced that the most practical output in this application is a packing list; something the receiving department can use to tell them exactly how to load a truck. It needs to state exactly which types of containers and how many of each type need to be loaded on each truck. The printout below (Figure 40) shows a sample packing slip for a consolidated load.

Figure 40: Packing slip – consolidated load

GGA "PACKING LIST" DE CONTENEDORES VACIOS

Fecha _____/_____/_________ Firma de Empleado ____________________

de caja ________________ Firma de Supervisor ____________________

Notas de supervisor

Supplier/Route	CARTER2
Number of Trucks	1
Freight Mode	CARTER2

(1) CP353547	3
(1) RK484534	22
(10) TFFI55SH (1) BSCM4848 (1) BSCM4848	1
(12) TFCB32CB (1) BSCM3032A (1) BSCM3032A	14
(15) TFCM05SI (1) BSCM3032A (1) BSCM3032A	5
(24) BC241114 (1) BSCM4548	2
(36) BC150807 (2) BSCM3032	42
(60) BNRDUNBE (1) UB303224	1
(7) TFTU89BTA (1) BSCM4848 (1) BSCM4848	5
(9) TFTU89BT (1) BSCM4848 (1) BSCM4848	23
(90) BNRDUNBE (1) UB303224	4

Having these printouts creates numerous advantages for the receiving staff at GGA. One advantage is that the receiving department knows exactly what to load. Another advantage is the ability to load by container type rather than loading by supplier. In the past, when shipping out containers on consolidated loads, the receiving staff had to separate containers by supplier. This meant that for common container types, they would have to put separate stacks in different parts of the truck and label each stack individually to communicate to the 3PL exactly to which supplier the stack needs to be sent. Under the new system, they can stack common container types all together in one grouping. This allows the receiving staff to stack homogeneous groups of containers higher and more safely than they could with mixed container types. Also, the GGA receiving staff does not have to concern themselves with the individual demands of each supplier in a consolidated load. GGA simply packs in consolidated bulk and then with the bulk shipment they send an envelope filled with the individual packing lists by supplier as displayed below (Figure 41). The result is an easier and less error-prone process for GGA.

Figure 41: Packing slip – individual supplier

GGA "PACKING LIST" DE CONTENEDORES VACIOS

Fecha _____/_____/_________ Firma de Empleado ________________________

de caja _________________ Firma de Supervisor ________________________

Notas de supervisor

Supplier/Route	NORTH AT&G CANTON
Number of Trucks	1
Freight Mode	CARTER2
(36) BC150807 (2) BSCM3032	1

6. Implementation & Results

6.1 Partial-scale Test Runs & Adjustments

The first step of implementation was to test that the output from the program was usable. The way this was done was by taking sample packing lists output from the system and loading truck according to these outputs. This allowed the project team to correct error data from the system before full implementation. Some of the issues that became evident were errors in the way that container volume was recorded, especially pertaining to the height of the container. As a simple example, if a container was three feet tall, knowing that a standard trailer is 96 inches, or eight feet tall, then the program would calculate that containers can be stacked 8/3 or 2.66 units high. However in reality these containers can only be stacked two units high. Therefore the height of the containers as documented in the PFEP had to be changed to four feet to account for this stacking limit.

Making these data adjustments before the widespread implementation of the system was critical. We knew that any hiccups during the full-scale implementation of the system would deteriorate confidence in the system among the GGA materials team. An erosion of confidence before the system took off could potentially cause the department to revert back to the previous system. If a first implementation failed, it would be almost impossible to gain widespread support for a second run.

6.2 Implementation Plan

At this stage, the data in the system is accurate, and the functionality of the system is proven. We are confident that with widespread support and education about the system, it will succeed. The most important things to define therefore are the responsibilities of different groups within the department and the potential issues that could cause deterioration of confidence in the system.

6.2.1 Department Responsibilities for Returns Program

Section 4.3.6 outlined the key organizational issues that have made the current system a failure. The key fault is that each of the groups involved in container returns have incentives that are not aligned with their responsibilities. Specifically, the logistics group has essentially no control over container returns, yet the poor execution of container returns hurts their department the most.

New programs group: In the current state, new programs was given the responsibility to set up the returns schedule, since they are the ones responsible for ordering and initiating new containers and part numbers. However, they have no stake in the effectiveness of the schedule/system after the new materials ramp up into production. We feel that the new programs group is poorly placed to manage this program and should not have a significant role in the system. ***Supplier scheduling group:*** This group theoretically should have little to do with container returns. However since they are the conduit to the supplier, they have traditionally had to step in to help expedite containers to a supplier that was running low. We think they should continue to maintain this communication with the supplier, but we expect that such intervention will become less necessary because the new system will maintain proper inventories at the suppliers.

Logistics group: This is the group whose performance is most closely aligned with the effectiveness of the container returns system. Therefore we feel that the role of the logistics department should increase. A single associate in logistics should be responsible for the week-to-week running of the program, including calling for trucks as demanded by the program. They should run the user heuristics to optimize freight mode and consolidation combinations. They should also print the packing lists and maintain regular communication with the receiving department to ensure that the system is being followed and to troubleshoot any issues that arise. This person should specifically be evaluated on the metric of logistics cost for container returns as a percentage of total logistics cost.

Receiving group: This team should continue their role in shipping out the returnable containers. However management needs to regularly verify that they are in fact shipping containers based on the packing lists provided and that they are reporting issues as they arise rather than working around them. The role of receiving essentially stays the same, but their job will become easier with a successful implementation of the program.

***IT Department*:** Currently the returns program is entirely programmed in Excel. This has given our team the opportunity to refine the algorithms and logic using a simple platform. However, Excel does not make for an exceptionally user-friendly interface with the regular users, and it is susceptible to system-wide bug being caused by something as routine as an unintended change in format. This fragility of the program means that someone at GGA needs to understand the back-end functionality of the program incase bugs arise. Furthermore we recommend that if the program is implemented with success, that GGA invest in transferring the logic out of Excel into a more stable platform.

6.2.2 Process Procedures

The project team has left a detailed set of procedures for the existing materials team at GGA. These procedures include step-by-step instructions for week-to-week processing and the heuristics for user initiated changed.

6.2.3 Potential Implementation Challenges

There exist a number of potential challenges in the implementation process. The first potential issue is that the packing slips represent an unfeasible loading of a trailer, as described in section 6.1. We saw this as the most critical issue, and therefore we created initial test runs to validate the packing lists before initiating full-scale implementations.

In addition to packing list feasibility, there may be other critical issues. These have been identified as follows:

Container Availability: The recommended container shipments as described in the program are based on demand at the supplier and don't necessarily correspond with the inventories at GGA. Therefore when a packing list calls for a specific container, that container may not be available. When this occurs, the system has planned shipments and adjusted supplier inventories based on the assumption that all containers on the packing list will be shipped. If they are not shipped, trucks will go out sub-optimized or the receiving department will have to send out other containers as a substitute, which would corrupt the integrity of the data in the system.

The issue described above can come from one of two fundamental root causes. Either 1) There are not sufficient containers in the system; or 2) The containers in the system are not properly allocated between GGA and its suppliers. With some very minor exceptions, our team is convinced that the first possibility is not the case. After speaking with several industry experts about the topic, the common consensus was that automotive companies typically have many more containers than they need. However, there is always a shortage because the containers are not sent to the right place. The Ford Europe returnable container study confirms this consensus. (Palumbo) Some sort of

RFID tracking is the best solution, but since this is not a possibility, our team's proposed solution will ensure that containers only go to suppliers that actually need them. With regards to the allocation of containers, this issue corresponds closely to the initial supplier inventory of containers, which is described in the following paragraph.

Initial supply container inventory: As described in section 4.3.2, the current allocation of shared containers does not correspond to the actual demand for containers at those suppliers. Some suppliers are overstocked while others are running out of containers. Our system requires sufficient inventory be available at GGA so that packing slip quantities are always available to ship. If certain suppliers are overstocked, GGA will not have sufficient quantities to ship. Also, our system requires that suppliers have some buffer inventories to account for the week-to-week rounding of the shipments. It is therefore essential that initial container inventories at suppliers represent their actual need.

Our team has begun to solve this by identifying the most critical common containers and their high-volume suppliers. One to two weeks before live implementation, these suppliers need to be contacted. If they are understocked, GGA needs to increase the next shipment. If they are overstocked, this needs to be noted in returns program and that suppliers demand for the first week be set to zero. This process of contacting suppliers to check container inventories should be the responsibility of the logistics associate in charge of the returns system.

6.3 Results

At the time that the project team completed their work at GGA, implementation for the returns program had not yet begun. Therefore specific results can neither be documented nor recorded. Efforts to implement by the project team were met by delays and a lack of response from management. As mentioned in the introduction, the materials department at GGA has been experiencing a series of more pressing matters, largely stemming from the decline in the sales of large trucks.

In any case, the project team still believes that there are large potential savings from implementing a real-time planning method for container returns, as documented in this work. We still believe the figure of $614k annual savings stated in section 4.1 is a valid figure. We are confident that if the materials department at GGA were to follow the recommendations of the project team, these savings could be realized and the day-to-day effectiveness of the container returns process would be improved.

7. Other Savings Opportunities

The project looked upon the issue of container returns in somewhat of a micro sense in this thesis. A significant amount of effort was made to optimize logistics returns within a certain framework that we took as given. We took as assumptions the fact that GGA was committed to using returnable containers. We also isolated the system we analyzed to only include GGA and its immediate supplier base. Within the scope and timeframe of the project, these were necessary simplifications. However, if we removed these assumptions that we used to frame the problem, a number of intriguing possibilities emerge.

7.1 Returnable vs. Expendable Containers

While the vast majority of inbound materials to GGA come in returnable containers, many containers come in expendable containers – either cardboard or wooden crates. Of these, cardboard is significantly cheaper, but there are situations in which wood is needed in order to maintain the structural integrity of the container. This may be because the parts are too heavy or they are at a high risk of being damaged. Intuitively, wood crating is more expensive than cardboard.

One reason some parts come in expendable is the distance to the supplier. If a supplier is overseas, generally the cost of sending back a returnable container almost always outweighs the cost of paying for an expendable. Also, by virtue of being overseas, the transit time is greater, and therefore does not turn enough times to justify the capital investment in the container. Another reason may be that the part number is a low usage part. In third member assembly, GGA uses a large variety of shims that are fitted to each individual axle, and therefore one container of shims may last several months. Therefore, this inventory does not turn enough times to justify investment in a returnable container.

The above examples show that GGA uses a tradeoff analysis to determine for which part numbers to use expendables versus returnable containers. There is no reason why the above logic cannot be expanded to the part numbers currently shipped in returnables. As the cost of shipping from GGA to the U.S. and Canada increases, more parts fit into this category. The leading candidates are fasteners and other small parts that can be shipped in cardboard rather than wood, specifically those that are low volume parts.

7.2 Potential Intra-company Container Pooling

For those part numbers where it will continue to be advantageous to use returnable containers, it is of value to think about the supply chain beyond just GGA and its suppliers and to incorporate all of AAM into the container returns system. In doing so, certain opportunities emerge, specifically situations where US-based AAM plants in Detroit import raw parts from Mexico, and then send back the empty containers. This creates a clear source of waste where we have empty containers flowing in both directions. A more efficient solution would be as follows:

1. GGA to sends empty containers to DGA's Mexico-based supplier
2. Mexico-based DGA supplier sends material to DGA
3. DGA sends empty containers to US-based GGA supplier
4. US-based GGA supplier sends material to GGA

When the project team inquired about this possibility, one of the issues that arose was that the container types used by the Mexico-based GGA suppliers were specialized and could not be used with other suppliers. Herein lays an issue that will be developed further in section 7.3.

7.3 Potential Inter-company Container Pooling

Beyond looking at other plants within the AAM umbrella, value can also be created by looking to other firms that use returnable containers. For example, there are tier one automotive suppliers that server the same OEMS as AAM who have manufacturing plants in Mexico. From these manufacturing plants they supply parts to US-based OEM assembly plants, which in turn send empty containers southbound. There could potentially be benefit in pooling to prevent the long-distance shipping of empty containers. Automotive is not the only industry in which this issue exists. However this again leads to the issue of specialization versus communization of containers as described in section 7.4. It would also require a shared ownership across companies, invoking the type of cooperation that rarely exists within the supply chains of North American automotive OEMs. A study on intermodal shipping of ocean freight containers found that in 2000, 716,000 empty containers moved eastbound from marine terminals in the US, while at the same time 1.9 million empty containers flowed eastbound, and a significant cause of this issue was ownership mismatch.. (The Tioga Group)

7.4 Communization of Containers

As mentioned in previous sections, specialization of containers is a significant detriment to GGA being able to eliminate waste in container logistics. While GGA uses common bins and baskets for castings, forgings, and fasteners, machined parts, brake pads, rotors, and other major components used customized thermoform trays. This has been deemed as necessary in order to protect the parts from damage. These trays, rather than being customized for a certain general type of part, are specialized for a specific part number. This means they are essentially useful for one part, and are generally thrown away after the end of the life cycle of that part. Any form of communization would smooth variations in demand for any individual part number. It would also extend the useful life of the tray beyond the life cycle of the part. Finally it would allow for the potential pooling of containers between plants or even between companies as described in sections 7.2 and 7.3. The issue of common versus specialized containers is a critical issue when comparing GGA's container system to that of Ford's European business as described by Palumbo. At Ford, Palumbo was able to minimize the travel of empty containers by ensuring that empty containers moved to the nearest supplier site that demanded containers. In GGA's case where each container is limited to one supplier and one assembly site due to container specialization, this is not an option.

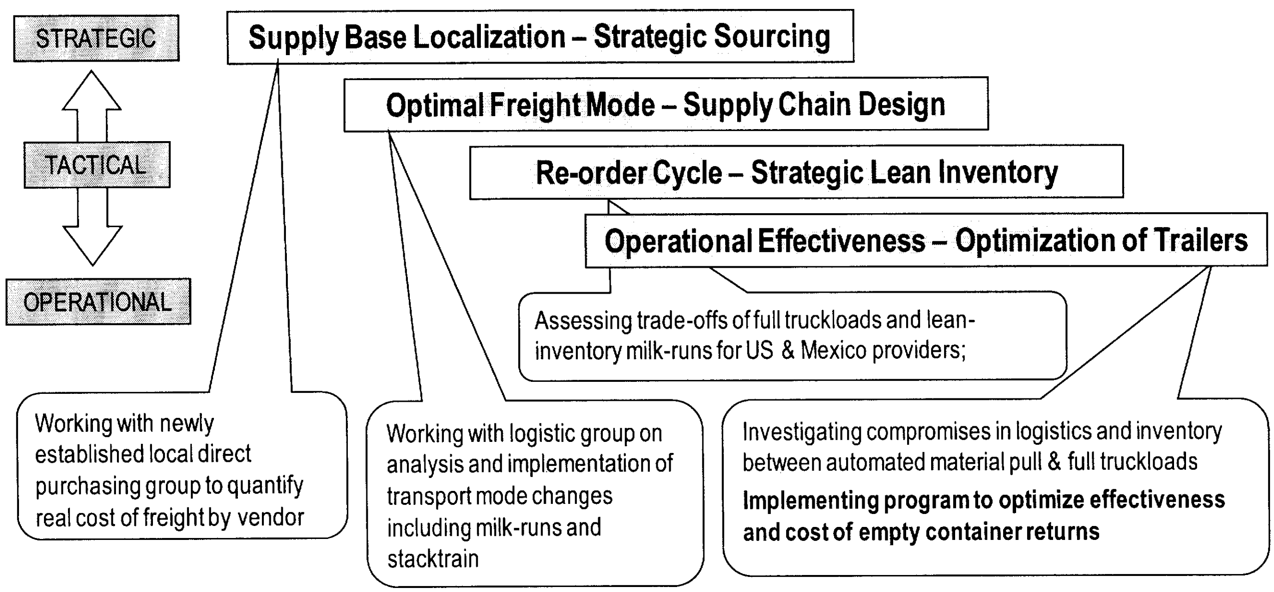
7.5 Outsourcing Container Returns Function

Most of the benchmark examples we have studied in this thesis outsource the function of container returns, including the supermarket industry and Ford's European operations. Outsourcing allows the contactor to develop economies of scale in sharing containers across plants and companies. These contractors can also develop network management and container tracking as core competencies, possibly investing in technology such as RFID chips. However, in the case of GGA, this may not be the best solution because a large and growing part of the supply base is in Mexico, and such contractors do not currently exist in Mexico. If GGA were to outsource this operation for US and Canada-based suppliers, they would still have to develop the capability for their in-country suppliers. Therefore outsourcing for only part of the supply chain does not make sense.

8. Conclusion

In looking at the GGA facility's inbound supply chain, tremendous opportunities in logistics are present. We have approached the problem from the perspective shown in the diagram below (Figure 42).

Figure 42: Diagram of Approaches to Logistics Cost at GGA



The greatest potential impact is the strategic move of supplier localization. This was judged to be out of the scope of a six-month internship focused on logistics. The more tactical and operational decisions were assessed in greater detail. The lowest level of the diagram describes the operational optimization of individual trailers. We assessed that this is where the project team could have the greatest impact, specifically with regards to container returns.

The greatest potential is in the localization of the supply base to Mexico. This would allow the supply chain to further benefit from lower labor costs, while at the same time reducing waste involved with excessive transportation and inventory within the supply chain. A key facet of the Toyota Production System is the collocation of supplier sites within the OEM supply chain. This collocation was the motivation for AAM's initial move to open GGA. However, the benefits of this move are diminished if it does not include tier two and tier three suppliers. Moving to Mexico simply allowed the OEMs to transfer the burden of managing a diffuse supply chain down to AAM. AAM needs to continue to strengthen its localization efforts in Mexico.

With regards to freight mode and delivery frequency, GGA needs to continually re-evaluate the tradeoffs between FTL (including stacktrain) and LTL (including milkrun). It is critical to continue working with the 3PL to develop capabilities of milkruns, as they are an inherently less wasteful form of transport that LTL. However, in the effort to lean the supply chain, GGA must ensure they are working towards the objective goal of minimizing landed costs. Therefore, they must make sure not to overemphasize low raw material inventories at the expense of significantly higher logistics cost. Often FTL or stacktrain is the cheapest solution despite higher inventory.

Finally, we feel that a significant opportunity exists in the planning of container returns. Due to the international nature of GGA's supply base and the lack of qualified 3rd parties in Mexico, they should maintain container returns as an in-house operation. Furthermore they should move to a planned system based on forecast container demand and optimized truck loading such as the plan we have created. Successful implementation of said plan has potential to give GGA over $600k in annual savings.

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