Optimizing the Use of Dedicated and Contract Transportation Assets to Maximize Total System Profit

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Abstract

Each week, FruitCo (FC) ships over a thousand containers of fresh fruits to its various port facilities in the US. Once the containers arrive at the port, approximately half of these containers are received by customers while the remaining half is handled by FC and delivered to customers by either a dedicated or contract carrier. For each containers delivered by FC, heuristics and cost-analysis are used to make the carrier decision. Like other shippers with multiple carrier options, FC needs to both maximize profit and preserve service quality.

FC's existing decision framework focuses on fronthaul profit for *each* delivery while its heuristics do not reflect specific service or cost strategies. Additionally, the existence of backhaul revenue, late returns of containers, limits on containers and dedicated drivers, and a variable ship arrival and departure schedule meant that existing decisions were limited in scope and rarely maximized profit for FC's delivery operations (part of port operations) as a whole.

In our thesis, we created a new decision framework to maximize FC's container operations at one of its ports, Port A (PA). We grouped containers from a single ship as an interdependent set of deliveries, forming a single cycle. Accounting for various constraints and potential backhauls, our optimization maximized the profit of a single cycle. The decisions made by the optimization achieved a weekly profit improvement of over 30% without affecting service quality. Supplementing our model, we conducted a sensitivity analysis on the number of containers and dedicated drivers to provide FC insight into its optimal asset size at PA.

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1 Introduction

FruitCo (FC) has tremendous transportation assets in both ocean and surface transportation. It currently controls nearly every step of the delivery of its produce to retailer or wholesaler. As FC move its products inbound to the United States, it arrives in FC shipping assets and in FC owned containers. As the containers arrive at its various US port facilities, the containers are either picked up by customer arranged transport or, if delivery was requested by the customer, sent by dedicated or contract carrier.

At issue are the containers that arrive at the port and are to be delivered by FC to its customers. FC is just one of many companies who rely on freight transportation to deliver their products to their customers. A common question for many companies who ship large quantities of products is whether they should manage a private or dedicated fleet, use contract carriers, or employ a mixture of the three. FC has a dedicated fleet and access to numerous contract carriers. FC's decision to use either a dedicated or contract carrier bears similarity to many corporations who employs a mixed fleet. Companies, including FC, that have to make these decisions need to compare the profit and cost, reliability, service quality and restrictions of the various options and mediate these differences to find the *best* delivery decision. What becomes of great importance then, is to assess and define what "best" is so that all decisions can be made with that consideration

Specifically, the definition and scope of cost and profit are paramount to this thesis. FC delivers to customers by individual containers. If it is a dedicated carrier delivering the container, FC controls the driver, the truck, the chassis, the container and the generator set; essentially, every piece of the vehicle (figure 1 on the next page). Upon delivery, the container is emptied and what FC is left with is a truck that can potentially pickup backhaul and, in the process, earn additional revenue for FC before the truck and chassis is due back at the port.

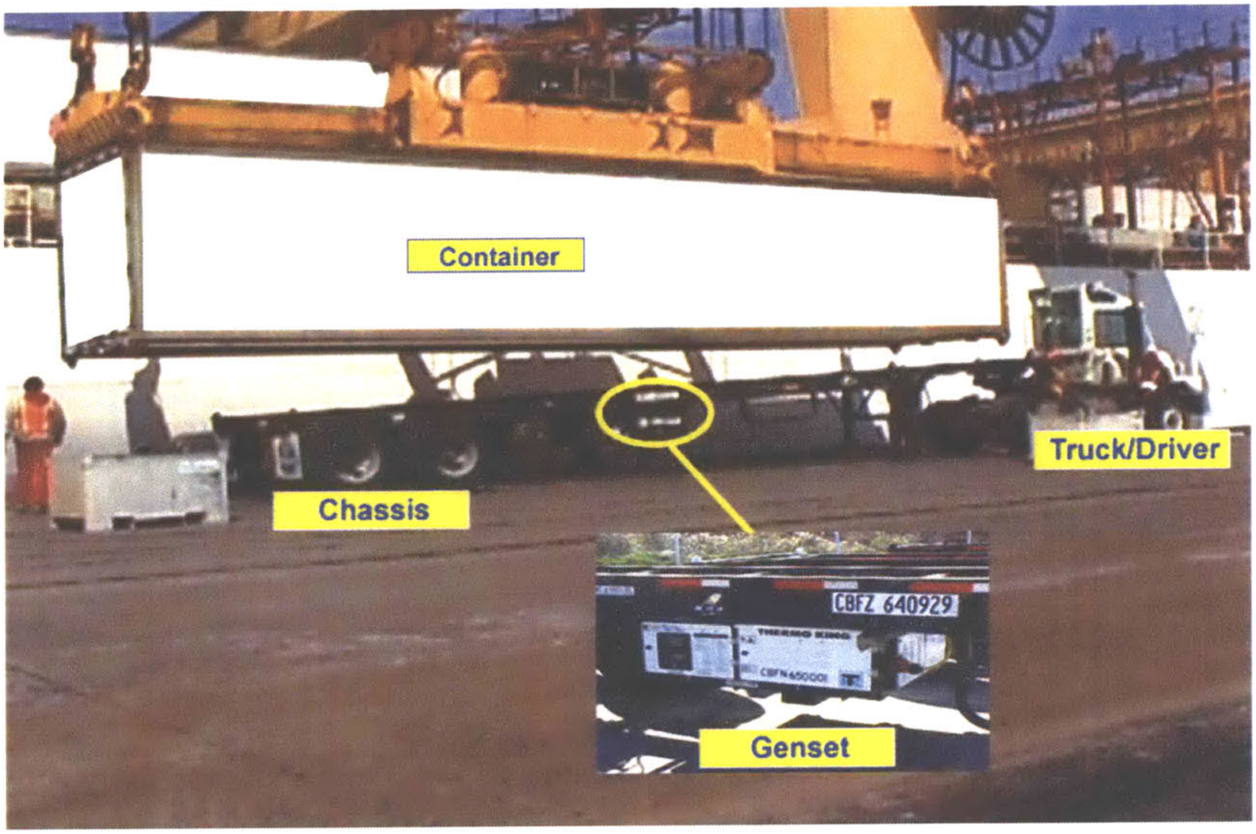


Figure 1 – Components of Carrier

This first section of the thesis serves five purposes: provide background information on the company of focus (**section 1.1**), give a background to the situation and its current issues (**section 1.2**), outline the focus of our thesis (**section 1.3**), summarize previous similar research conducted (**section 1.4**), and give an overview of the overall thesis organization (**section 1.5**).

1.1 Company Background

FruitCo (FC) is among the world's largest distributor fruits and other fresh produce. Its headquarters is based within the US and its major business lines include fresh fruits and fresh vegetables. With most products typically coming from tropical countries and with these same produce requiring worldwide distribution, FC has an extensive transportation and logistics operation. These logistics operations are most notably reflected through its ocean fleet. FC operates its own private fleet of ships as well as leasing other ships. As well, within its ship operations, it oversees all global ocean transportation and logistics of FC produce.

Because FC has ownership of its produce from production (or post-production when purchasing from third-party suppliers) all the way through to customer delivery, there is an intricate supply chain that exists that starts at the farms and ends at the customer. Once produce is collected, it is then placed in containers which are then loaded onto the various container ships destined for its worldwide ports. Upon arriving at the destination port, the containers are offloaded and await either customer arranged pickups or delivery to the actual customer. The pickup or delivery option is decided by the customer who may choose to arrange its own transport to pickup at the port (like Wal-mart) or elect to pay FC for the delivery (like Krogers).

While FC serves nearly all major international markets, Europe and North America are its two major markets; nearly a quarter of all FC produce within one of its business lines are destined for these two markets. The two markets combined form the majority of FC's revenue and profits with North America itself contributing to 30% of FC's total earnings. Figure 2 on the next page illustrates a simplified view of this supply chain.

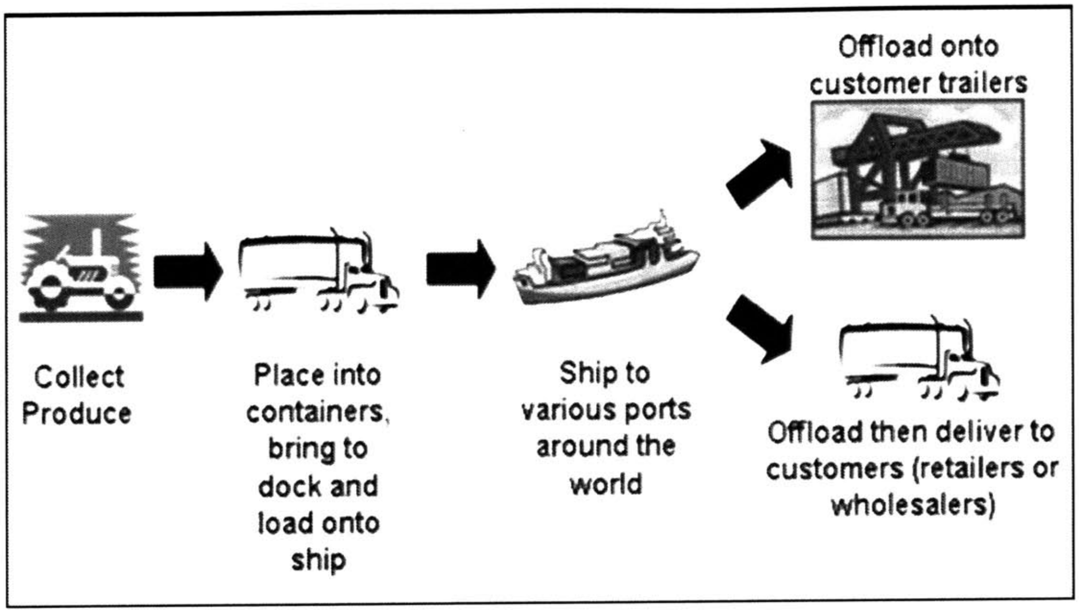


Figure 2: Logistics from Produce Collection to Customer Delivery

1.2 Current Situation & Problems

Port A (PA) is FC's biggest NA port and also the port with the lowest percentage of tendered backhaul. FC wanted to evaluate whether their existing decision methods were sufficiently capturing the full potential profit of the backhaul opportunities created by its fronthaul deliveries. The current situation for making the decision between contract and dedicated carrier is based on heuristics and a profit analysis between the two carrier options. However, the current profit analysis is a review of only the fronthaul profit and costs, and does not take into consideration the potential backhaul available to dedicated carriers on the return leg.

Port A (PA) has three ships that service it on a constant rotation (figure 3). Every week, one of these three FC ships arrive at the PA to offload approximately 475 containers of fruit which had just earlier in the week been loaded from various locations within Central America. The other two ships are either en route to Central America, picking up containers of fruit throughout various Central American ports, or en route back to PA. Once these containers are offloaded at PA, containers that just returned from last week's delivery (or sometimes the week earlier) are loaded, either empty or with international backhaul, onto the ship for delivery to Central America to continue that cycle.

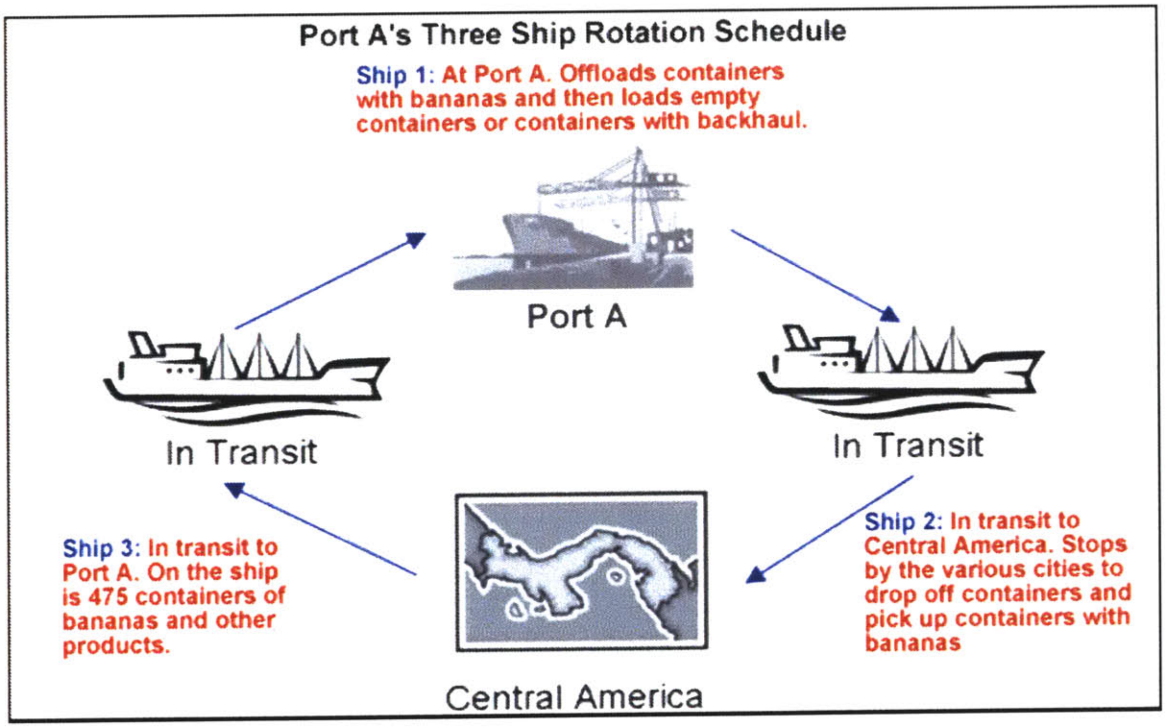


Figure 3: Port A's Three Ship Rotation

Of the containers that are offloaded at PA, approximately 50% of them are picked up by customers throughout the week directly at the port while the remainder is placed onto dedicated or contract carriers and shipped to their destinations between the time of offloading and the next ship's arrival. The destinations and delivery/pickup dates for each container is given in the delivery manifest which is available to PA staff a few days before each ship arrival. FC's current decision framework for making the dedicated versus contract carrier decision for such deliveries have been facilitated by a combination of heuristics, which were formed more on following existing decision patterns than on a specific strategy, and a profit analysis which focuses on the fronthaul leg. While these methods have aided in making more informed decisions, there were two key issues that FC recognized was not being considered.

The first issue is that the profit analysis used to make the carrier decision focuses only on the fronthaul. Currently, FC compares the cost and revenue for dedicated and contract options. However, these various costs and revenues formulations essentially ignore the possible backhaul that can be tendered for many of its routes. While FC's main priority is the fronthaul delivery of the fruit to its customers, FC's transportation assets can tender both domestic backhaul, backhaul which originates and terminates within NA, and international backhaul, backhaul which originates in NA but terminates at one of FC's Central American ports (for PA). Additionally, although not guaranteed, backhaul is significantly more profitable than fronthaul.

Although FC has heuristics and ad-hoc decisions which override the model's carrier decision - usually because FC is aware of possible backhaul - there is no clear cut backhaul calculation. This means that any decision made is a rough estimate and not a calculated decision. With backhaul profit significantly higher than fronthaul profit, FC has an incentive to capture those opportunities. Figure 4 below illustrates the current situation and both an improved and optimal method. When we consider that the profit for backhaul is significantly higher than fronthaul for a dedicated carrier, if we identify the deliveries that have the most likelihood of getting backhaul, FC can divert its dedicated assets to make these deliveries.

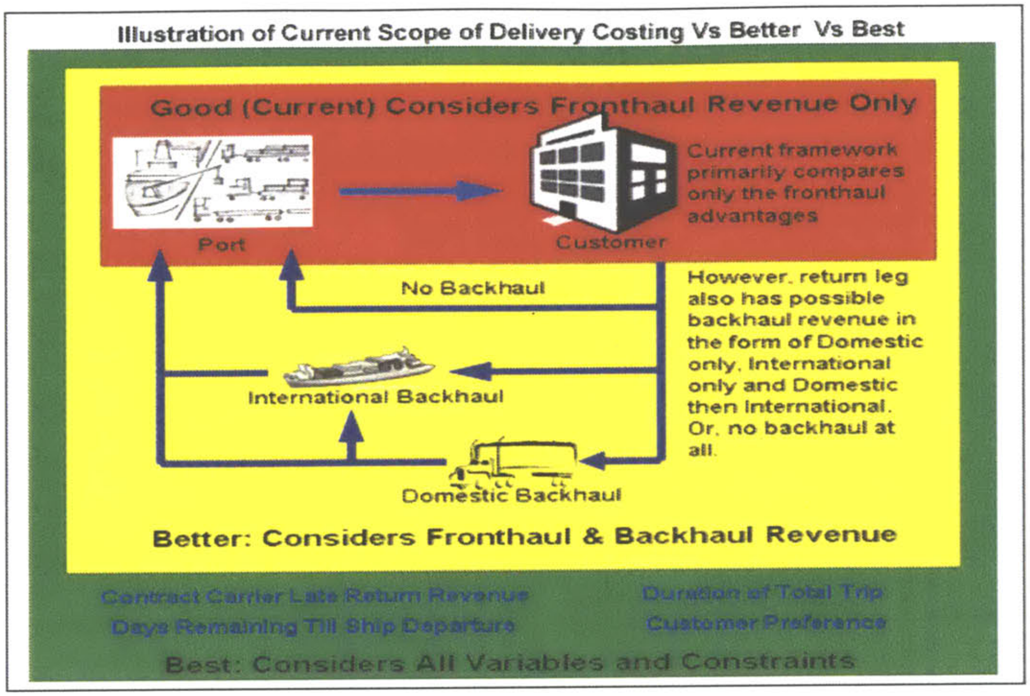


Figure 4: Current vs Better vs Best Container Costing

While the current decision methodology does not prevent FC's dedicated assets to pickup such backhaul revenue, the current method of evaluating the carrier decisions individually means that the combined decisions are likely not the optimal solution to maximize a port operations profit. If FC can evaluate the carrier decision where cost and profit are considered for fronthaul, potential domestic backhaul and potential international backhaul, then there are likely to be more profitable decisions.

The second issue is that the current decisions focus on individual container deliveries. This means that each container that is required to be delivered by FC is individually reviewed for the dedicated versus contract decision independent from the decisions made for the other deliveries. This non-linked decision format causes a problem because deliveries have different durations depending on location and there is a limit on dedicated drivers. If for example, all dedicated drivers are used in an earlier period and have still not returned, FC could potentially be forced to deliver a container using a contract carrier even though the cost advantage of using a dedicated carrier in that specific instance was of greater financial benefit than the use of a dedicated carrier for a container delivery previous to this one. Essentially, by reviewing carrier options independently for each container, FC is not using its dedicated carriers efficiently.

A simplified example of this situation is illustrated on the next page in Figure 5. In this example, there are six dedicated drivers available to serve 12 hypothetical deliveries where using a dedicated carrier has a cost advantage over contract carriers. As can be seen, the current FC framework does not optimize usage of its dedicated fleet and instead operates on a "first-come, first-serve" approach in the dispatching of its dedicated carriers. It does not factor in the potentially greater profits from serving later deliveries – in fact, the current system views a container by itself, unaware of the containers in the same time period.

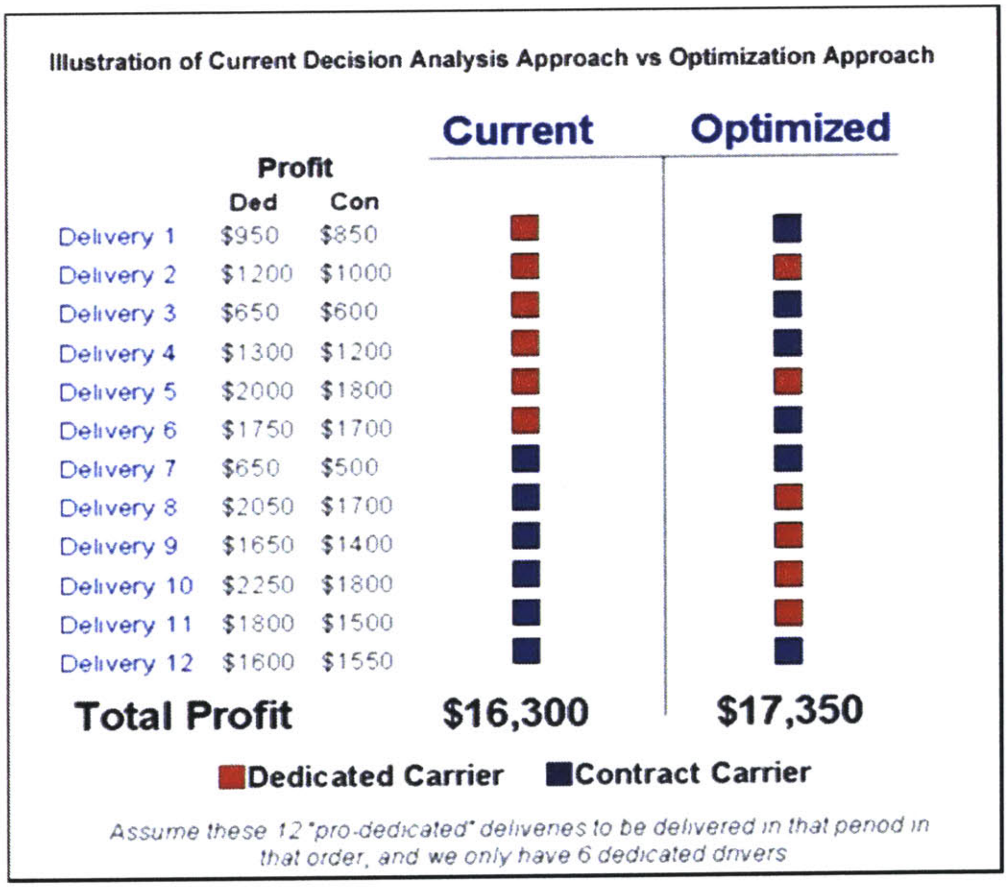


Illustration of Current Decision Analysis Approach vs Optimization Approach

	Profit		Current	Optimized
	Ded	Con		
Delivery 1	$950	$850	🟥	🟦
Delivery 2	$1200	$1000	🟥	🟥
Delivery 3	$650	$600	🟥	🟦
Delivery 4	$1300	$1200	🟥	🟦
Delivery 5	$2000	$1800	🟥	🟥
Delivery 6	$1750	$1700	🟥	🟦
Delivery 7	$650	$500	🟦	🟦
Delivery 8	$2050	$1700	🟦	🟥
Delivery 9	$1650	$1400	🟦	🟥
Delivery 10	$2250	$1800	🟦	🟥
Delivery 11	$1800	$1500	🟦	🟥
Delivery 12	$1600	$1550	🟦	🟦
Total Profit			**$16,300**	**$17,350**

🟥**Dedicated Carrier** 🟦**Contract Carrier**

Assume these 12 "pro-dedicated" deliveries to be delivered in that period in that order, and we only have 6 dedicated drivers

Figure 5: Example of Current Vs Optimized Container View

In the example above, because the current system was not designed to view all the deliveries as a single system, it dispatched all available dedicated carriers for deliveries where the dedicated option had the profit advantage in the order the delivery came - it does not take into account comparative savings. However, the Optimized methodology demonstrates that by evaluating all deliveries within a period and then dispatching dedicated drivers by ranking the profit advantage of the deliveries, FC can realize larger profits. In reality, at PA, FC has 21 dedicated drivers who can make approximately 50 – 150 deliveries a week while at least half of the weekly deliveries (~150) will have a comparative advantage in using the dedicated carrier.

In both of the above instances, FC is not maximizing its PA profits because of limited scope. The first problem was the limited fronthaul-only view of the container's cost analysis and the second problem was that containers are viewed independently.

A third issue, arisen from the first two, is containers returning to the ship empty. When the ship leaves PA, it needs to load 475 containers for shipment back to South America. Since FC has no required shipment for those containers, those containers can be used for international backhaul (IBH). However, each week up to 150 of the containers going on the ship are empty, approximately $120,000 in profit. Considering there is almost an unlimited supply of IBH nearby with two companies, PA should be capturing more of these IBH opportunities.

The focus of this thesis then is to understand and resolve the two primary obstacles. If FC can find a way to resolve the above two issues and integrate them into its container delivery decision framework, a substantial increase in operating profits for the ports that implement such a decision framework can be realized. This will arise from the chain reaction of efficiencies which will eventually lead to FC making the best carrier decision for capturing more domestic backhaul (DBH) and IBH while maintaining the service quality for its fronthaul deliveries.

1.3 Research Focus

This thesis focuses on FC's operation at Port A (PA) and the containers intended for delivery to customers. FC chose this port because the local port area offers extensive international backhaul and there is significant undeveloped domestic backhaul for the return legs of many fronthaul destinations. By creating a model that improves FC's ability to capture such backhaul opportunities, FC increases backhaul container utilization, which increases revenue without significant changes in its operating practices.

Approximately every seven days (the ship schedule is susceptible to delays, so the actual gap between one ship's arrival and the next is typically between 6 – 8 days), one of the three PA-dedicated ships arrives at PA and offloads its containers. Before the next ship's arrival, these containers of fruit are delivered to, or picked up by, the customer and returned for loading onto the ship (some containers who have to travel further are expected to return in time for the following ship's arrival). For deliveries, once the containers are emptied at the customers, there are four return paths for the container: return empty, pick up DBH, pick up IBH or pick up DBH and then IBH. For both carriers, empty containers are lost profits. For dedicated carriers, FC benefits from picking up DBH and IBH. For contract carriers, FC only benefits from IBH.

This is where PA is unique compared to other ports. PA is within two miles of companies that need Central American bound container space to ship their cars. So in addition to normal IBH (now on termed as "**Other IBH**"), which is picked up far away from PA and brought back to the port for loading, PA containers also have nearby IBH (now termed as "**Near Port IBH**") from these two shippers. International backhaul is a crucial element to this study because each filled container if IBH adds $800 or $700 in profit depending on which carrier type picked it up.

Profit-wise, the ideal situation is to be able to use a dedicated carrier for delivery, pick up DBH back en-route to PA, and pick up IBH after dropping off the DBH. This would minimize deadhead miles on its total journey. Additionally, although contract carriers do not share DBH revenue, contract carriers will reduce their fees on deliveries where they see high likelihood of obtaining DBH. With this in mind, it is evident that understanding the DBH and IBH opportunities for the different routes will allow FC to better allocate its dedicated and contract carriers, using its dedicated carriers on the routes with the highest backhaul potential. A contract carrier should be used when there is a delivery that is unlikely to tender domestic backhaul, does not have Other IBH available and cannot return in time to pick up Near Port IBH. This is because there is no potential revenue beyond the fronthaul so it makes no sense to use limited dedicated carriers.

If a framework can identify and rank the profit of the different container deliveries, then FC will know the best way to dispatch its dedicated carriers. However, constraints exist throughout the process. Backhaul is not guaranteed; while customer deliveries are known before the container ship arrives, backhaul may come as late as when a container is on its return to the port. Additionally, dedicated assets are constrained to existing agreements (currently 21 dedicated drivers and trucks), so even if costs favor one carrier type over another, FC needs to utilize its dedicated assets to maximize their worth. Furthermore, containers driven by contract carriers routinely do not return on their predetermined per diem time (the time FC allows for a contract carrier to complete the delivery and return the container to port). Many contract carriers use FC's empty containers to pickup their own backhaul, without sharing the profit, and so these containers may return late and either misses the ship or the opportunity to pick up Near Port IBH, even though it is available.

While these late returns may sometimes cause missed Near Port IBH, there are situations that exist where FC makes a larger benefit than if the container were on time. For example, a container can return beyond the per diem time but arrive back in time to pickup Near Port IBH – here FC benefits from both penalty revenue and IBH revenue. What this essentially means is that a lot of options exist, and that there is no clear cut "most profitable" decision - not if we analyze it in single pieces (as current FC practices does with evaluating only fronthaul). We need to consider revenue and costs that comes from fronthaul, backhaul, penalties and other variables.

The main focus for the thesis is to enable FC to make the dedicated-contract carrier decision with a comprehensive view of all important considerations, including the ones described previously. This goal necessitates a creation of an optimization which incorporates and prioritizes the various considerations that exist within these individual container decisions. Furthermore, while the decision framework will be optimized for PA's current and past delivery schedules, the solution will be designed with the mindset that it needs to be flexible enough to be carried over to other ports, and adaptable to integrate changes to PA characteristics.

For us to solve this, we need to define a "system" for the FC containers at PA. How can FC create a decision framework that is flexible enough to work with an uncertain ship schedule, dependant container movements, and numerous variables within individual container decisions? Can a model coordinate the use of dedicated and contract transportation decisions in order to maximize a system profit defined by that definition? In fact, how should FC even begin to define a "system?" By time periods, in days, weeks, months or years or by number of containers passing through the system or by number of ships and its associated containers? Essentially, how can we fill the gap between FC's current practice (with the two main problems of scope) and what FC's decision framework should be structured like? We know that containers are interconnected, but to what extent? By defining this system, we can then create a decision framework to capture the maximum value that is generated because we know what containers and variables are part of this system

While meeting with FC, there were also secondary issues that were raised which could help improve FC's port operations if resolved. The thesis will also address these issues in order to provide FC with a comprehensive set of tools to elevate the operations efficiency. These issues are:

- What would be the ideal number of containers and dedicated drivers?
- How can we improve or shape contract carrier behavior?
- Can we offer a set of heuristics which would expedite the dedicated/contract decision process while still taking into consideration the maximization of system profit?
- Can the model be flexible enough to adapt to different ship cycles, container counts, and backhaul probabilities?

This thesis will attempt to cover all these issues and present an optimization for FC for the main dedicated-contract decision framework, and research and suggestions for the secondary issues.

1.4 Literature Review

The issue of utilizing both dedicated and contract transportation assets for freight transportation to a customer is a common problem faced by shippers. Companies with a portfolio of private fleet, dedicated fleet and contract carriers need a method to select between them. Much of the research done on freight transportation has been on the potential cost savings within contract carriers through the bidding, contract negotiations or costing process.

Zhelev (2003) proposes a special contract carrier arrangement where the customer agrees to use a certain capacity over a certain period but have the option to pay a penalty if the customer does not use that agreed to capacity or, if it needs more than that capacity, the arrangement offers the shipper a predetermined maximum for how much extra capacity the carrier can offer. In essence, Zhelev's concept of real options for such an agreement is a hybrid carrier that is created by merging the flexibility of a contract carrier with the committed capacity resources offered by a dedicated carrier. In this type of agreement, the carrier has to commit the resources to fulfill a certain capacity. If either under-utilized or over-utilized, the shipper has to pay additional fees. However, those fees may be less inhibitive and costly than the restrictions of a dedicated carrier.

Harding (2005) suggests that instead of looking at optimization analysis or models that focus on traditional costing methods with fixed variables (such as demand figures and container capacity), delivery purchasers should also focus on the uncertainties of the economic and social environment, such as macro-economic conditions, which drive increases and decreases in container capacity. By understanding the effect of dynamic forces on the container market, a company can go beyond its company's existing decision framework for tendering a carrier and find a cost advantage that is otherwise not identified by its current costing analysis which . His research provides insight into the possible improved costing analysis a company can do when evaluating contract carriers and although FruitCo uses a mix of contract and dedicated carriers, Harding's suggestions for improving the costing analysis of contract carriers may make the decision for companies with two or more carrier options more accurate.

While the above two researchers focus on capturing more value for the shipper with contract carriers, Mulqueen (2006) looks at the growing need for a shipper to use a mix of dedicated and contract carriers. In his research, he studies the different economics involved with operating dedicated and contract carriers and considers these differences in tandem with the specific routing and load a company has. Specifically, he evaluates how managing network aggregation and lane segmentation can increase the value of using certain carriers. Mulqueen's research also concludes that using a private fleet to haul third party freight (like backhaul) has an economic benefit to the private fleet owner. Similarly, FC's hub-spoke delivery method results in significant deadhead for carriers returning to the port. FC can try to capture third party freight to realize a greater economic benefit for its dedicated fleet.

Taylor, DuCote and Whicker (2006) research the concept of regional fleets. The authors suggest that while historical methods of dispatching drivers leave the shipper and customer happy – the shipper reduces empty miles by searching for backhaul, the customer has his items picked up or delivered immediately – the driver's quality of life is affected negatively from such heavy routing. Taylor et al focus on quantifying the regional fleet concept, the idea of breaking down a large service region (such as North America) into smaller regional buckets. Taylor's research concludes that the ideal region size for each regional fleet should be a radius of approximately 300 miles. Additionally, fleets should be spread base on region and density of loads to maximize the possible loads that the fleets can capture while minimizing the need for drivers to move significantly far from its origin. While FC uses port specific fleets, the concept of regional fleets may prove useful since FC delivers throughout North America starting from its five US ports.

Central to our decision framework for FC was the construction of a mixed-integer linear program (MILP). Kallrath (2005) discusses the growing effectiveness of MILPs to solve complex supply chain problems, even in the face of uncertainty. Because MILPs are built on quantitative inputs, MILPs cope with cost issues and other intrinsically quantitative-related decisions very well. Also, the speed in which MILPs find the optimized solution(s) is such that such programs can be deployed over the web to enable more users to access to such resources for solving a variety of problem. Kallrath adds that while there is no MILP standard for addressing scheduling problems, the progress that has been made in the field of planning and scheduling is encouraging. More solutions for such issues now integrate some form of deterministic planning, and look promising in assessing different types of uncertainties in such situations.

In addition to Kallrath's research on the effectiveness of MILPs, Bausch, Brown and Ronen (1994) had observed that most research focused on cost minimization for companies who use only one type of fleet. In their research, Bausch et al focused on companies who had mixed carrier options – a private fleet and a common carrier option. With the choice of heuristics, simulation or optimization to find the ideal solution, Bausch created an optimization model to minimize costs by using Elastic Set Partitioning (ESP), an integer programming model. Bausch's findings revealed that minimized cost did not equal least traveled miles as the effects of other constraints outweighed the cost savings from traveling a shorter distance. Our model for FC shows some similarity but with additional constraints incorporated into our model to account for the variable ship schedule and the near port international backhaul unique to FC. Additionally, while Bausch's optimization requires a mainframe or a microcomputer with specialized software, our optimization will run on a personal computer with a spreadsheet add on add-on.

1.5 Thesis Organization

This thesis aims to cover four key areas relevant to our research of FruitCo's decision framework for choosing between a contract and dedicated carrier. The thesis is organized into four major sections to give the reader enough background of the situation, our solution development, our solution effectiveness and key learning from this experience. The areas are as follows:

Current Situation and Problem: Section I and II of the thesis introduces the company, the motivation for the thesis, and a background of the situation that we were to explore.

Model Development Process and Details: Primarily at the end of Section II and all of Section III, the content focuses on explaining the considerations we had in deciding our attempt to create a solution. In addition to the considerations, we concentrate on explaining the different components that form the model and how they come together to create the optimization. Finally, we also critique the model for areas to develop upon to improve the robustness of the model.

2 Research Focus

This section gives an overview of the crucial information necessary to understand the operating environment and considerations necessary to create the solution. The section begins with an overview of Port A **(section 2.1)** – FC's designated "test" port – and an overview of the various container movements that exist for the containers that offload there **(section 2.2)**. The latter half of this section moves towards FC's available data **(section 2.3)**, and our initial considerations for developing a solution **(section 2.4)**. Finally, the last part **(section 2.5)** summarizes the consideration we believed was necessary to be accounted for in the development of our solution.

2.1 Port A Characteristics

While there are more commonalities between FC's North American ports than differences, it is important to understand the unique characteristics of PA to better understand how that affects the creation of the optimization and how that optimization can then be adapted to other ports. Specifically, because the optimization is to be comprehensive and adaptive, factoring in these attributes allows us to create a more robust and thorough model.

PA's unique attributes are:

- It serves the Northeastern region of the United States, a relatively dense delivery area with many cities near the port. Many deliveries are so close that multiple trips can be completed by a driver in a single day. Alternatively, a port in the mid-west serves the mid-western United States ands covers a geographically much larger area, and less customer-dense, than PA.

- The point above is also relevant to backhaul, where picking up backhaul is likely to be closer than if the port was focused on the mid-west region, where the deliveries are more spread. This means a dedicated driver who has a backhaul opportunity is likely to have less deadhead as it travels off its return route (if necessary) to pick up, and drop off (if DBH), the load.
- It has its own dedicated ships which delivers ~475 containers of fruit a week to the port. Three ships are used in this system to continue this high quantity of weekly deliveries. While seemingly unimportant, having a dedicated ship that travels a fixed route means that FC does not have to worry about container slots allocated for certain destinations (as is the case for other ports which may share a single ship).
- While PA deliveries have domestic backhaul opportunities, FC has not aggressively pursued capturing these backhaul opportunities. Historic data shows that dedicated carriers had backhaul for only 0.5% of total deliveries. FC has indicated that it will ramp up, considerably, the amount of backhaul its dedicated carriers tender in the PA region.
- PA has a nearly unlimited supply of international backhaul within 2 miles of the port through the two nearby companies shipping cars. These two companies ship damaged cars to Central America for repair and resale. What makes this especially promising is that as long as containers are empty and come back to PA with enough time before loading onto the ship headed back to Central America, containers can be loaded with this international backhaul, regardless of whether it was a contract or dedicated carrier and pick up ~$800 profit ($700 if a contract carrier picked it up).

- Five of PA's top ten delivery destinations are not customers, but its own distribution centers (DC). What this means is that possible warehousing strategies can be deployed, as typically the customer controls the arrival date of the container to its warehouse or store. However, since FC owns its DCs, FC may be able to control the delivery schedule to free up its dedicated carriers better.

2.2 Description of Container Movement

This section explains the path of a container from the point where it is offloaded from an arriving ship (at PA) until it is loaded back onto the next ship (or the ship after) back towards Central America. The total container movement description involves five steps. These steps are: Containers Arrive at Port, Delivery or Pick-up Option, Fronthaul Delivery to Customer, Return Leg and Return to Port.

Customer Pickups are not covered in the model as FC has no control over whether the customer chooses a customer pickup, when they return and what the path of the container was from the moment it leaves the port headed to the customer and the moment it returns.

1) **Containers Arrive at Port:** Shipments are meant to come in every Tuesday, but because PA ships have multiple stops in Central America and sea travel is unpredictable, there are often delays in the system which then changes the arrival date for a ship. However, because FC has three ships in the PA system, it usually knows in advance which ships will arrive when at each stop and can mediate any customer delivery issues with this knowledge by readjusting the delivery manifest to the new arrival date. Because of

unpredictability, the FC ships arrive on Monday, Tuesday, Wednesday or Thursday. In our model and related trials, we ran only Tuesday and Wednesday arrivals – as they composed the bulk of the day-of-week arrivals. Typically if a delay of two days materializes for one week, by the next week, FC intentionally mediates the other two ship's schedules to dampen the effects of the delay and keep the three ship system running smoothly. Once that ship arrives at PA all containers are offloaded. It typically takes a full workday to offload all containers onto the port. In most cases, all containers are picked up or sent out from PA between the day it arrives and the arrival of the next ship. So, on average, the 475 containers are moved over a period of five working days (weekend excluded).

2) **Delivery or Pick-up Option**: Once a container is offloaded from the ship, there are two major options for that container to arrive at the customer. Even before the ship arrives at PA, there is a manifest detailing whether each container will be picked up or delivered. For the containers that need to be delivered, the manifest also details where the containers need to be delivered to and on which day.

    a. **Customer Pickup:** The customer arranges its own transportation to pick up the container and will return the empty container no later than the allowed per diem time. The per diem time is established based on total mileage divided by a pre-defined schedule. Approximately 120 – 200 containers are slotted for customer pick-up each week.

b. **FC Delivery:** The customer pays FC a delivery fee, and it is FC's responsibility to arrange transport (using dedicated or contract carrier) to deliver the container(s) to the respective customers at their requested times. The two options for making deliveries are:

  i. **Dedicated Carrier:** While not a private fleet in the sense that all the assets are fully owned by FC, FC has a contract with Worldwide Dedicated Services (WWDV), a subsidiary of UPS, to carry out FC's dedicated carrier deliveries. The revenues of any backhaul completed by the dedicated carrier are fully owned by FC.

  ii. **Contract Carrier:** A number of different contract carriers are used by FC to fulfill customer deliveries. Usually, specific selection is based on customer preference to a specific carrier (or its driver), or advantageous costing pertaining to that distance or locale (i.e. certain carriers will offer lower rates to regions where they can likely secure backhaul). In most cases, revenues of backhaul are not shared with FC unless special arrangements were made (exceptionally rare).

3) **Fronthaul Delivery to Customer:** For the containers that are delivered by FC every week, regardless of whether it is delivered by dedicated or contract carrier, the fronthaul journey is the same. FC needs to deliver containers to customers by certain dates. The transit time is calculated by total mileage divided by an average distance traveled per

hour (same for both dedicated and contract). Containers leave the port based on when they need to arrive at the customer.

4) **Return Leg:** Once a container arrives at its fronthaul destination (usually a retailer, wholesaler or a FC distribution center), the container is emptied of its contents and the truck and container will then have a few options on its way to returning back to the port. For contract carriers, while they may also conduct DBH with FC's containers, FC typically does not share in this revenue and is not even aware of it. For IBH however, there is a sharing of that revenue between FC and the contact carrier, if one was used in picking up that international backhaul (IBH). The six main options in the return leg are illustrated in Figure 6 below with an explanation on the following page.

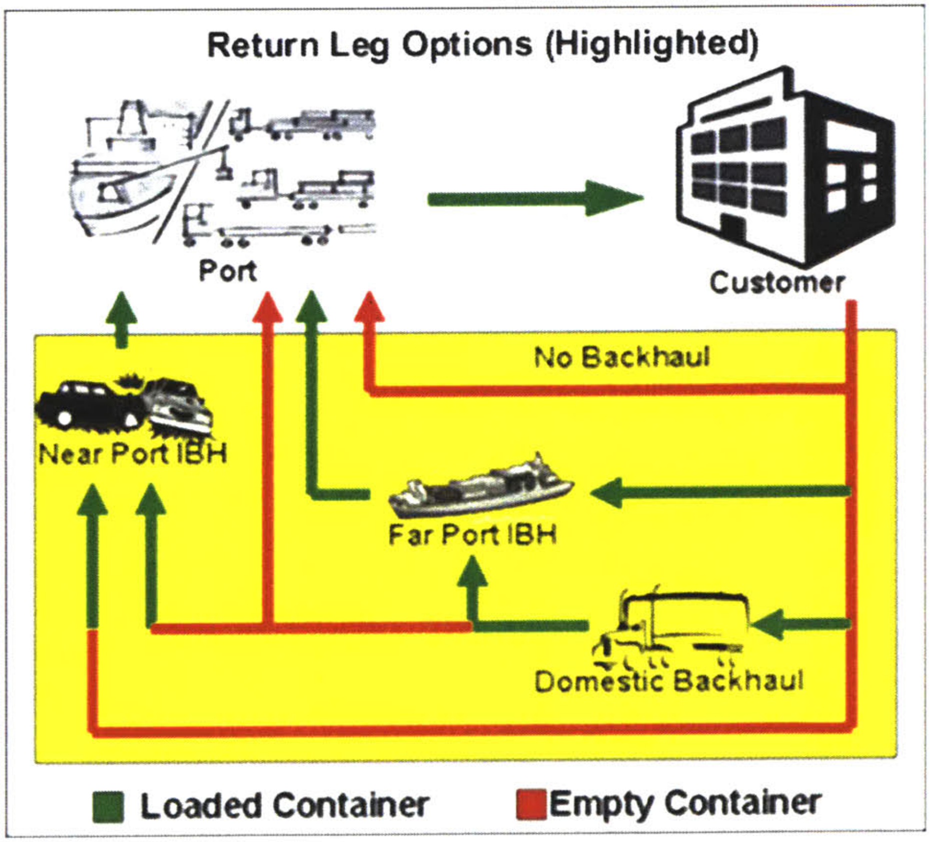


Figure 6: Illustration of Return Leg Options

a. **No Backhaul:** A returning container does not pick up any backhaul and heads back to the port empty.

b. **Domestic Backhaul Only:** On the way back to the port, the carrier picks up domestic backhaul (DBH) and drops it off to another location before the carrier arrives back to the port with an empty container.

c. **Other IBH Only:** For PA, we categorized IBH into two categories. Near Port and Other. Near Port is PA's unique supply of two customers from Near Port IBH. Other IBH is more similar to IBH at other ports where a load that is picked up within the region of the return path from the customer to the part is loaded into the container and meant to be loaded onto the ship and sent to Central America. These containers when loaded, will return to the port full, waiting for loading onto the next ship.

d. **Near Port IBH Only:** Once the container gets close to the port, it stops by *the* two customers and loads the cargo into the containers and heads back to the port as a full container awaiting loading onto the next ship.

e. **DBH and Other IBH:** This is one of two ideal situations for FC in its return routing (if a dedicated carrier is being used). On the return leg, the carrier first picks up a DBH and drops it off at another location and as it continues its journey back to the port it picks up an Other IBH and heads back to the port with a loaded container.

f. **DBH and Near Port IBH:** This is second of two ideal scenarios for all dedicated carrier routes. On the return leg, the carrier first picks up a DBH and drops it off at another location and upon arriving near the port, it picks up the Near Port IBH and then returns to the port as a full container waiting to load onto the next ship.

5) **Return to Port:** The ideal situation is that containers return to PA for their intended ship date (typically to leave on the next ship or the ship after). For each ship that arrives, 475 containers of fruit are offloaded and are to be reloaded with 475 containers for return to Central America to fill with fruit once again. Because FC does not have its own load to fill the southbound ship's containers, FC maximizes the efficiency of the trip to Central America, and improves profits, by carrying international backhaul in those empty containers to the Central America ports it otherwise would still have to dock and offload at. When containers do return to the PA, they can return late or on-time and empty or filled with international backhaul. Depending on how late they are, and the status of the containers, the profit situations changes for FC. The following are the possible combinations of container arrival statuses.

   a. **Container Returns Empty to PA**

      i. **Within Per Diem/On time for Near Port IBH/On time for Loading:** In this situation the container arrives back in the allotted time allowed for that distance, and is early enough to do a "reload." A reload is essentially a container who comes back to the port empty and is taken by a dedicated carrier to the two Near Port IBH locations to load with IBH. After the reload is completed, the container is returned to the port to await loading onto the Central America-bound ship. **Result:** IBH revenue is captured

ii. **Within Per Diem/Late for Near Port IBH/On time for Loading:** In this situation the container arrives back in the allotted time allowed for that fronthaul plus return leg distance, is early enough to load onto the next departing ship but does not have enough time to do a reload, hence it will load onto the ship empty and miss the IBH revenue. **Result:** Misses IBH revenue

iii. **Within Per Diem/Late for Loading:** This situation is where the container arrives back within the allotted time allowed for the delivery but is late enough to just miss the final loading time for the departing ship. In this case, the container can do a reload for IBH and load onto the following ship. For the ship that is leaving, because it expects to have 475 containers and this container was to be one of them, in its place, FC will load a spare container (typically empty). **Result:** Misses IBH revenue (although captured next week, this week's empty container loading onto the ship can't be recaptured)

iv. **Outside Per Diem/On time for Near Port IBH/On time for Loading:** In this situation the container arrives back outside the allotted time allowed for the delivery, however, it arrives early enough to do an IBH reload and load onto the next departing ship. **Result:** Late Fee Revenue (if using contract carrier) + IBH Revenue

v. **Outside Per Diem/Late for Near Port IBH/On time for Loading:** This situation is where a container arrives back outside the allotted time allowed for the delivery, and while still is in time for loading onto the ship, it does not have enough time to do a reload for the IBH revenue. **Result:** Late Fee Revenue (if using contract carrier) but misses IBH revenue

vi. **Outside Per Diem/Late for Loading:** This situation is where the container arrives back outside the allotted time allowed for the delivery and is late enough to miss the final loading time for the ship it was suppose to load on. In this case, the container can do a reload for IBH and load onto the following ship. For the ship that is leaving, because it expects to have 475 containers and this container was to be one of them, in its place, FC will load a spare container (typically empty). **Result:** Misses IBH revenue + Late Fee (if using contract carrier)

b. **Container Returns Full (with IBH) to PA**

   i. **Within Per Diem/On time for Loading:** In this situation the container arrives back in the allotted time allowed for that distance, and is early enough to load onto the next departing ship. **Result:** IBH revenue is captured

   ii. **Outside Per Diem/On time for Loading:** In this situation the container arrives back outside the allotted time allowed for that distance, but can still be loaded onto the next departed ship. **Result:** Late Fees (if using contract carrier) + IBH Revenue

   iii. **Outside Per Diem/Late for Loading:** In this situation the container arrives back outside the allotted time allowed for that distance and has just missed the next departing ship. In its place, the ship will load an empty container. **Result:** Late Fees + Missed IBH revenue

For returning containers, whether empty or full. The ideal situation is to have the containers filled with IBH. Additionally, if managed correctly, contract carriers can return containers late while still loading on the next departing ship with IBH. Figure 7 below is an overview of the container movement starting at the containers unloading from the vessel and its eventual return to load back onto the next container ship.

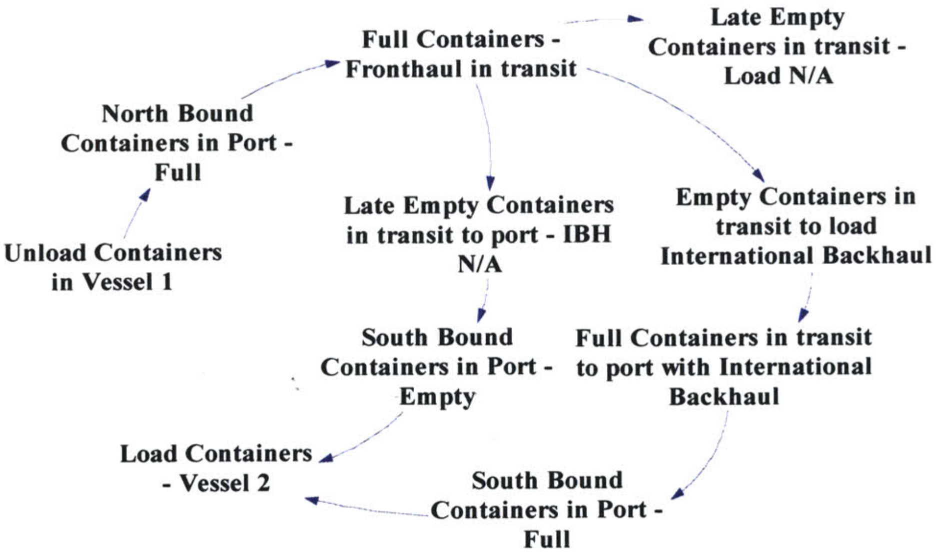


Figure 7: Container Movement Summary

2.3. Available Data & Data Analysis Tools

FC has an in-house supply chain and logistics team within its Cincinnati headquarters that oversees logistics operations for its various North American ports' operations. Extensive analysis has been done to examine the productivity of FC's assets so there is great availability of information available to conduct analysis. In this section, a brief description is given for five data and data analysis tools that were relevant in our research and eventual construction of the optimization.

1. **Company Fleet Management System (CFMS):** The CFMS is a FC owned database that is flexible enough to handle queries that can track containers by location, time period, container number or any combination of these (and more). The CFMS tracks the time a container reaches, enters, or exits a FC owned location. Each container in FC's transportation network has a unique identifying serial number, and each time a container passes through a FC location, the CFMS takes down the container number, time and location and records it as a single record with a unique movement number. The CFMS data can tell us the exact duration a container is away, from the moment it leaves the port for fronthaul delivery until it returns. By piecing it together with other available data, we would then be able to figure out the exact duration for various deliveries, not just use per diem estimates. CFMS' weakness is we can figure out the total time a container was outside the port doing fronthaul, backhaul and deadhead. However, we cannot further segment these types.

2. **Port A History (Excel Sheet):** Every container move that is tendered by FC's PA operations is recorded in the Port A History sheet (PHS). This includes fronthaul, backhaul and international backhaul legs, with each of these segments recorded as a single record (similar to that of the CFMS, but with tracking outside FC locations

when a dedicated carrier is used). Each record shows the origin, destination, distance, profit, carrier used, its completion status and the requested pickup date (typically the day the container begins its journey to the destination). The advantage of the PHS is that it shows what the CFMS doesn't; the individual segments of a journey as a carrier leaves the ports to make a delivery and comes back, possibly doing backhaul. With the PHS, an individual can calculate the exact profit of every segment and also, by identifying backhaul routes, create a plot of all backhauls and figure out backhaul dense regions. The downside of PHS is that it doesn't identify the specific container being used. So even though container A may make a fronthaul, backhaul and international backhaul move, the PHS records it as three separate records with no relation to one another. For an individual to link them together, it can only be done by best guessing based on the location of the customer, the backhaul location and the dates. Additionally, it doesn't track contract carrier moves, as contract carriers tender their own backhaul and is essentially an unknown until it returns to the port.

3. **Port A Daily Activity (Excel):** The Port A Daily Activity sheet (PDAS) gives a view of the container and chassis utilization for PA's operations. Managing the chassis and containers is crucial to the smooth running of PA's operations, if there is a shortage of containers or chassis, deliveries will be delayed. The PDAS gives a daily snapshot of where all the containers are. The possible status of a container can be "loaded on the ship", "inbound", "outbound" and "on the road", all with more specific categorizations that further segment the containers.

4. **Variable Cost Allocation (Excel):** Currently, for a delivery that does not fall into a decision defined by heuristics, staff at the PA uses a Variable Cost Allocation sheet (VCAS) to calculate the cost advantage of using either a dedicated or contract carrier. The VCAS was created by FC's in-house logistics operations and takes into account the existing fronthaul cost, and return cost (it assumes a deadhead return leg), typically calculated by adding up an upfront cost, the total mileage costs (the rate per mile times the total miles), and an accessorial amount. As billable is the same to the customer whether a contract or dedicated carrier is used, the lower cost would typically be the decision the PA staff makes when assigning a carrier. While the VCAS is accurate in assessing the fronthaul, the assumption that it returns as a deadhead fails to reflect the large profit that comes from executing backhaul opportunities. Additionally, the VCAS calculates by individual container, so staff have to mediate this by manually taking into account the upcoming deliveries and likely profit potential.

5. **Delivery Manifest:** Before the arrival of the container ship at PA, a list of containers on that ship is contained within the delivery manifest. With each container record, there is a customer pick-up or delivery designation, and the requested date of pickup or deliver-on date. This is essential to the planning FC does, as it allows PA staff to pre-plan certain route carriers based on heuristics or just "common-sense" practices if staff sees certain routes with high probability of backhaul. The delivery manifest forms the foundation of the optimization as it provides us with the required fronthaul move of every container on the arriving container ship.

2.4 Preliminary Model Considerations

As explained previously, FC's current framework for making the carrier decision is not optimizing the potential system profit. This is because of limited scope with the way it calculates a container's potential profit through the delivery and return leg, and the fact that it calculates the cost advantage of a container individually rather than as a group. Furthermore, additional constraints and variables which affect profits exist but have not been included into the arrival of these decisions.

Before we create a model that can optimize PA's fronthaul deliveries – and also be adaptable to other port's deliveries -, we have to take into consideration all the options in four key areas: Model Approach, Constraints and Variables, Incorporated Data, and System Definition. After listing all these considerations, we can then prioritize the most important aspects that should be incorporated into the model and also establish secondary requirements.

a. **Model Approach:** There were three major approaches we could approach in trying to solve this carrier decision issue. We could approach it strategically, with a view of the entire situation and offer suggestions and insights meant to improve FC's operations across a large time frame (months and years). The strategic perspective meant that our suggestions would function as guidelines, not actual actions or tools for implementation. We could also approach our solution from a tactical perspective, cutting the time-frame perspective from years or consecutive months in the strategic model, to a weekly or monthly decision. The output of such a model would be more specific and directly applicable to FC operations, with FC still retaining some control to secondary issues. The final approach option is to operate in the daily perspective.

Within this perspective, decisions are evaluated daily, and the model's output is specific and can be directly implemented into FC's operations with almost full direction controlled by the model's output.

b. **Constraints and Variables:** There are numerous variables that can be integrated into the model. However, each variable that is ultimately used in the model needs to be defined. Will some variables be fixed based on historic data? If so, how long in history should we go back (we have up to two years of PA's history and more for CFMS data)? If the variable isn't fixed and should reflect current trends, how do we eliminate certain biases? Some of the main constraints that seem to justify inclusion into the model were the fronthaul leg revenue and costs, backhaul leg revenue and cost, and probability of backhaul (both international and domestic). Additionally, less obvious but important, were customer preferences to certain carriers, probability of lateness by specific contract carriers, and the trend for domestic backhaul to increase. Aside from these, there were also container, chassis, genset, and driver limits, each of them individual variables that can be modeled into the decision.

c. **Incorporated Data:** FC has many sources of data available for its ports, PA is no exception. The question is which data is critical and necessary for the prototype optimization to be accurate. Furthermore, what data would be considered as input variables and what would be considered part of the model itself. Current available data within the CFMS and Port A History sheet have important information nested within thousands upon thousands of records. Crucial information include containers transit times, probability and length of domestic and international backhaul.

Additionally, the delivery manifest for PA will be necessary to establish the required container moves and define certain restrictions for carrier decisions.

d. **System Cycle Time Definition:** As an extension to the various approaches (strategic versus tactical versus daily), we needed to define what a system cycle was. How could we optimize the "system" if we didn't clarify what encompassed that system. Would it be measured in time, by ships arriving, by containers or by deliveries? Without that system cycle definition establishing the linked containers, it would not be possible to optimize. The question is what is the best way to define the period? Each hour? Day? Week? Month? Year? Or do we model it based on a certain number of containers moving through PA, or base it on each ship (or X number of ships) that come through to PA or by a certain number of deliveries?

For us to help FC achieve greater profits in the carrier decision process, the model had to accurately identify the related chain of events that occur between different containers and be able to identify those as a networked list of tangible constraints and input data. The four categories above have options within them which ultimately allow us to interpret FC's "system" in different ways. That system definition will ultimately control the effectiveness of the optimization in real-life application at PA.

2.5 Model Decision

The goal of the solution we were creating is that it could be used as a foundation to build a real-life decision framework for PA (and in the future, other FC ports). This solution would be the base optimization that made the first critical decision – dedicated or contract carrier. As such, the model and heuristics we were to create needed to be practical in preparation for its potential deployment to actual FC usage.

To create a relevant optimization model for FC, the following needed to be considered:

- What was the primary issue? Were there secondary issues that FC's port operations needed solved?
- What form would the solution take that would best benefit FC?
- What were all the existing and potential variables that really drove profits?
- How can we prioritize those variables best to best reflect the priority in FC's own decision-making process?
- What information would FC readily have access to make its dispatch decisions?
- How could we create the model to run quickly so that it could be used daily?
- How can we make it robust enough to go beyond PA, and work at other ports with minimal change to the base model?

It is important to remember the two biggest shortcomings of FC's existing methodology: lack of accurate revenue and costing in the individual container view, and lack of representing the inter-connectedness of how an action on one container would affect other containers' profitability. With the considerations above, and to resolve these two issues, guidelines had to be established for the model.

One of FC's driving initiatives was to build a practical tool that could help them make the carrier decision. The first question was to define the system. FC wanted useable solutions, not just guidelines, so the strategic approach was eliminated. Considering that drivers would go on deliveries that ranged from three hours to five days, the daily model couldn't encompass the changing driver availability. Because FC has the delivery manifest ahead of time for each ship, the tactical model was chosen with the system defined as each arriving ship's containers. Additionally, because not all containers return for the next departure the model has to reflect that certain containers and dedicated drivers would not be available in the following week. So, in addition to the system cycle period defining the system we also need to factor for the unavailable resources still in use for the previous cycle's deliveries.

Defining the system allowed FC to view the containers in a connected relationship. The next step was to improve FC's assessment of individual container costing. The individual container costing needed to reflect the existence of DBH and IBH, in addition to the fronthaul revenues. As well, contract penalties needs to be integrated into the profit calculation for contract carriers.

For information needs, we integrated CFMS and Port A History data for the model. The model also requires the PA delivery manifest as an input, giving us the set of fronthaul container moves. Finally, to cover the secondary issues, the Port Activity sheet was reviewed and analyzed to provide a better view of container activity.

3 Optimization Model

The goal is to create a model that will correctly make the crucial contract-dedicated decision. The challenge is how to structure the model so we can achieve this goal. This section centers on the basic concept of the model we chose to pursue **(section 3.1)**, an overview of its main components **(section 3.2)**, and a critique of the strengths and potential limitations of our model **(section 3.3)**. A detailed explanation of the build-up of the model is attached in Appendix A.

3.1 Model Overview

After taking all the potential factors (covered in **section 2.4**) into consideration, we constructed a model that was designed to maximize the total profit of a single container shipment cycle. A container shipment cycle is defined as the period between a ship's arrival and the next ship's loading. The total profit is calculated as the sum of the profit from fronthaul delivery, Near Port IBH, Other IBH, DBH, and the charges collected from contract carriers for the late arrival of containers minus the fixed weekly cost of the dedicated carrier.

The justification for optimizing a single container shipment cycle is that the entire operation cycle is in fact based on a container shipment cycle. The time between a ship's arrival at PA until the next ship's departure approximately seven days later best represents a repeating cycle. Within each cycle, containers are offloaded from the ship at arrival, delivered to customers, conduct domestic backhaul and pick up international backhaul, then load back onto the next ship. Additionally, the delivery manifest is designed around this shipment schedule and provides the fronthaul moves of all the containers. This information allows our model to calculate the probability of DBH, IBH and lateness revenue in addition to the fronthaul profits.

Within the model, instead of structuring time units by days, we fragmented the days into four units of 3 hours each. This serves two purposes. First, it represents the 12 hour work day of truck drivers from 6AM to 6PM. Second, certain total trip time (delivery and return) can be completed within three hours. If we didn't have the time partitioned into these three hour blocks, dedicated driver resources may be underestimated. For example, if we used a model with a single unit day, a driver who completed a three hour trip would be considered blocked for the entire day.

The model is composed of four parts; historical and input data, conversion of input data, optimization model, and result report. Each component is constructed in modules to insure that the model is easy to understand, robust, and able to rapidly deploy so it can be implemented for actual use. For the optimization, we used a multi-integer linear programming to create the optimization. With a tolerance of less than 0.01%, it completes the calculation quickly and accurately. Additionally, it generates a number of reports – including the carrier decision for every required container delivery – that will enable PA to operate more effectively.

3.2 Model Construction: Four-Step Process

The model we created has four major steps that take FC's current available data, to an optimized system through specific container delivery decisions. The first step is the input-data itself, taking the delivery manifest and inserting it into the model. The second step is converting that manifest into useable and appropriately structured information for the model. The third step is running the optimization as it looks for the most profitable combination of carrier choices with all the constraints involved. Finally, the last step is to interpret the results through the model's table and graph outputs.

The way the model has been constructed, the user involvement with each step, except the final results output where he needs to take the results and actually implement them to the container movements, is minimal. The model is meant to be run before the ship's arrival date. It can be run once the delivery manifest and customer pickup information is known, and the next ship's departure date is known. The next four sub-sections explain each part of the four-step optimization process in more detail, with each sub-section dedicated to each step.

3.2.1 Input data

There are two types of data related to the model; the data that is incorporated into the model which controls the variables and the data that is inserted into the model when running the optimization. This section focuses on the data that is inserted into the model for a specific optimization. The data that is incorporated into the model and forms the actual model is explained in 3.2.3, which focuses on the actual mechanics and parts of the optimization formulation itself.

There are three major pieces of required input data that is necessary to make the specific optimizations. These three inputs are the delivery manifest, the customer pickup details, and the count for dedicated carrier and containers still in use from the previous cycle (the "Tail"). In addition to these three inputs, there are also two additional inputs, grouped as "Miscellaneous Variables."

Delivery Manifest: The delivery manifest is a crucial piece of information as it contains the delivery information for the containers in the arriving ship and when these containers need to arrive at the customers. A new manifest is created for every ship that arrives, and is essentially unique each time. With the delivery manifest, we can convert that information into useful information for the model to run its optimization.

Customer Pickups: Out of the 475 containers that arrive on each ship, anywhere from 100 – 250 of the containers will be picked up by the customer directly. However, while this means that FC has no control of its domestic backhaul, FC can still load the Near Port IBH if the containers are returned in time for a "re-load" (explained in **Section 2.2**). For the re-load to happen, we need to manage dedicated drivers so that there are enough drivers to take these containers for a re-load.

Carried Over Assets (from the "Tail" Effect): Because delivery times range and are made every day between the ship's arrival until the day before the next ship's arrival, a number of deliveries made during the cycle do not complete until the beginning or middle of the next cycle. This creates a significant problem in way of dedicated driver and container availability. Figure 8 below highlights the problem of this Tail effect.

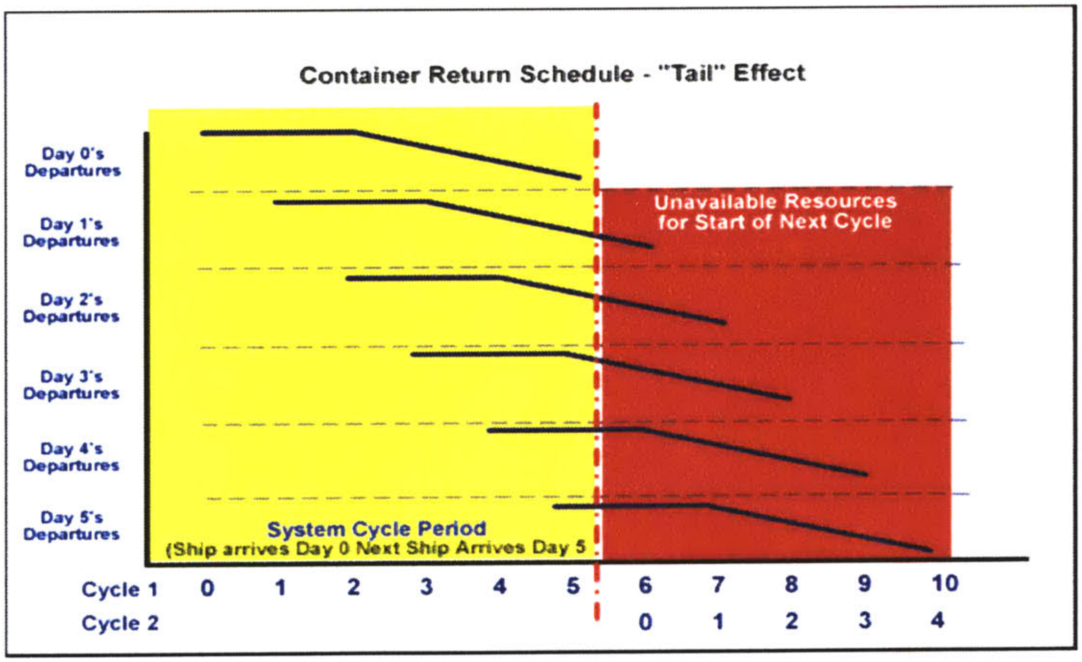


Figure 8: Container Return Schedule Highlighting the "Tail" Effect

In Figure 8, the dashed red line indicates the arrival of the next ship. As can be seen in that image (which uses a simplified view of container returns), many containers that leave later in the cycle do not return for the departure of the next ship, and, more importantly, block out dedicated drivers for the start of the next cycle. This means that even though FC has 21 dedicated drivers at PA, at the beginning of each cycle, there are likely fewer than 21 available drivers because of this tail effect. The model overcomes this by taking account of the previous cycle's duration. That duration lets us know, based on information provided by FC, the likely resource return schedule to PA, resulting in the optimization modeling the return of dedicated drivers each day of the new cycle.

The Tail effect can be addressed in two ways. If the user is running the model for the first time (with no actual data from last week), or the user just wants to model the approximate return schedule of containers, the user enters the number of days of the previous cycle's duration into the model. This will return the data provided by FC showing the typical return schedule based on the previous cycle's duration. Alternatively, if the user wants to specifically enter the tail data, he can do so by changing the specific information within the model's tables, allowing the optimization to run based on the specific return schedule based inputted.

As an extension to the conceptual illustration in exhibit 3-1, the next two pages have two tables that show actual figures based on the runs we did. The model has to take into account that some of dedicated carriers and containers are still conducting previous week's operation, thus there are constraints on the usage of total assets. If the previous week's cycle was four days, which is three days shorter than the average cycle, seven dedicated carriers and 160 containers are still occupied completing the previous cycle's operations at the first day of current cycle's operation. Table 1 shows the number of carried forward dedicated drivers while Table 2 shows the number of containers occupied in previous-cycle's operation.

Number of Carried Forward Dedicated Carriers		Number of days of previous week's vessel cycle							
		4	5	6	7	8	9	10	11
day0	6AM - 9AM	7	6	5	4	3	2	1	0
	9AM - 12AM	7	6	5	4	3	2	1	0
	12AM - 3PM	7	6	5	4	3	2	1	0
	3PM - 6PM	7	6	5	4	3	2	1	0
day1	6AM - 9AM	6	5	4	3	2	1	0	0
	9AM - 12AM	6	5	4	3	2	1	0	0
	12AM - 3PM	6	5	4	3	2	1	0	0
	3PM - 6PM	6	5	4	3	2	1	0	0
day2	6AM - 9AM	5	4	3	2	1	0	0	0
	9AM - 12AM	5	4	3	2	1	0	0	0
	12AM - 3PM	5	4	3	2	1	0	0	0
	3PM - 6PM	5	4	3	2	1	0	0	0
day3	6AM - 9AM	4	3	2	1	0	0	0	0
	9AM - 12AM	4	3	2	1	0	0	0	0
	12AM - 3PM	4	3	2	1	0	0	0	0
	3PM - 6PM	4	3	2	1	0	0	0	0
day4	6AM - 9AM	3	2	1	0	0	0	0	0
	9AM - 12AM	3	2	1	0	0	0	0	0
	12AM - 3PM	3	2	1	0	0	0	0	0
	3PM - 6PM	3	2	1	0	0	0	0	0
day5	6AM - 9AM	2	1	0	0	0	0	0	0
	9AM - 12AM	2	1	0	0	0	0	0	0
	12AM - 3PM	2	1	0	0	0	0	0	0
	3PM - 6PM	2	1	0	0	0	0	0	0
day6	6AM - 9AM	1	0	0	0	0	0	0	0
	9AM - 12AM	1	0	0	0	0	0	0	0
	12AM - 3PM	1	0	0	0	0	0	0	0
	3PM - 6PM	1	0	0	0	0	0	0	0
day7	6AM - 9AM	0	0	0	0	0	0	0	0
	9AM - 12AM	0	0	0	0	0	0	0	0
	12AM - 3PM	0	0	0	0	0	0	0	0
	3PM - 6PM	0	0	0	0	0	0	0	0

Table 1: Number of carried forward dedicated carriers

Containers Occupied in previous-cycle's operation		Number of days of previous week's vessel cycle							
		4	5	6	7	8	9	10	11
day0	6AM - 9AM	155	135	115	95	75	55	35	15
	9AM - 12AM	150	130	110	90	70	50	30	10
	12AM - 3PM	145	125	105	85	65	45	25	5
	3PM - 6PM	140	120	100	80	60	40	20	0
day1	6AM - 9AM	135	115	95	75	55	35	15	0
	9AM - 12AM	130	110	90	70	50	30	10	0
	12AM - 3PM	125	105	85	65	45	25	5	0
	3PM - 6PM	120	100	80	60	40	20	0	0
day2	6AM - 9AM	115	95	75	55	35	15	0	0
	9AM - 12AM	110	90	70	50	30	10	0	0
	12AM - 3PM	105	85	65	45	25	5	0	0
	3PM - 6PM	100	80	60	40	20	0	0	0
day3	6AM - 9AM	95	75	55	35	15	0	0	0
	9AM - 12AM	90	70	50	30	10	0	0	0
	12AM - 3PM	85	65	45	25	5	0	0	0
	3PM - 6PM	80	60	40	20	0	0	0	0
day4	6AM - 9AM	75	55	35	15	0	0	0	0
	9AM - 12AM	70	50	30	10	0	0	0	0
	12AM - 3PM	65	45	25	5	0	0	0	0
	3PM - 6PM	60	40	20	0	0	0	0	0
day5	6AM - 9AM	55	35	15	0	0	0	0	0
	9AM - 12AM	50	30	10	0	0	0	0	0
	12AM - 3PM	45	25	5	0	0	0	0	0
	3PM - 6PM	40	20	0	0	0	0	0	0
day6	6AM - 9AM	35	15	0	0	0	0	0	0
	9AM - 12AM	30	10	0	0	0	0	0	0
	12AM - 3PM	25	5	0	0	0	0	0	0
	3PM - 6PM	20	0	0	0	0	0	0	0
day7	6AM - 9AM	15	0	0	0	0	0	0	0
	9AM - 12AM	10	0	0	0	0	0	0	0
	12AM - 3PM	5	0	0	0	0	0	0	0
	3PM - 6PM	0	0	0	0	0	0	0	0

Table 2: Number of containers occupied in previous-cycle's operation.

Miscellaneous Variables: Two numbers need to be inserted into the model. The first is the departure of the next ship. This date helps the model to establish the range of days it has for the containers to return on time. The second number is the total number of "active" containers on the ship. Although there are approximately 475 containers on each ship, and most of those containers are delivered or picked up, there may be a handful of containers that are empty or non-designated and saved for backups for customers who may need additional containers of fruit. This number lets the model calculate the number of containers for delivery and customer pickup.

3.2.2 Conversion of Input Data

While the manifest gives us the foundational information we need for the optimization, the data itself is not in the needed form. Because the model is developed for potential use by FC on a weekly basis, there is a series of conversions that we have created which is initiated by pasting the shipping manifest (with customer pickups filtered out) and the remainder of the information described above. The conversion process is automatic and covers three main areas: Destination Matching, Days Remaining and Costing.

Destination Matching: With the delivery manifest pasted, the model automatically scans the records and tries to match the delivery destination to one of 15 locations. Together, these 15 locations comprise 86.5% of all deliveries (based on a review of PA's deliveries in the last year). If the fronthaul destination does not match any of these locations the model than categorizes the delivery based on the mileage. .

The assignment of containers to one of these 21 possible categories (top 10 customers + 5 distribution centers + 6 mileage categories) is for the purpose of assigning DBH, Near Port IBH and Other IBH probability. The backhaul probability was determined by three ways. The first method involved taking historical data and calculating the DBH probability for the top destinations. This was done by pairing up fronthaul trips with backhaul deliveries. The second method was information provided by FC. Because PA's backhaul is still developing, FC provided us with backhaul probabilities they intended to reach, giving the model more applicable figures when modeling for future scenarios. The third method was based on the day of the week. We realized that it is a possibility that certain days of week have more IBH and DBH opportunity, so the model gives FC the option to choose whether to use day of week or the destination to determine backhaul probability.

Because each location has a different DBH and IBH probability, it was best to give the model the flexibility to change the DBH/IBH probabilities for specific lanes. Below is the table with FC's assigned DBH and IBH probabilities. Table 3 is a snapshot of the 21 brackets and their respective IBH and DBH probability.

Top 15	Customer Description	Probability of Other IBH_Dedi	Probability of Other IBH_Contract	Probability of DBH
1	Distribution Center 1	25.0%	0%	0%
2	Distribution Center 2	0.0%	5%	20%
3	Distribution Center 3	0.0%	10%	0%
4	Customer 1	0.0%	50%	0%
5	Distribution Center 4	5.0%	15%	20%
6	Distribution Center 5	20.0%	15%	0%
7	Customer 2	25.0%	25%	0%
8	Customer 3	0.0%	0%	100%
9	Customer 4	0.0%	15%	0%
10	Customer 5	0.0%	15%	0%
11	Customer 6	0.0%	15%	0%
12	Customer 7	0.0%	15%	0%
13	Customer 8	5.0%	15%	5%
14	Customer 9	0.0%	15%	0%
15	Customer 10	0.0%	15%	0%
Mileage	M1	85.0%	10%	0%
Bracket	M2	85.0%	20%	0%
	M3	0.0%	20%	25%
	M4	0.0%	20%	25%
	M5	0.0%	20%	15%
	M6	0.0%	20%	20%

Table 3: IBH and DBH Probability

Additionally, this assignment of deliveries into these 21 brackets permits the user to input specific rules to a specific bracket. But for most uses, it is primarily to identify the various backhaul potential of the different destination and mileage brackets.

Days Remaining: The model automatically takes the date of delivery information from the delivery manifest, currently in calendar-date form, and converts it to a relative day. By backtracking the distance and the delivery date, we are able to establish which day each container leaves. With the departure from PA to the customer of each container known, we can establish the number of days remaining till the container is required to return for loading on the ship. This gap between the day of delivery and the day the next ship departs lets the model calculate which containers can capture Near Port IBH for re-loads if it were to come back empty.

Costing: The fronthaul costs that are in FC's current decision framework still exist, but it is only one part of the cost and revenue components for each container delivery. Additionally, since the delivery manifest includes the miles from PA to the customer, the model extracts the mileage and multiplies this mileage to the respective rate for both the contract and dedicated carrier to arrive at the total contract cost and the total dedicated cost. This allows the model to interpret the mileage in dollars rather than distance. Furthermore, the delivery manifest also includes the billable amount to the customer, so the model converts and outputs the profit of each option into the optimization.

Once the information in 3.2.1 is collected, the model automatically converts the above three pieces of information. This internal step converts the existing available FC information for PA to model-specific data in the correct format that facilitates the optimization to run.

3.3 MILP Model Formulation

We built an MILP (mixed-integer linear programming) model for optimization, based on the following summarized concepts. A detailed explanation of each formula is described in the next section (3.2.4)

Given:

- For each delivery lane, information regarding profit, duration, probability of domestic backhaul and probability of other IBH, for using dedicated and contract carrier is given respectively.
- Number of containers used in customer pick-ups is given.
- Number of containers and dedicated carriers used for previous week's operation is given.
- Fleet size (number of vehicles) of contract carriers is unconstrained

Find:

- Choice of using dedicated / core transportation asset for each front haul delivery and near-port international backhaul, in a single week operation cycle.

Subject To:

- Number of containers occupied cannot exceed the total number of containers
- Number of power units occupied cannot exceed the total number of power units.
- Number of containers with IBH (near port IBH and other IBH) cannot exceed fixed loading capacity of a vessel.
- Maximum number available for near port international backhaul is 20 in 3hour time unit.

- Each customer's demand must be satisfied

The mathematical model is as follows.

Index

i = set of requested front haul deliveries: {0, 1, 2, …, n}

j = set of time in days: {0.375, 0.5, 0.625, 0.75, 1.375, …, t}

(0.375 is 9AM in day 0, 0.5 for 12AM, 0.625 for 3PM, 0.75 for 6PM in day 0, and so on.)

Parameters

1) Parameters related to assets

i) Containers

C_{ld} = Number of containers loaded in a vessel

$C_{cp}(j)$ = Number of containers in used for customer pick-up in day j

$C_{fw}(j)$ = Number of carried forward containers in used for previous week's operation in day j

$C_{\max}$ = Total number of containers in a single operation cycle.

ii) Dedicated carriers

D_{total} = Number of total power units

$D_{fw}(j)$ = Number of carried forward power units in used for previous week's operation in day j

$D_{\_fh}(i,j)$ = Number of power units used for front haul in day j

$D_{\_dbh}(i,j)$ = Number of power units in used for domestic backhaul in day j

$D_{\_oibh}(i,j)$ = Number of power units in used for other IBH in day j

$D_{\_npibh}(j)$ = Number of power units in used for customer pick-up in day j

c_d = Fixed cost per power unit per week

2) Parameters related to operations

i) Front haul deliveries

$p_{d\_fh}(i)$ = Profit for i, using dedicated carrier

$p_{c\_fh}(i)$ = Profit for i, using contract carrier

$$C_{d\_fh}(i,j) = \begin{cases} 1, & \text{if container is used for } i \text{ in day } j \text{, with dedicated carrier} \\ 0, & \text{if not used} \end{cases}$$

$$C_{c\_fh}(i,j) = \begin{cases} 1, & \text{if container is used for } i \text{ in day } j \text{, with contract carrier} \\ 0, & \text{if not used} \end{cases}$$

w = percentage of late containers in deliveries made by contract carriers

y = late container charge to contract carriers

ii) Domestic backhauls

p_{d_dbh} = Average profit for domestic backhaul using dedicated carrier

$r(i)$ = Probability of domestic backhaul for a given front haul delivery i

$$C_{dbh(i,j)} = \begin{cases} r_i, & \text{if container is used for domestic backhaul after } i \text{ in day } j \\ 0, & \text{if not used} \end{cases}$$

iii) Other international backhauls

p_{d_oibh} = Average profit for other IBH using dedicated carrier

p_{c_oibh} = Average profit for other IBH using contract carrier

$q_d(i)$ = Probability of other IBH for a given i, using dedicated carrier

$q_c(i)$ = Probability of other IBH for a given i, using contract carrier

$$C_{d\_oibh}(i,j) = \begin{cases} q_d(i), & \text{if used for other IBH after } i \text{ in day } j \text{, with dedicated carrier} \\ 0, & \text{if not used} \end{cases}$$

$$C_{c\_oibh}(i,j) = \begin{cases} q_c(i), & \text{if used for other IBH after } i \text{ in day } j \text{, with contract carrier} \\ 0, & \text{if not used} \end{cases}$$

iv) Near port international backhauls

p_{d_npibh} = Average profit for near port IBH using dedicated carrier

p_{c_npibh} = Average profit for near port IBH using contract carrier

$C_{d\_npibh}(j)$ = Number of containers used for near port IBH using dedicated carrier

, in day j

$C_{c\_npibh}(j)$ = Number of containers used for near port IBH using contract carrier, in day j

S = Maximum number of near port IBH available in a time unit.

Variables

$$B_d(i) = \begin{cases} 1, & \text{if using dedicated carrier for } i \\ 0, & \text{if using contract carrier for } i \end{cases}$$

$$B_c(i) = \begin{cases} 1, & \text{if using contract carrier for } i \\ 0, & \text{if using dedicated carrier for } i \end{cases}$$

$I_d(j)$ = Number of near port IBH completed using dedicated carrier in day j

$I_c(j)$ = Number of near port IBH completed using contract carrier in day j

$I_d(j), I_c(j) \geq 0$, integer $\forall j$

Objective function

Maximize:

$$\sum_{i=1}^{n}\left[\left\{p_{d\_fh}(i)+p_{d\_dbh}(i)\cdot r(i)+p_{d\_oibh}\cdot q_{\_d}(i)\right\}B_{\_d}(i)\right]$$

$$+\sum_{i=1}^{n}\left[\left\{p_{c\_fh}(i)+p_{c\_oibh}\cdot q_{\_d}(i)\right\}B_{\_c}(i)\right]$$

$$+\sum_{j=0.375}^{t}\left\{p_{d\_npibh}\cdot I_{d}(j)+p_{c\_npibh}\cdot I_{c}(j)\right\}$$

$$+\sum_{i=1}^{n}\left\{B_{\_c}(i)\cdot w\cdot y\right\}\ -D_{total}\cdot c_{d} \tag{1.1}$$

Constraints

Subject to:

$$\begin{aligned}&\sum_{i=1}^{n}\left\{C_{d\_fh}(i,j)+C_{c\_fh}(i,j)+C_{d\_dbh}(i,j)+C_{d\_oibh}(i,j)+C_{c\_oibh}(i,j)\right\}\\&+C_{d\_npibh}(j)+C_{c\_npibh}(j)\quad\le\quad C_{ld}+C_{fw}(j)-C_{cp}(j)\ ,\quad\forall\, j(\le t)\end{aligned} \tag{1.2}$$

$$\sum_{i=1}^{n}\left\{D_{\_fh}(i,j)+D_{\_dbh}(i,j)+D_{\_oibh}(i,j)\right\}+D_{\_npibh}(j)\ \le\ D_{total}-D_{fw}(j)\ ,\quad\forall\, j(\le t) \tag{1.3}$$

$$\sum_{j=1}^{t}\left\{I_{d}(j)+I_{c}(j)\right\}\ \le\ C_{ld} \tag{1.4}$$

$$I_d(j) + I_c(j) \le S, \quad \forall j(\le t) \tag{1.5}$$

$$B_{\_d}(i) + B_{\_c}(i) = 1 \tag{1.6}$$

3.4 Explanation of the MILP Model

The optimization can be run once the input is in (as the data is automatically converted). It is important to understand what composes the internal components that make the optimization run. The best way to approach this explanation is to break up the optimization into four parts, with each part focusing on one aspect of the model construction and optimization procedure. In this subsection, we will explain each of the following areas in the listed order: Objective Function, Decision Variables, Constraints and Logical Structure

1) Objective function

Maximize:

$$\sum_{i=1}^{n} \left[\left\{ p_{d\_fh}(i) + p_{d\_dbh}(i) \cdot r(i) + p_{d\_oibh} \cdot q_{\_d}(i) \right\} B_{\_d}(i) \right]$$

$$+ \sum_{i=1}^{n} \left[\left\{ p_{c\_fh}(i) + p_{c\_oibh} \cdot q_{\_d}(i) \right\} B_{\_c}(i) \right]$$

$$+ \sum_{j=0.375}^{t} \left\{ p_{d\_npibh} \cdot I_d(j) + p_{c\_npibh} \cdot I_c(j) \right\}$$

$$+ \sum_{i=1}^{n} \left\{ B_{\_c}(i) \cdot w \cdot y \right\} - D_{total} \cdot c_d \tag{1.1}$$

The objective function expressed in (1.1) is defined as the total profit of FC's operation at the Port A in a given cycle. Revenue is generated from the following five sources from each container.

Total Profit =

+ Fronthaul Delivery profit + Near Port IBH profit

+ Other IBH profit + DBH Profit

+ Per diem charge collected for late containers (contract carriers only)

- Fixed cost of dedicated power units

Fronthaul delivery: FC delivers goods based on the manifest and earns a fixed billable amount to the customer for each delivery. Because the cost structure is different, shorter routes tend to favor dedicated assets while longer routes may favor contract carriers. Short routes favor dedicated carriers because there is usually a surcharge associated with each delivery for a contract carrier, and for short distances, it is increases the average cost per mile. Fronthaul profit is calculated by taking the billable minus the total fronthaul cost for the respective carrier type (mileage times the cost per mile).

Fronthaul Profit = $\sum$ profit of each fronthaul delivery

Near Port International Backhaul: The two nearby car shipping customers (Exhibit 3-5) are the sources of Near Port IBH. Both IBH customers are located within 2 miles from PA and fill FC containers with used cars destined for Central America. The average profit per Near Port IBH is $800 for a dedicated carrier and $700 for core carrier (FC has a special arrangement with certain contract carriers where the contract carrier will go to either of the two customers and pick up the IBH). The duration to make the IBH pickup is only three hours. Even if a container comes back empty, if it has time before loading onto the departing ship, it will be sent back out to pick up this Near Port IBH.

Customer	% in total IBH delivery	Distance from Wilmington Port
Customer A	44%	<2 miles
Customer B	16%	<2 miles

Table 4: Two major sources of international backhaul deliveries

The model assumes that the latest time for a container to be back to port to conduct Near Port IBH is 3 PM before the day before the next ship's departure, which is 18 hours before the departure of the vessel, 9AM the day after. Also, in any given 3-hour time bracket, 20 loads are the maximum available IBH that can be picked up by the combined IBH customers due to capacity constrains from the customers.

Near Port IBH Profit =

= avg profit per dedi_IBH delivery × number of IBH delivery by dedicated carrier

+ avg profit per core_IBH delivery × number of IBH delivery by core carrier

= $800 × number of IBH dedi_delivery + $700 × number of IBH core_delivery

Other International Backhaul: Other IBH comprises 25% of total international backhauls. The model assumes that availability of far-from-port international backhaul for a certain delivery is a probability based on that lane's location or history of picking up Other IBH. The model assumes Other IBH increases the return leg duration by 12 hours and generates an average profit of $300 for dedicated carriers and, for contract carriers, Other IBH increases the return journey time by 15 hours and earns approximately $250.

Other IBH Profit =

$= \sum \text{avg profit per other IBH delivery\_dedi} \times \text{probability of other IBH for each lane}$

$+ \sum \text{avg profit per other IBH delivery\_core} \times \text{probability of other IBH for each lane}$

$= \$300 \times \sum \text{probability of other IBH for each lane\_dedi}$

$+ \$250 \times \sum \text{probability of other IBH for each lane\_dedi}$

Domestic Backhaul: Currently, domestic backhaul at PA currently comprises only 0.5% of the total number of container deliveries (which means for ever 1000 container deliveries, only 5 pick up DBH. However, FC has a plan to increase PA's domestic backhaul operations by increasing their aggressiveness in looking for DBH customers on their deliveries' return leg. Regardless of the exact state of DBH, the optimization model considers the effect of domestic backhauls, since the percentage of domestic backhauls in other ports is much higher and we realize for this model to be portable to other ports and for it to adapt to PA's growing DBH revenue, the DBH profit component needs to be integrated into the model. Within the model, the DBH component allows the user to increase or decrease the probability figure for DBH, thus changing the optimization as that figure changes. In the model, only dedicated carriers are conducting DBH as contract carriers, even if they do conduct DBH, do not disclose the usage of the container beyond the fronthaul delivery for FC.

Domestic Backhaul Profit =

$$= \sum \text{avg profit per DBH delivery} \times \text{probability of DBH for each lane}$$

$$= \sum \$400 \times \text{probability of DBH for each lane}$$

Per Diem Charge (contract carriers only): If the actual delivery date of containers is later than the date specified on the contract, they are charged by given penalty rate. Currently, 10% of containers are late. (We will further discuss the impact of increasing the charge in part 5.2 Secondary issues on contract penalty rates.) The model assumes that there is no container delivered back after fourth day, thus all late containers charge $50.

Range of lateness	Charge
First through the Third Day	$ 50
Forth through the Sixth Day	$ 75
Seventh day and thereafter	$ 100

Table 5: Per Diem charge for core carriers

Per Diem Charge Profit =

= Number of front haul delivery by core carriers × lateness × charge per late container

= Number of front haul delivery by core carriers × 10% × \$50

Fixed Cost: The fixed cost is the yearly cost of the dedicated carrier contract divided by 52 weeks to reflect the weekly cost – which is the closest to reflect a single cycle period. That figure is then added to miscellaneous weekly costs for dedicated carriers that might arise.

2) Decision Variables

$$B_d(i) = \begin{cases} 1, & \text{if using dedicated carrier for } i \\ 0, & \text{if using contract carrier for } i \end{cases}$$

$$B_c(i) = \begin{cases} 1, & \text{if using contract carrier for } i \\ 0, & \text{if using dedicated carrier for } i \end{cases}$$

$I_d(j)$ = Number of near port IBH completed using dedicated carrier in day j

$I_c(j)$ = Number of near port IBH completed using contract carrier in day j

$I_d(j), I_c(j) \geq 0$, integer $\forall j$

The main "output" of the optimization is to tell the user which carrier to use for every single delivery. FC either uses a dedicated carrier or a contract carrier. There are 690 decision variables in which 626 of those are the binary decision variables for the container carrier decision. The remaining 64 integer variables are created by segmenting the days into 3 hour units (total of four time segments a day) and then multiplying that by the option to use both dedicated and contract carriers (four time units a day of 3 hours each X 8 days X both dedicated and contract carrier). These are the time segments that are allocated for Near Port IBH. Since the optimization makes the decision for when the dedicated carrier should pick up the Near Port IBH, it also needs to choose the best time for the carrier to make that pick up, and it needs a way to assign the driver to make the pick up at a certain time.

When we tried to use Excel's built-in functions to run the optimization, Excel failed to do so as the decision variables exceeded 100; instead, we used an Excel plug-in called "*What's Best*" by *Lindo System Inc.* *What's Best* can complete a linear optimization with up to 800 integer variables.

3) Constraints

There are five types of constraints in the optimization model expressed as following. These constraints ensure both that the model does not overextend resources that are not available and does not create and account for more revenue than possible.

1) Constraints on the number of Containers

$$\begin{aligned}&\sum_{i=1}^{n}\left\{C_{d\_fh}(i,j)+C_{c\_fh}(i,j)+C_{d\_dbh}(i,j)+C_{d\_oibh}(i,j)+C_{c\_oibh}(i,j)\right\}\\&+C_{d\_npibh}(j)+C_{c\_npibh}(j) \quad \le \quad C_{ld}+C_{fw}(j)-C_{cp}(j)\,, \quad \forall\, j(\le t) \qquad (1.2)\end{aligned}$$

Constraint (1.2) states that the number of containers occupied cannot exceed the total number of containers. The maximum number of containers operating in one cycle is calculated as the sum of the containers loaded from the vessel plus the containers carried forward from the previous week's operation (the containers that returned late or left late and would not return for the soonest departing ship). In this case, the maximum number of occupied containers is 615 since 475 containers are being unloaded and 140 containers are carried forward. Each container must be categorized in one of four statuses. First, it could be considered as in the port waiting to be picked up or in transit for any type of delivery with exception to Near Port IBH. Second, it can be considered in transit for Near Port IBH. Third, a container can be slotted for a customer pickup, in which case, only until it returns to the port does the status possibly change to another status. Lastly, the container might still be completing a movement from the previous cycle. The sum of the containers from the above four statuses should be less than or equal to the maximum container number of 615.

2) Constraints on the number of dedicated carriers

$$\sum_{i=1}^{n}\left\{D_{\_fh}(i,j)+D_{\_dbh}(i,j)+D_{\_oibh}(i,j)\right\}+D_{\_npibh}(j) \;\leq\; D_{total}-D_{fw}(j)\,, \quad \forall j(\leq t) \tag{1.3}$$

Constraint (1.3) indicates that the number of containers occupied cannot exceed the total number of dedicated carriers (or power units). The number of dedicated carriers available for the current operation cycle is determined by the total dedicated carrier fleet size minus the still-in-use dedicated carriers from the previous cycle's deliveries. Currently, the number of total dedicated power units is fixed as 21, and the carried forward usage pattern is assumed as function of previous week's length of cycle. For example, the operation cycle of the week before the Feb 15 was five days, resulting in six dedicated carriers that were unavailable at the beginning of the new cycle as they were still completing the previous cycle's delivery. Each dedicated carrier that is occupied by a previous cycle's delivery reduces the total available dedicated carriers by one until that dedicated carrier returns to port. So, if we look at the chart below, from day 6 and beyond we have full access to the 21 dedicated carriers. Following is the snap shot of the dedicated carried constraints of the model.

3) Constraints on the number of IBH containers

$$\sum_{j=1}^{t} \{I_d(j) + I_c(j)\} \le C_{ld} \qquad (1.4)$$

Constraint (1.4) says that number of containers with IBH (near port IBH and other IBH) cannot exceed fixed loading capacity of a vessel. While the total containers in movement can be 615 because of the offloading 475 containers plus the containers from the previous cycle, there can only be a total of 475 containers loaded back onto the ship. So, there is a constraint for the total containers holding IBH to be no more than 475. While in reality, there can be more than 475 containers with IBH at PA (they can be held for the following ship), the way the current model is developed requires that this constraint be inputted.

4) Constraints on the supply of near port IBH

$$I_d(j) + I_c(j) \leq S, \quad \forall j(\leq t) \tag{1.5}$$

Constraint (1.5) states that in any given 3-hour time unit, no more than 20 containers can be filled at the combined two customers (*both nearby the Port*). This has to do with physical constraints on the land for the container to sit in, and resources to load the used cars in.

5) Constraints on the binary variables for front haul delivery

$$B_{\_d}(i) + B_{\_c}(i) = 1 \tag{1.6}$$

Constraint (1.6) indicates that loads are picked up once and only once.

3.5 Output of the Model

For this model to be effective, not only do the results need to be accurate, but the information must be presented in a clear and easy to understand format. There are two types of information for the user to review: Actual Vs Model Comparisons and Carrier Decision Implementation Information.

1) Actual Vs Model Comparisons: This model was developed with the intention that its decisions would optimize the system cycle better than the existing combination of heuristics and profit analysis. As such, there are three sheets within the model that concentrate on these side by side comparisons. In order to create the "Actual" results, the user has to manually enter the decisions by FC to produce the results to compare to. In the future, as an extension to the model, it is possible to create an optimization that runs based on the current heuristics. The three sheets that focus on comparing the actual results to the model's optimized results are sheets "Profit analysis", "Container status analysis", and "Dispatch date distribution analysis" in the excel file, which are explained in Sec 4.2.

i. Profit Analysis: While the sheet is quite straightforward, as all the information sources themselves from the various parts of the model, the most important information is the bar graph at the end of the sheet. The bar graph shows the relative profit of both the actual and model across the different components (Front haul, Near Port IBH, Other IBH,). We did not compare the profit from domestic backhauls and charges from late contract carriers since the actual profit from these components were hard to track, and also considered insignificant since these comprise less than 1% of the total profit.

ii. Container status analysis: This is a table, and accompanying graph, that shows container status and is a good indication of how well containers are taking IBH. In fact, the table and graph shows the containers in one of seven statuses. Containers could be 1) at the port waiting to be picked up, 2) picked up by the customer directly, 3) carried forward from previous week's operation, 4) in transit conducting front haul delivery, 5) in transit doing domestic backhaul, 6) arrived to the port filled with other IBH goods, or 7) arrived in the port filled with near port IBH goods. As the week progresses, containers with IBH will gradually increase, while returns from previous cycle and in transit will decrease to reflect the return of containers with IBH.

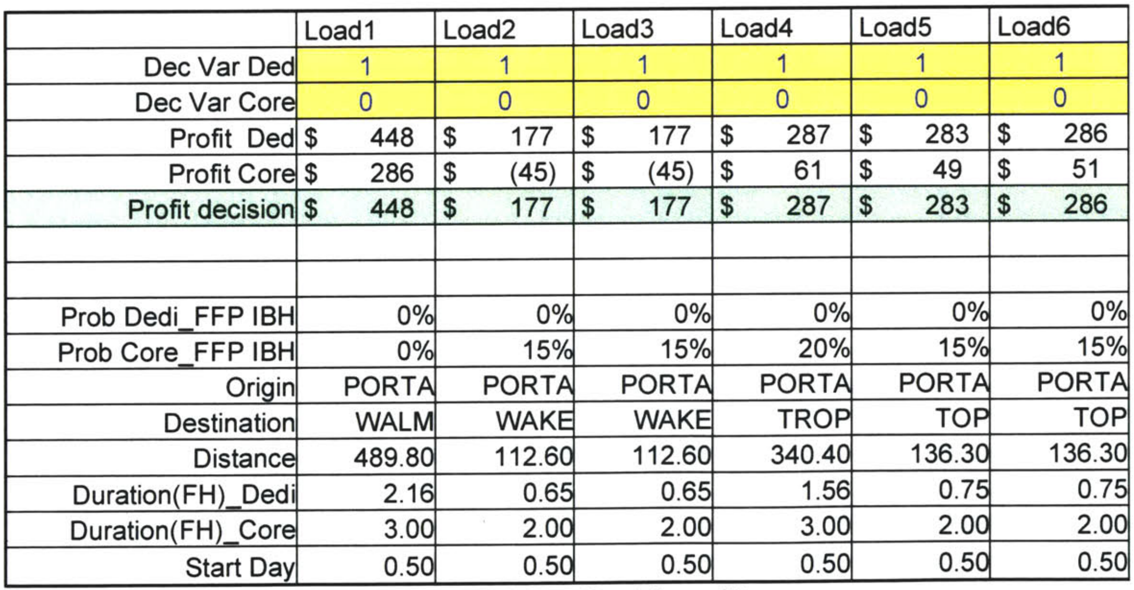
iii. Dispatch date distribution analysis: Two sheets are created for the analysis; one for front haul analysis, the other for near port IBH analysis. The former sheet gives the user a look at how the front haul carrier decisions were distributed between dedicated and contract carrier for each day of the cycle. There is a difference between actual and model distribution because the model is trying to give dedicated carriers the routes with the most chance for near port IBH. There are two graphs, one is the actual distribution and the other is the model distribution. The graph provides a quick visual of possible major differences between actual decisions and model decisions. If the graphs of the actual and model are very similar, it means that the actual decisions in that cycle were close to the optimal decisions; the more alike the graphs are, the more close to optimal the actual decisions were.

Similar to the front haul distribution sheet, the near port IBH sheet focuses on showing the distribution of near port IBH by days and by carrier type. By having a bar graph for both the actual and model results, it provides the user with a visual comparison between the two different decision strategies.

2) Carrier Decision Analysis: The most important information for the user is which carrier type to use with each container delivery, and whether that decision is correct. There are only two steps to ensure that if this model were to be implemented that it is the optimized solution. The first is to confirm that the optimization is creating the best combination of decisions, and the second is simply to take the sheet with the lanes, and follow it for the appropriate delivery.

i. Confirming the Optimization: The first sheet of the model "WB! Status" is a summary of *What's Best* run. The important thing to note here is that it shows *Globally Optimal* in the status row. Globally Optimal will show if the model is left to run to completion and has exhausted all possibilities. Alternatively, if the user wishes for a quicker solution, he can interrupt the run and it will provide a solution status within 5 minutes that is "feasible" which is still very close to the optimal solution, within 0.05% of tolerance level.

ii. Viewing the Decisions: The optimization has been designed to automatically change the cells under each lane in the "1. Model" sheet. The decision has been designed to be binary, and summing to 1, therefore, each lane will either go dedicated or contract. The one that is selected will have a "1" in its cell, the other a "0." Below is Table 4, a snapshot of a small part of that sheet, showing the critical cells with the decision.



	Load1	Load2	Load3	Load4	Load5	Load6
Dec Var Ded	1	1	1	1	1	1
Dec Var Core	0	0	0	0	0	0
Profit Ded	$ 448	$ 177	$ 177	$ 287	$ 283	$ 286
Profit Core	$ 286	$ (45)	$ (45)	$ 61	$ 49	$ 51
Profit decision	$ 448	$ 177	$ 177	$ 287	$ 283	$ 286
Prob Dedi_FFP IBH	0%	0%	0%	0%	0%	0%
Prob Core_FFP IBH	0%	15%	15%	20%	15%	15%
Origin	PORTA	PORTA	PORTA	PORTA	PORTA	PORTA
Destination	WALM	WAKE	WAKE	TROP	TOP	TOP
Distance	489.80	112.60	112.60	340.40	136.30	136.30
Duration(FH)_Dedi	2.16	0.65	0.65	1.56	0.75	0.75
Duration(FH)_Core	3.00	2.00	2.00	3.00	2.00	2.00
Start Day	0.50	0.50	0.50	0.50	0.50	0.50

Table 6: Snapshot of Lane Decisions Sheet

3.4 Model Critique

While the model was created to be robust and adaptable to other FC ports, we also realize that there may be areas where the model can be improved upon. These are the major areas where we feel the current model has not been fully developed upon.

Approximated Data: Many of the inputs into the model were based on the averaging of historical data. One question to consider is how far should we go in history when using such data? Additionally, how can we better segment the data to avoid considering distinct groups of data as a single group? Essentially, how can we get better input for our model's base assumptions?

Continuous Timeline (Hours): The current model breaks down each day into four units of three hours each. While this allows for a fairly accurate optimization, if we can bring it closer to real-time (such as 15-minute time brackets), the optimization will be able to create more profit by synchronizing activities and carriers to a higher degree.

Continuous Cycle: The current optimization runs by individual cycle. We know that in any cycle, deliveries that leave later in the week may not always return by the end of the cycle, thus, affecting the next cycle. The way we have modeled these depleted resources is to have a "tail" add-on in the model to compensate for carriers that are still being utilized from the previous cycle, however, that return schedule is approximated. If we can create a model that runs continuously, and uses the previous week's output to feed into the coming cycle (along with our inputted delivery manifest), then the optimization will be more accurate.

Calculating Profit: While we have secured many of the revenue drivers for both carrier types, there are associated costs in operating dedicated and contract fleets that have not been integrated into the model. By having a clearer picture of the total costs involved in its container delivery operations, we can achieve more accurate figures. These figures can than be used for more in-depth analysis with actual historical figures.

Non-Conforming Rules: At current, a carrier decision may be chosen because the customer has a preference to a certain carrier or its driver. This means that some lanes, even if it makes sense to use a dedicated carrier, will use a specific contract carrier because of the customer's request. The model assumes that no such preferences exist, with the goal only to make the best mathematical decision for each lane. If these preferences must be accounted for, the model will need to be designed to identify these special preferences while giving the flexibility to assign them to the applicable lanes.

4 Results & Analysis

Three optimizations were run in our model using past delivery manifests from three different system cycles. In this section, we review and explain the results we received from running optimizations on these three sets of data. The first part **(section 4.1)** gives background to the three sets of data we used, while the second and third subsections **(section 4.2 and 4.3)** center around the results and preliminary analysis from the respective runs. Afterwards, we outline the key insights (**section 4.4**) from the combined results. Finally, the last section **(section 4.5)** addresses the potential profit increases by adjusting our container count and dedicated carrier constraints.

4.1 Explanation of Primary and Validation Data

The best way to measure the effectiveness of our model is to compare the profits achieved by the model's decisions to the actual profits achieved in those same periods. To make sure the two sets of figures are comparable, we took the profits from the same components when we could; front haul, other IBH, near Port.

We did a total of four runs, with one run acting as the sample run and the remaining three serving as validations to our findings. Section 4.2 provides a detailed view of the side by side results in all the major output information offered by the model of the sample run's performance versus the actual performance in that same period. Section 4.3 compares the three additional runs' performances with their respective actual cycle performance. The three additional runs function as validation, to ensure that the profit earnings captured by using the model is consistent and tangible.

It is also important to note the cycle periods we used as tests. We took the delivery manifest and customer pickup count for four different weeks, and took the actual profit from those weeks by taking FC earnings data and running our model to assess the model's profit. Below table is a summary of the data we used for the four runs.

Run	Dates (all in 2006)	Previous week's operation cycle(day)	Number of required fronthaul deliveries	Total containers offloaded	Total containers capturing IBH
Primary	Feb 15~23	6	313	475	456
Validation 1	Jan 11~18	7	249	475	176
Validation 2	Mar 22~29	7	282	475	335
Validation 3	Mar 31~Jun 7	7	278	475	334

Table 7: Description of the Runs

Run	Actual Profit	Model Profit	Increased by(%)	Actual Fronthaul Dedicated	Model Fronthaul Dedicated	Actual NP IBH Dedicated	Model NP IBH Contract
Primary	218,686	360,833	65.0%	93	89	129	403
Validation 1	151,511	396,713	161.8%	100	67	77	401
Validation 2	137,744	457,766	232.3%	92	62	113	436
Validation 3	142,994	401,985	181.1%	80	52	63	454

Table 8: Results of the Runs

Primary Run (Cycle Period February 15 – February 23 2006): When we were searching for a cycle to use as a test period we believed it was important to find the weeks where IBH was captured the highest. This is because IBH drives profits greatly, and if we could show that our model still improves upon one of

FC's top performing weeks under its current decision framework, it would indicate that the model, if applied at PA, will consistently reap higher profits. We eventually selected the cycle for the ship that arrived to PA on Feb 15, 2006. The reason why we chose this cycle was because in the next departing ship, it had very few empty containers. It is important to understand that within Wilmington's past two years worth of cycles, this February 15 – 23 period is among its best performing periods.

Validation Run 1 (Cycle Period Jan 11 – Jan18 2006): This cycle period is one of three periods selected to validate the findings from the primary run. We expect the profit improvement (when comparing the model's optimization to the actual performance) from this run to be higher than the Feb 15-23 cycle because this validation cycle was chosen at random while the Feb 15-23 cycle was specifically chosen because it represented a high-profit, high-performing cycle for FC's existing methodology.

Validation Run 2 (Cycle Period Mar 22 – Mar 29 2006): This cycle period is the second of three periods selected to validate our findings from the primary run. Similar to the other validation run, we expect the profit improvement (when comparing the model's optimization to the actual performance) from this run to be higher than the Feb 15-23 cycle.

Validation Run 3 (Cycle Period Mar 31 – Jun 7, 2006): This cycle period is the third of three periods selected to validate our findings from the primary run.

4.2 Primary Run Results & Analysis

To test the effectiveness of the model's decision, we used the delivery manifest from one of FC's best cycle performances, from February 15 – 23, 2006, to run in our optimization. This allowed us to do a comparison between the actual results and the model's results. The model increased the total profit by 65%, or $142,147, versus the actual profits. Three reports are generated from the model, which describe the improvements in operational efficiencies and increase in total profit. First is the report focuses on the profits on front haul deliveries, near port IBH, and other IBH. Second is the container status report, which shows the status of containers at each time unit starting from day 0 until day of departure. Finally, the third report compares the distribution patterns of carrier dispatch, in both day and carrier type, for both fronthaul deliveries and Near Port IBH.

1) Profit Analysis

The model generates a report that analyzes profit from front haul profit, Near Port IBH, and Other IBH based on both the actual data and the model's output. Below figure 9 gives a visual side by side comparison of the profit in each revenue component while the table 7 shows the actual figures for comparison. As can be seen, the model positions the containers to pickup Near Port IBH at a much higher frequency than what is currently being executed by FC. The result shows that even though the model's profit in four components was lower than the actual's, the influence Near Port IBH has on earnings (the only component where the model's profit was higher than actual's) brought up total earnings beyond what the actual performance could achieve. In fact, the net effect of the model for this run was an increase in total profit by $142,147, or 65%, of actual total profit. The optimization model increased the number of Near Port IBH because it has both a higher margin and less delivery time versus any other profit-generating option.

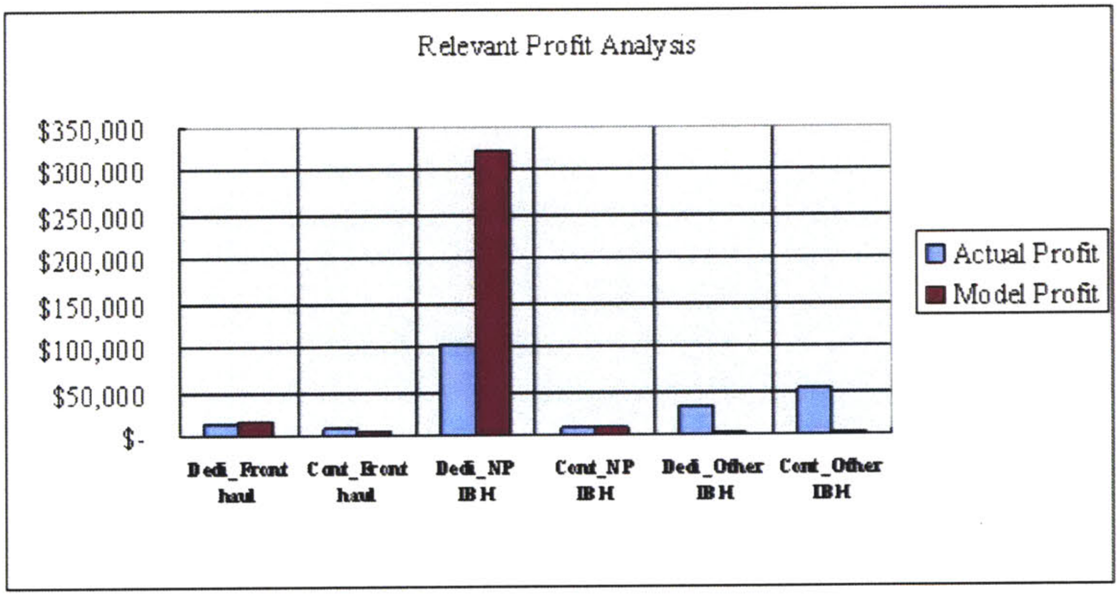


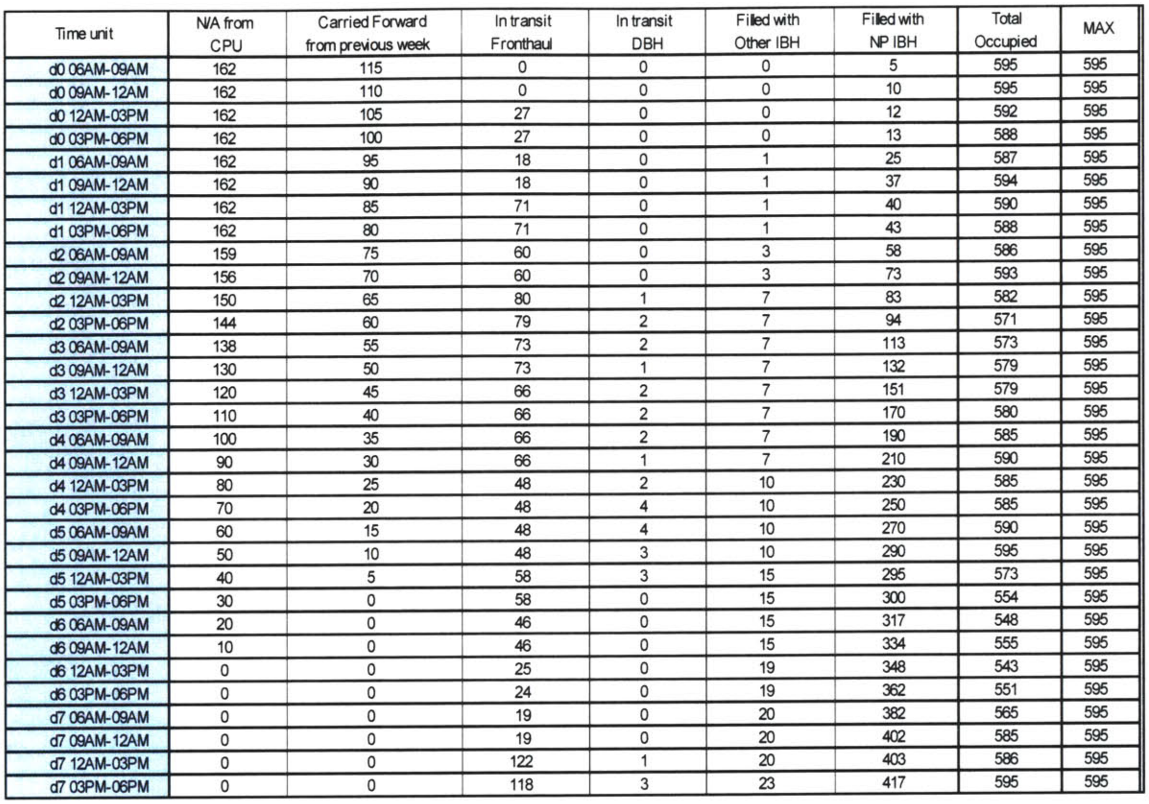
Figure 9: Profit Analysis (Feb 15 - 23)

	Actual Profit	Model Profit	Profits Increase by	% increase
Dedi_Front haul	$ 14,342	$ 16,734	$ 2,392	17%
Cont_Front haul	$ 8,644	$ 5,893	$ (2,751)	-32%
Dedi_NP IBH	$ 103,200	$ 322,400	$ 219,200	212%
Cont_NP IBH	$ 8,400	$ 9,800	$ 1,400	17%
Dedi_Other IBH	$ 32,100	$ 1,680	$ (30,420)	-95%
Cont_Other IBH	$ 52,000	$ 4,325	$ (47,675)	-92%
Total	$ 218,686	$ 360,833	$ 142,147	65%

Table 9: Profit Analysis (Feb 15 - 23)

2) Container Analysis

The container analysis gives the user a quick snapshot of where all the containers are during the entire cycle period. Below table 10 shows the output sheet.



Time unit	N/A from CPU	Carried Forward from previous week	In transit Fronthaul	In transit DBH	Filled with Other IBH	Filled with NP IBH	Total Occupied	MAX
d0 06AM-09AM	162	115	0	0	0	5	595	595
d0 09AM-12AM	162	110	0	0	0	10	595	595
d0 12AM-03PM	162	105	27	0	0	12	592	595
d0 03PM-06PM	162	100	27	0	0	13	588	595
d1 06AM-09AM	162	95	18	0	1	25	587	595
d1 09AM-12AM	162	90	18	0	1	37	594	595
d1 12AM-03PM	162	85	71	0	1	40	590	595
d1 03PM-06PM	162	80	71	0	1	43	588	595
d2 06AM-09AM	159	75	60	0	3	58	586	595
d2 09AM-12AM	156	70	60	0	3	73	593	595
d2 12AM-03PM	150	65	80	1	7	83	582	595
d2 03PM-06PM	144	60	79	2	7	94	571	595
d3 06AM-09AM	138	55	73	2	7	113	573	595
d3 09AM-12AM	130	50	73	1	7	132	579	595
d3 12AM-03PM	120	45	66	2	7	151	579	595
d3 03PM-06PM	110	40	66	2	7	170	580	595
d4 06AM-09AM	100	35	66	2	7	190	585	595
d4 09AM-12AM	90	30	66	1	7	210	590	595
d4 12AM-03PM	80	25	48	2	10	230	585	595
d4 03PM-06PM	70	20	48	4	10	250	585	595
d5 06AM-09AM	60	15	48	4	10	270	590	595
d5 09AM-12AM	50	10	48	3	10	290	595	595
d5 12AM-03PM	40	5	58	3	15	295	573	595
d5 03PM-06PM	30	0	58	0	15	300	554	595
d6 06AM-09AM	20	0	46	0	15	317	548	595
d6 09AM-12AM	10	0	46	0	15	334	555	595
d6 12AM-03PM	0	0	25	0	19	348	543	595
d6 03PM-06PM	0	0	24	0	19	362	551	595
d7 06AM-09AM	0	0	19	0	20	382	565	595
d7 09AM-12AM	0	0	19	0	20	402	585	595
d7 12AM-03PM	0	0	122	1	20	403	586	595
d7 03PM-06PM	0	0	118	3	23	417	595	595

Table 10: Container Status Analysis (Feb 15 - 23)

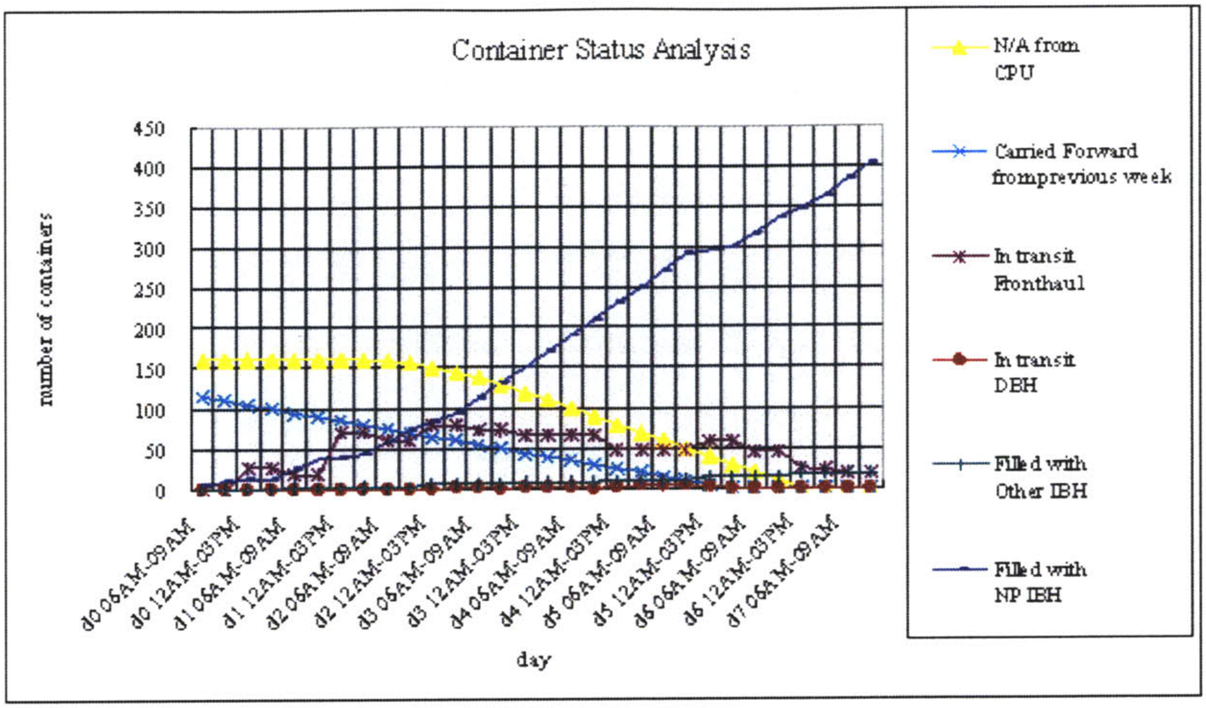


Figure 10: Container Status Analysis (Feb 15 - 23)

Figure 10 visualizes the data from Table 10. Two points can be seen from this chart. Firstly, the number of containers in the port waiting to be picked up decreases in a step-function. This is because the model is assuming that all the containers for fronthaul delivery are picked up at noon of the pickup day. Secondly, and more important, while containers with DBH and Other IBH doesn't vary significantly, containers filled with Near Port IBH is increasing continuously. At the end of day 7, the number of containers filled in near port IBH is 417, comprising 95% of total IBH. This result suggests that since the profit earned by conducting Near Port IBH is higher than the profit of any other single operation, for both dedicated and contract carriers, the model is trying to maximize the total profit by maximizing the number of Near Port IBH. Also, we can expect that as number of containers arriving back from customer pickups or from previous week's operations, it increases the number of free containers, thus increasing the number of near port international backhauls.

3) Carrier Dispatch Date Analysis

An analysis is made for both fronthaul and Near Port IBH container utilization.

Front haul: As can be seen in the two exhibits below, there are differences between the model's dispatch pattern and the actual dispatch patterns. Chi-tests are conducted to measure the significance of the difference. Null hypothesis is set as 'There is not much difference between the two sets of data in 90% significance level'. P-value was only 0.0017 for dedicated carriers, which rejects the null hypothesis, meaning that there are significant differences between two sets of data. The comparative dispatch of dedicated drivers are increased by up to 400% in day 4 and decreased by 50% in day 6. For contract carrier distribution, p-value was 0.16, indicating that there is no significance difference between actual data and model result. Additionally, 89 dedicated carriers are used while 93 are used in actual data. This is because the model saves the dedicated carriers to make the Near Port IBH pickups, which earn more profit.

Dispatch Date	Dedi_Model	%	Core_Model	%	Dedi_Actual	%	Core_Actual	%
0	14	4.5%	13	4.2%	11	3.5%	16	5.1%
1	9	2.9%	46	14.7%	13	4.2%	42	13.4%
2	6	1.9%	38	12.1%	11	3.5%	33	10.5%
3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5	16	5.1%	21	6.7%	4	1.3%	33	10.5%
6	3	1.0%	3	1.0%	3	1.0%	3	1.0%
7	20	6.4%	87	27.8%	32	10.2%	75	24.0%
8	21	6.7%	16	5.1%	19	6.1%	18	5.8%
sub total	89	28.4%	224	71.6%	93	29.7%	220	70.3%
Total	313				313			

Table 11: Front haul Carrier Dispatch Date Analysis (Feb 15 - 23)

Near Port IBH: Both p-value for dedicated and contract carriers are 0, saying that there are significant differences. In this instance, the raw data showed that almost all the Near

Port IBH was dispatched on day 5. The way the model picks up Near Port IBH is much more efficient as it spreads the pick ups throughout the entire cycle (likely aided by the constraint of total number of Near Port IBH that can be loaded in any block of three hours). Additionally, the model minimizes the usage contract carrier for picking up Near Port IBH because contract carriers result in less profit. The only time where it is used substantially is on day 7, the deadline for Near Port IBH to return to the port. This is when the model makes a decision that it does not have the dedicated carriers to pick up the IBH so must use a contract carrier, and make slightly less, instead of loading an empty container onto the ship.

Dispatch Date	Dedi_Model	%	Core_Model	%	Dedi_Actual	%	Core_Actual	%
0	13	3.1%	0	0.0%	0	0.0%	2	1.4%
1	30	7.2%	0	0.0%	2	1.4%	1	0.7%
2	51	12.2%	0	0.0%	0	0.0%	7	5.0%
3	76	18.2%	0	0.0%	0	0.0%	1	0.7%
4	80	19.2%	0	0.0%	0	0.0%	0	0.0%
5	50	12.0%	0	0.0%	120	85.1%	1	0.7%
6	62	14.9%	0	0.0%	0	0.0%	0	0.0%
7	41	9.8%	14	3.4%	7	5.0%	0	0.0%
Sub total	403	96.6%	14	3.4%	129	91.5%	12	8.5%
Total	417				141			

Table 12: Near Port IBH Carrier Dispatch Date Analysis (Feb 15 ~ 23)

The results demonstrate that the model is working correctly. This is indicated not only by the consistent and substantial increased profit but by the logic in which it uses the dedicated carriers. If we consider the dedicated carrier usage for fronthaul deliveries versus the usage for Near Port IBH pickups, the model has reduced its dedicated carrier usage in the fronthaul leg in order to pick up more Near Port IBH. This makes sense because while using a dedicated carrier might have a relatively small profit advantage over using a contract carrier in the fronthaul leg, a fronthaul leg can take anywhere from three hours to five days. However, if a dedicated carrier was allocated to an IBH pickup, it would take approximately two hours with a profit $800 each time. Likely, the optimization shifts to contract pick up of Near Port IBH once it reaches a balance point where there is no more availability of dedicated carriers.

4.3 Validation Results & Analysis

Three additional cycles were inputted into our model to validate our profit improvement from the primary run. We expected the profit improvements from these runs to be higher than the primary run (Feb 15 – 23 cycle) because that cycle was specifically identified as among the PA's best cycle performances.

Validation Run 1: Jan 11 ~ 18, 2006

Profit Change: $245,201.62 (162% improvement)

Type of Operation	Actual Profit	Model Profit	Profits Increase by	% increase
Dedi_Front haul	$ 16,902.82	$ 16,108.17	$ (794.65)	-5%
Cont_Front haul	$ (4,591.93)	$ 794.35	$ 5,386.28	117%
Dedi_NP IBH	$ 96,800.00	$ 348,800.00	$ 252,000.00	260%
Cont_NP IBH	$ 9,800.00	$ 24,500.00	$ 14,700.00	150%
Dedi_Other IBH	$ 12,600.00	$ 1,635.00	$ (10,965.00)	-87%
Cont_Other IBH	$ 20,000.00	$ 4,875.00	$ (15,125.00)	-76%
Total	$ 151,510.89	$ 396,712.52	$ 245,201.63	162%

Table 13: Profit Analysis (Jan 11 ~ 18)

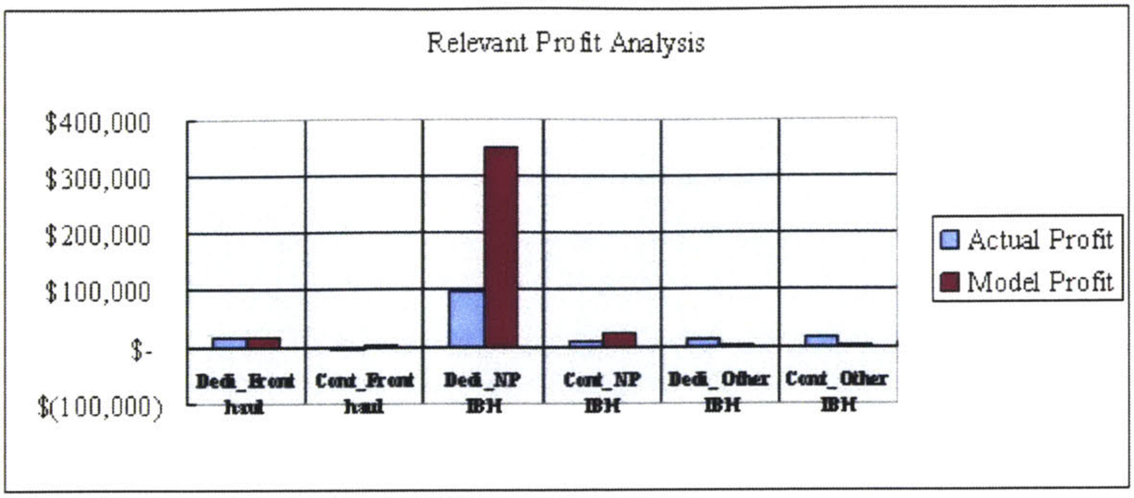


Figure 11: Profit Analysis (Jan 11 ~ 18)

Validation Run 2: Mar 22 ~ 29, 2006

Profit Change: $320,022.44 (232% improvement)

Type of operation	Actual Profit	Model Profit	Profits Increase by	% increase
Dedi_Front haul	$ 14,376.49	$ 30,005.80	$ 15,629.30	109%
Cont_Front haul	$ (22,532.49)	$ 975.65	$ 23,508.13	-104%
Dedi_NP IBH	$ 61,600.00	$ 417,600.00	$ 356,000.00	578%
Cont_NP IBH	$ 9,800.00	$ 1,400.00	$ (8,400.00)	-86%
Dedi_Other IBH	$ 40,500.00	$ 6,660.00	$ (33,840.00)	-84%
Cont_Other IBH	$ 34,000.00	$ 1,125.00	$ (32,875.00)	-97%
Total	$ 137,744.01	$ 457,766.44	$ 320,022.44	232%

Table 14: Profit Analysis (Mar 22 ~ 29)

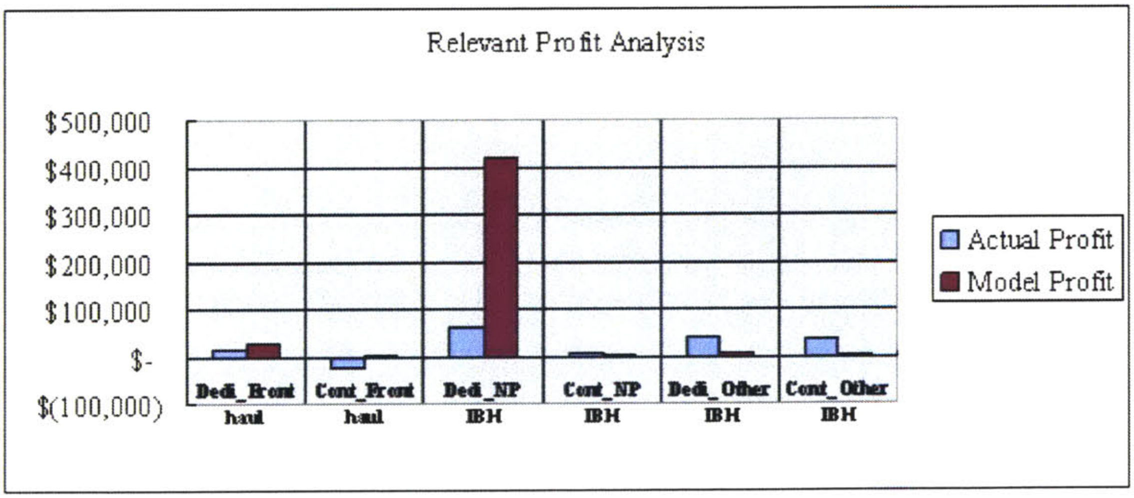


Figure 12: Profit Analysis (Mar 22 ~ 29)

Validation Run 3: May 31 ~ June 7, 2006

Profit Change: $258,990.79 (182% improvement)

Type of operation	Actual Profit	Model Profit	Profits Increase by	% increase
Dedi_Front haul	$ 13,467.74	$ 12,158.27	$ (1,309.46)	-10%
Cont_Front haul	$ 2,176.45	$ (2,233.29)	$ (4,409.75)	-203%
Dedi_NP IBH	$ 51,200.00	$ 363,200.00	$ 312,000.00	609%
Cont_NP IBH	$ 9,100.00	$ 21,700.00	$ 12,600.00	138%
Dedi_Other IBH	$ 12,300.00	$ 1,035.00	$ (11,265.00)	-92%
Cont_Other IBH	$ 54,750.00	$ 6,125.00	$ (48,625.00)	-89%
Total	$ 142,994.19	$ 401,984.98	$ 258,990.79	181%

Table 13: Profit Analysis (May 31 ~ June 7)

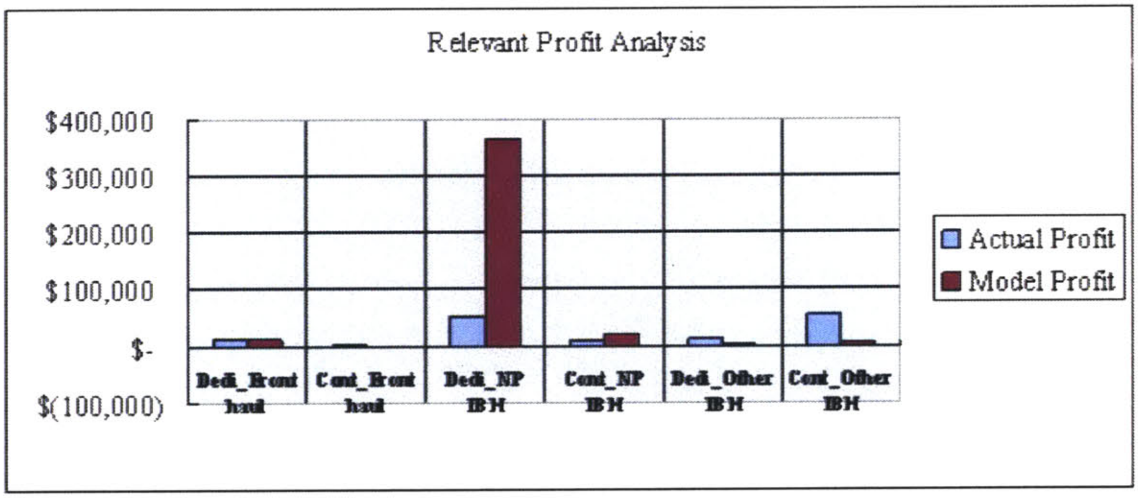


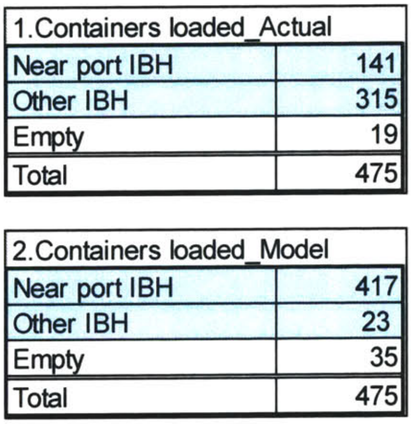
Figure 15: Profit Analysis (May 31 ~ June 7)

The results from all three runs confirm the same findings from the primary run. Once again, the model sacrifices dedicated carrier profits in the smaller (by profit) components that a carrier can complete, and diverts the dedicated carriers to pick up Near Port IBH. As such, we saw profit increases of 162%, 232%, and 182% - significant increases in profit.

4.4 Insights of Results

Reviewing the results and the patterns revealed by the outputs offered by the four runs, these were three additional insights that were garnered from the data beyond the initial analysis.

Intentional Empty Return: In the current situation at PA, containers which returned empty could be "re-dispatched" to pick up Near Port IBH. That move was not a strategic design, but a move created by circumstance – the container could not pick up IBH on its return leg. The optimization identified an opportunity to specifically load Near Port IBH. Given that Near Port IBH is the most profitable component of the entire journey the optimization gave first priority to loading Near Port IBH by a dedicated carrier, even if Other IBH was available. Our preliminary analysis circled around the concept of boosting profits by minimizing deadhead miles. However, this situation has highlighted that FC can create a strategy of returning empty to fulfill Near Port IBH demand which results in higher profits and less coordination than fulfilling Other IBH. Below table shows the difference in container loading between actual and model. Notice that even though the model loads less IBH, because the Near Port/Other mix were heavy towards Near Port for the model, the profits were substantially higher.



1.Containers loaded_Actual	
Near port IBH	141
Other IBH	315
Empty	19
Total	475

2.Containers loaded_Model	
Near port IBH	417
Other IBH	23
Empty	35
Total	475

Table 16: IBH Analysis (Feb 15 ~ 23)

Distributed Pickup of Near Port IBH: FC's current strategy is to dispatch dedicated carriers to collect Near Port IBH approximately two days before the next ship's departure. This move was meant to minimize empties as best as possible before the next ship departed. While this move makes sense by concept, the optimization revealed that FC would benefit substantially more by committing approximately 2 or 3 dedicated drivers everyday to fulfill only Near Port IBH. This benefits FC in two ways. First, the operations at the two near port customers, while having no supply constraint, has a constraint on number of containers it can fill in any three hour period, which is 20. Secondly, dedicated carriers make slightly more profit than contract ($800 vs $700), so the model uses contract carriers only when necessary. It is very important to note that it is only in the final day before the next ship's departure that the model dispatches contract carriers to pickup Near Port IBH. This is an indication that even by using a distributed model for picking up Near Port IBH, FC has more empties than can be handled by its drivers in any single day. In the last day before loading, the model decided that it was not possible for dedicated drivers to complete all Near Port IBH, so contract carriers had to be dispatched (in order to minimize empties).

Isolate Profit Drivers within a System: The model's success in improving profit is made possible by a prioritization of completing the highest profit moves first. While this is easy to understand in concept, when FC did not have these integrated into a defined system with clear profit indicators for each option, the PA operations could not maximize profit captured. In fact, the optimization has revealed that the real routing might be for a carrier to do its fronthaul with a domestic backhaul allowed for its return leg, but then it would always be positioned for Near Port IBH first.

Changing the Mindset: FC had already indicated that while the fronthaul leg was the most important – the delivery of its fruit to the customer – both carrier types could fulfill it at similar service levels. Once that was understood, the drive should have been to maximize profit across the system. Of course, there was a natural inclination to look primarily at the fronthaul because that was the only "guaranteed" move as the route would not exist had it not been for an original fronthaul delivery to a customer. However, because FC stated the important of the fronthaul, there was a tendency to always view fronthaul moves first. This became an issue because the decision on the fronthaul had controlled the decision in the backhaul, hence the big difference in profit from our model versus actual.

Non-Transferable: While other ports will likely have improved profits by using our optimization, no other port has PA's almost unlimited supply of Near Port IBH. This is significant because while the model revealed a significant insight in its managing of the containers to return empty for Near Port IBH, the move was operationally simple – bring the containers back empty for a reload. If our model was used at other FC ports, it is likely that no single profit driver with such a significantly higher profit exists. In that situation, the optimization would maximize profits by coordinating and connecting the most profitable fronthaul and backhaul moves for carriers. This is also the situation that will show less distinct pattern of dispatching, because here there was a clear "preferred choice."

4.5 Sensitivity Analysis

A big question FC posed to us during our research was the question of whether PA's operations had the right amount of dedicated carriers and containers. While our research has focused on maximizing profits under the existing constraints, FC wanted to explore if their existing number of dedicated carriers and containers were the optimal number.

For containers, the pros of having more containers are the greater flexibility in containers returning back to port from deliveries or customer pickup. This is because extra containers act as "standby" containers and can be loaded with IBH to load onto the ship if containers en-route back to the port are late. Of course, with the addition of containers, there is an additional cost. Costs come from purchasing, maintaining and "storing" the container. PA arranges its port for quick loading. Instead of stacking containers on top of one another, each container has a designated space and is usually loaded onto a chassis for quick hitching. While this speeds up loading and unloading times dramatically, adding containers also directly increase land space requirements.

Dedicated drivers typically drive the shorter routes and the routes with more DBH and IBH potential. This is because in both instances, more value is captured by using a dedicated carrier Vs a contract carrier. With more dedicated drivers, more of these shorter routes and higher-potential DBH/IBH routes will be carried by dedicated drivers, so more profits will be realized. However, dedicated drivers have a fixed cost per year, and this commitment is usually long-term, so any evaluation must be considered against the demand pattern and routing pattern of the deliveries over the course of twelve months.

Container Count Manipulation:

Below Figure 14, we have isolated the dedicated drivers on the X-axis in order to highlight the profit increase by adding additional containers. The optimal number of additional carriers was 40. In fact, even though the individual profit curves are not identical in terms of how quickly they reach their profit peak and where they reach their profit peak, the 40 additional containers is the optimal choice regardless of what the additional number of dedicated carriers are. As to the reason why going above 40 results in a decreasing marginal profit, it is likely that above a count of 40 containers, there is no necessity for the excess "standby" containers. As well, with the increased container cost, and less opportunities for these standby containers to be utilized, the cost starts to overtake the additional revenue if adding more than 40 containers.

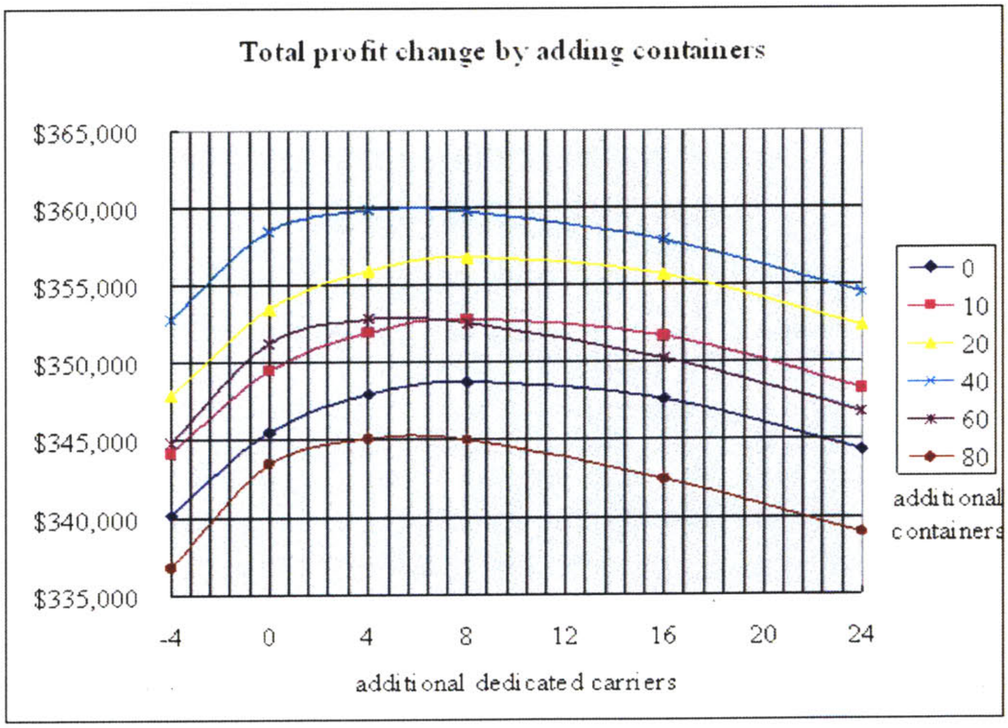


Figure 14: Profit change by adding containers

Dedicated Carrier Count Manipulation:

In below Figure 15, we have isolated the container count on the X-axis in order to highlight the profit increase by adding additional carriers (the different colored lines). While the chart confirms the previous observation that 40 additional containers is the optimal increased container count, the chart also indicates that adding between 4 to 8 dedicated carriers will result in the highest increase in profit and beyond that the net profit will actually be lower. To understand what is happening, we must remember that dedicated carriers generate the most profit when they are taking in IBH, either Near Port or Other. However, there is a limit to how much IBH is available (up to a maximum of 475 containers per week). Once that maximum is reached, there is no more IBH to capture, and any additional benefit a dedicated carrier advantage has is marginal and may even be under its cost (which is exhibited by the carrier count above 8, where it is lower than the current profit curve).

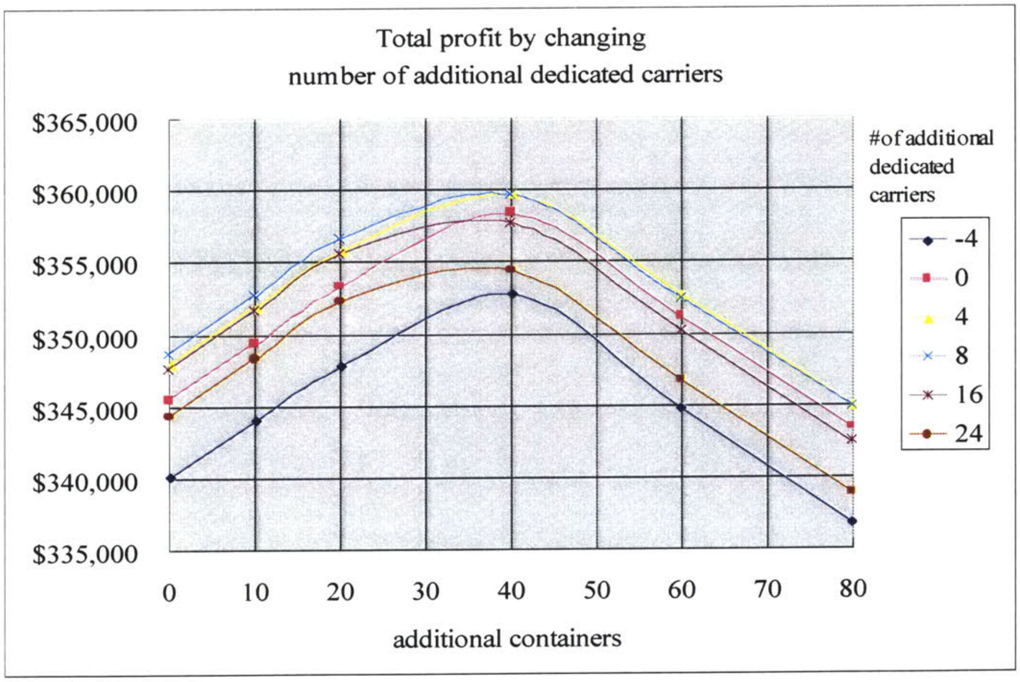


Figure 15: Profit change by adding dedicated carriers

Container and Dedicated Carrier Count Manipulation:

In this container and dedicated carrier analysis, we evaluated the profit potential of increasing and decreasing containers and dedicated carriers collectively. Whereas in the earlier two graphs we looked at only making a change to either the number of dedicated carriers or the number of containers, the table below shows the different net profit achieved by evaluating both dedicated carrier and container count simultaneously.

dedicated carriers(+) containers(+)	-4	0	4	8	16	24
0	-1.55%	0.00%	0.71%	0.94%	0.62%	-0.34%
10	-0.39%	1.14%	1.87%	2.10%	1.78%	0.82%
20	0.68%	2.30%	3.03%	3.26%	2.94%	1.98%
40	2.11%	3.76%	4.13%	4.12%	3.57%	2.59%
60	-0.20%	1.66%	2.11%	2.04%	1.37%	0.37%
80	-2.52%	-0.59%	-0.12%	-0.16%	-0.88%	-1.90%

Table 17: Profit change by varying number of dedicated carriers and containers

If we do not change either of the two counts, the current situation, the profit is $345,508. However, the table shows that the profit is not maximized at the current state. If we add four dedicated carriers and 40 additional containers, we can increase the total profit by $14,283. This means if we invest $4,000 for the additional carriers each week (carrier cost per week is ~$1,000) and an additional $16,000 for the additional containers each week (container cost per week is ~$400, this includes purchase cost broken down by total lifetime plus storage cost plus maintenance cost), for a total $20,000 of additional weekly cost, FC will realize total weekly revenue gains of $34, 283.

5 Conclusion

The conclusion covers three areas. What has been achieved (**section 5.1**), what were the significant learning lessons from conducting our research (**section 5.2**) and where is the next step to go from our research (**section 5.3**)

5.1 Summary

We created a model that captures more profit for FC. The next step is to bring this model from prototype to actual application at PA. The model currently shows a substantial increase in profit, and while there are certainly obstacles to bringing any project from a model to actual application, we believe that an integration of our model to PA will increase its profits.

We were able to achieve this by taking an in-depth look at FC's situation at PA. By speaking with FC staff in its headquarters and at PA, we formed a clear picture of the container movement at PA and the foundation of the existing decision framework for the carrier decision. When we considered our solutions approach, we focused on two objectives. First, maintain the priority on delivering the fronthaul. Second, maximize the system profit.

The model we created in Excel showed significant profit increase through four runs of data. At the lowest, we increased profit by 25%, and at the highest, we increased profit by over 200%. While this profit was realized by the model in concept, and not by actual application, the fact that the model is built with the real PA operation constraints suggests that bringing the model to implementation will not diminish the profit increases significantly, or at all.

From here, it is hoped that FC will take our model and refine it. First testing it at PA, and hopefully integrating it into all of its North American ports.

5.1 Key Takeaways

Identify the Profit Drivers: FC has always stressed that the fronthaul was the first priority. As such, the system is designed to fulfill the fronthaul making the decision based on the fronthaul profit. One issue that was not acknowledged was that both the dedicated and contract carriers could fulfill that fronthaul delivery without any difference in quality. Possibly because of FC's focus on fronthaul, its entire decision framework was designed around fronthaul and neglected other profit drivers, of which the potential profits overwhelmed what can be achieved within the fronthaul. While it makes sense for FC to keep the priority on the fronthaul, once it established the fronthaul would be serviced the same, it should have reassessed its decision framework based on the next highest priority – profit – and build the decision framework from that point. As outsiders, and building a model from a fresh perspective, we developed the model to focus on the profit drivers. Within the Port A, Near Port IBH is the main profit driver. If FC were to carry this model to other ports, it is likely that the profit driver will change as Near Port IBH is unique to PA.

Understand the Problem Fully: To solve a problem, the first step is to understand the situation in its entirety. While FC put effort to capture profit in the delivery of its containers, its view did not capture the full situation. FC viewed containers individually and focused only on the fronthaul when there was a relationship between containers from the same ship, and there were other revenue components beside the fronthaul. If the first step has shortcomings, each subsequent step will likely not be able to remedy the issues originated from the first step. While FC knew that they needed to reevaluate how they made the contract and dedicated carrier decision, the company still retained much of their original scope. Instead, because we came with a base knowledge of the problem and FC's approach, we were able to start from the first step and establish the relationships of different variables ourselves. From there, we reviewed how they looked at the system, and saw how we could change it.

Define the System: Once the problem is in full view, then we need to know what the answer should look like and based on what set of guidelines. Our model was created based on a specific combination of guidelines chosen among a list of alternatives (**section 2.4** outlined a number of considerations we had to filter through) which would define the system and drive its decisions. Each unique combination offers a set of different advantages and disadvantages, and we needed to be able to define the major candidates and evaluate which one offered the most relevant solution. Similar to any large-scale question, after we fully understand the problem, we need to assess the major ways to come to a solution.

Question the Confines of the System: In the next section, there is a summary of potential research add-on's to our existing research. Three of these considerations touch on the issue of shaping what are now inputs. Although we have maximized the potential value of the test runs based on the existing constraints imposed by the customer, carrier and our distribution centers, we should question whether we have some influence over how those function. Any time we have more control over different components within our system, we are then able to improve our output because most of the variables in the system are defined by us, and not outside controllers.

5.2 Areas for Additional Research

During our meetings with FC, the meetings resulted in identifying concerns that were related to the research but not exactly tied into the model itself. Most of these concerns revolved around making PA's operations more efficient, not just working efficiently within the constraints, but shaping them as well. Below are four notable areas that were discussed and a brief summary of the situation.

Contract Carrier Penalty Rates: FC believes that its penalty rates for contract carriers who return the containers late may be too low. If it really is low, what it does is actually encourage contract carriers to be late. This happens because if the daily late fee is cheaper than renting an empty container (which is what the contract carrier has after dropping off the fronthaul), if the contract carrier believes that the route it's traveling has a high probability of backhaul (or already has backhaul available), it makes sense to keep FC's container, as its cheaper and already on the truck, rather than to rent a more expensive container.

Two approaches stand out as a potential solution. One is to increase the penalty rate. However, we need to consider the tension it places on the relationship FC has with the carrier. Additionally, even if the penalty rate is increased, while it may initially reduce late returns, if the carrier has factored in this "discounted" rental fee when it procured the capacity, it may raise its billable to FC for the fronthaul delivery. So, while increasing the fee is a potential solution, there are many variables in how the contract carriers react that will ultimately determines the success of this approach.

The other possible solution is to improve the relationship. Instead of changing the penalty rates, increase communications with the carriers. Also, if FC offers incentives (such as the opportunity to choose the lanes) for having a consistent return record to contract carriers, this is a positive reinforcing method to achieve the same result. Regardless, the contract carrier penalty rate is, at present, not the most effective way to get the containers back on time. While our optimization models for the lateness from contract carriers, if we can reduce that lateness, it means total duration time for contract carriers will reduce, which means a lower operating cost and more captured value for FC.

Distribution Center Management: PA's top 15 destinations comprise ~85% of the total deliveries each week. Within those top 15 destinations, five of those are FC's own distribution centers, whose total deliveries make up almost 50% of the total containers allocated for delivery from PA each week. FC has mentioned that the distribution centers (DC) often use dedicated carriers in the assumption that it saves cost. Additionally, the DCs are one of the biggest reasons for why the dedicated carriers return late. The DCs' operations use PA's dedicated carriers for their own use and have them make deliveries for them.

There are three main problems with this situation. The first is that the current allocation of dedicated carriers for deliveries to DC is not necessarily the economical choice for PA. While PA does it to give the DCs more flexibility and control, by allowing the DCs to take greater control of PA's dedicated driver resources, it causes a chain reaction which eventually may limit dedicated resources from making more deliveries and picking up the potential DBH and IBH.

The second issue has to do with sharing resources. How does a company like FC with a fairly intricate logistics chain, calculate profit and costs. While the above actions cause PA to potentially lose profit, it may in fact cause a greater profit at the DCs. As these are all FC owned assets, FC makes a net profit from this decision. The problem is how should FC evaluate these separate operations? In essence, what defines the "system?" Additionally, even if they have defined the system, how do they then merge the costing procedures of disparate operations?

Finally, as an extension to the second issue, if the DCs are FC owned, maybe PA should manage the relationship better. Since they are all DCs, and are at times holding stock for various customer needs, maybe a warehousing strategy will allow more flexibility in PA's delivery dates (instead of strictly adhering to the delivery manifest). Giving PA operations more flexible delivery days (a range instead of a day) will mean that PA operations has more opportunities to fulfill the delivery of certain containers where the dedicated carrier profit advantage is significant.

Customer Pickup Analysis: In this thesis we have focused on maximizing the operations profits at PA by treating the all the deliveries on a ship as a single cycle and then optimizing the carrier decisions within this cycle. That optimization is based in large part by calculating the probability of revenue drivers (DBH, IBH, late fees) that are currently not integrated into FC's decision model and finding how to best capture the potential opportunities available to various deliveries. Because of the large profit IBH (~$800 per container) brought for the containers, the optimization also was coordinating the containers for the likelihood that it would return in time to pick up Near Port IBH or be on a lane where the return leg had high likelihood of Other IBH. While the model has shown a substantial weekly profit increase (ranging from 75% - 230%, we have, for the large part, neglected the potential increased profit from managing the customer pickups.

Each week, out of the 475 containers that arrive at PA, anywhere from 150 – 250 containers each week are designated as customer pickups and, throughout the week, are picked up by the customer's transportation. The return schedule for these containers is similar to contract carrier's per diem schedule, except there is no clear penalty for a late return. While our optimization has maximized the captured profit potential in a cycle based on both containers for delivery and customer pickups, the optimization does not model the variability in the return of CPUs as it does with contract carrier returns. Therefore, FC can improve profits in two ways.

1) Model for the uncertainty of CPU returns in the optimization itself
2) Manage the CPU returns by creating new guidelines and associated penalties and incentives for the CPUs to follow

For the first option, the integration is mathematical and one approach is to model the uncertainty of CPU returns just as we have modeled the lateness of contract carrier returns. This would mean assessing the probability of certain customers returning FC's containers late, and how late those containers are returned. While this and similar approaches will improve the accuracy of CPU returns, leading to a more accurate optimization, the second way to improve FC's profits is to actually shape CPU return.

Shaping CPU return is similar to the concepts in contract penalty rates and distribution center management. In these three situations, we can either work with what is given and merely replicate it in the model, or understand that FC may be in a position to shape how these components function.

Core Business Strategy: According to our optimization models, FC, at PA alone can increase its weekly profit by over $80,000. This is when comparing to one of their best utilized actual weeks. So, what we potentially have is an increase in profit earnings of above $5 million annually if FC implements this model – and it is effective – at PA. If similar results are achieved across the other FC ports, then FC is looking at a potential increase in profits of over $20 million annually. The next question then goes beyond just the math, which is what much of this thesis is built on, but to whether such a focus on driving backhaul revenue is appropriate for FC's business strategy.

FC is first and foremost a fruit company. While it has an extensive supply chain and logistics network to bring its produce from the tropical regions to all parts of the world, it's core business is fruits and fresh produce. While there is potential profit in targeting backhaul revenue, does this align with FC's core business strategy? Similar to Frito Lay, who also had an extensive private fleet network because of the need to distribute its products, also had to make a strategic decision to consider whether to capture the backhaul. This consideration was driven by whether such a move was in-line with the company strategy. Additionally, while FC has made it clear that delivering the fruit is first and foremost there is a risk with collecting the Near Port IBH. Near Port IBH are all half demolished cars which are being sent to Central America for repair and reselling. While FC routinely cleans their containers after such deliveries, it will only take one incident for FC's reputation to be severely damaged. How can FC calculate the risk for this?

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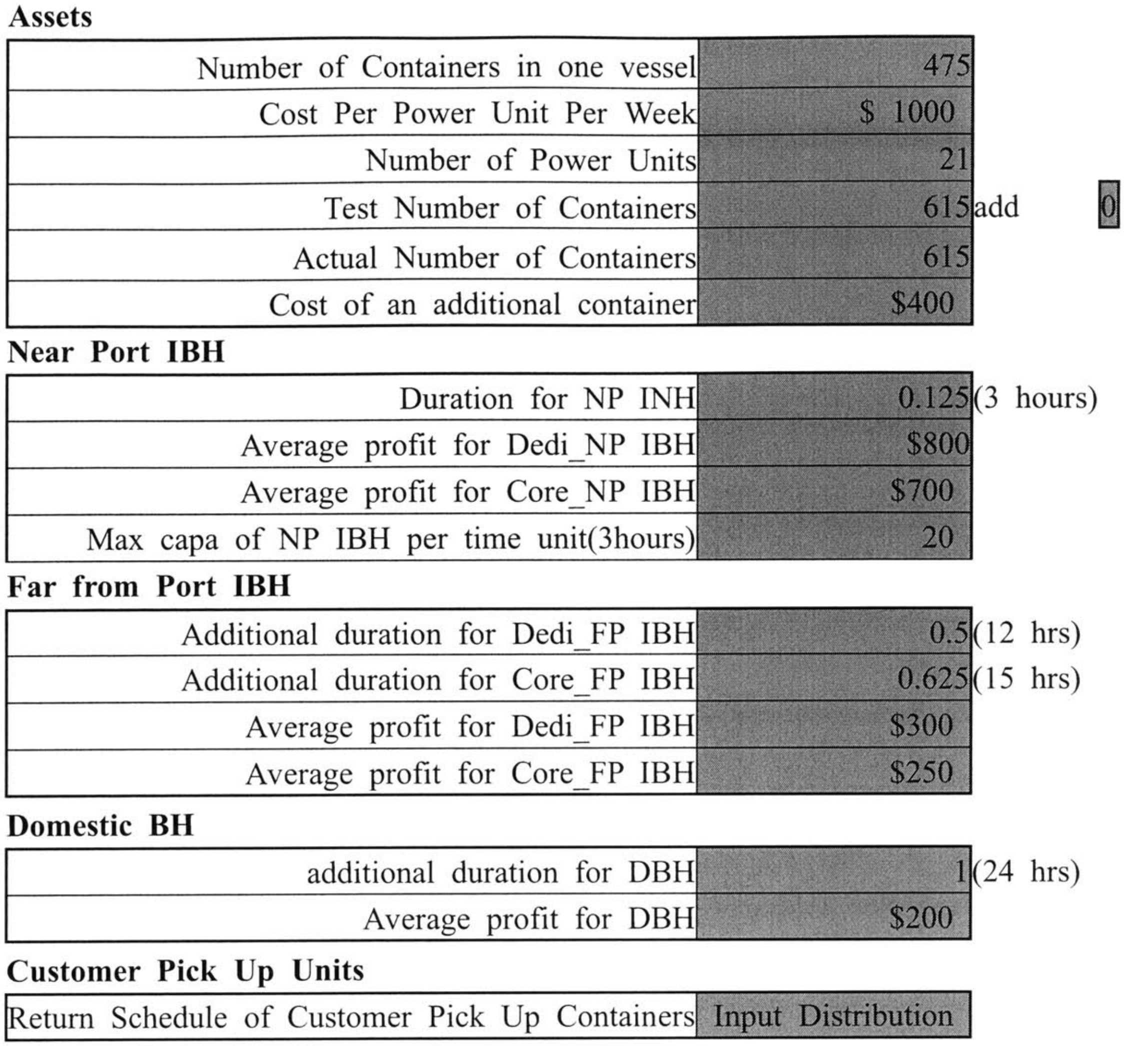
Appendix A.

Explanation of the Optimization Model Components

The optimization function is formed by combining the inputs (described in **section 3.2.1**), the four constraints (described in **section 3.2.3**) and eight separate logical components. This section will explain each of these components individually in order to give the reader the conceptual view of the model. Within the model itself, for simplicity to the end-user, each major component of the model is labeled with the "Part X" label so that the user can reference the detailed build-up explanation by looking up the respective part of the model.

Part 1 (Parameters): Many of the model's basic assumptions are stored in the Parameters section (starting from cell A5) of the sheet "1.Model." The model was designed to be flexible, and this section of the model facilitates one of our design goals of making it robust and flexible by allowing the user to quickly change various assumptions without having to manually rewrite the formulations. Exhibit 3-9 below is a snapshot of the Parameters section.

Part1.Parameters



Assets

Number of Containers in one vessel	475		
Cost Per Power Unit Per Week	$ 1000		
Number of Power Units	21		
Test Number of Containers	615	add	0
Actual Number of Containers	615		
Cost of an additional container	$400		

Near Port IBH

Duration for NP INH	0.125	(3 hours)
Average profit for Dedi_NP IBH	$800	
Average profit for Core_NP IBH	$700	
Max capa of NP IBH per time unit(3hours)	20	

Far from Port IBH

Additional duration for Dedi_FP IBH	0.5	(12 hrs)
Additional duration for Core_FP IBH	0.625	(15 hrs)
Average profit for Dedi_FP IBH	$300	
Average profit for Core_FP IBH	$250	

Domestic BH

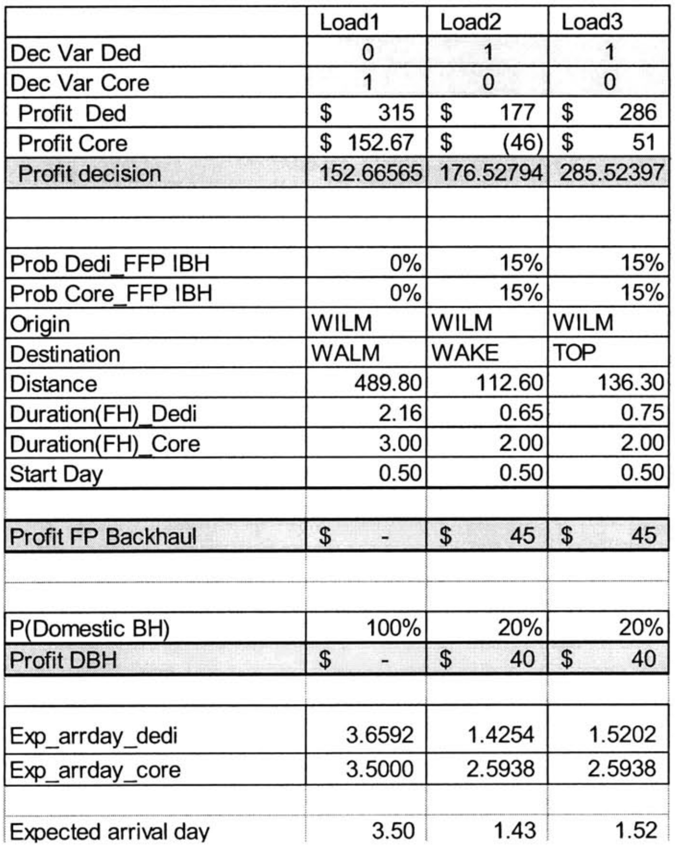
additional duration for DBH	1	(24 hrs)
Average profit for DBH	$200	

Customer Pick Up Units

Return Schedule of Customer Pick Up Containers	Input Distribution

Exhibit 1: Snapshot of Parameters Section

Part 2 (Fronthaul Delivery Data): This part of the model (starting from cell A45 in sheet "1. Model") shows the front haul delivery data (sourced from the automatic data conversion of the delivery manifest) and carrier decision (the yellow colored cells) for each delivery. The actual profit is calculated as the sum of the chosen carrier's profit components. Information regarding probability of other international backhaul (or FFP IBH: far from port international backhaul), origin, destination, duration, start day, and probability of domestic backhaul is automatically extracted from the "InputVariables+Input_Asset Pre" sheet (explained in **section 3.2.2** under "Destination Matching"). While this section of the sheet shows all the individual container information, all the data are sourced from other parts of the sheets. So this section is for viewing rather than input (at least not direct input). On the next page is Exhibit 3-10, a snapshot showing three lanes of the Fronthaul Delivery section.

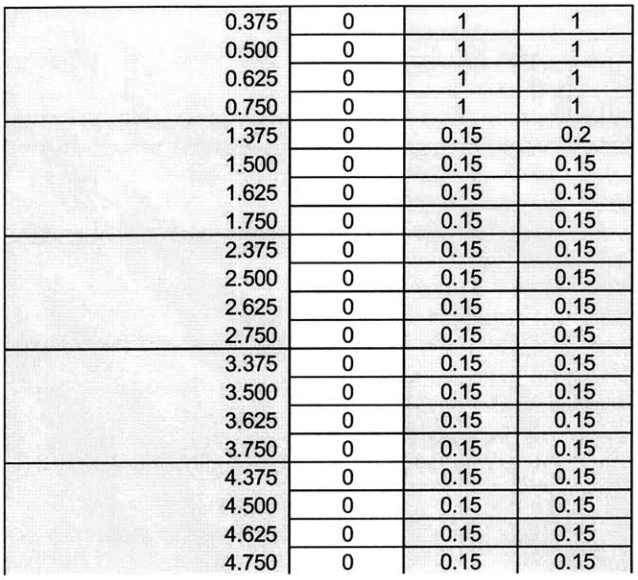


	Load1	Load2	Load3
Dec Var Ded	0	1	1
Dec Var Core	1	0	0
Profit Ded	$ 315	$ 177	$ 286
Profit Core	$ 152.67	$ (46)	$ 51
Profit decision	152.66565	176.52794	285.52397
Prob Dedi_FFP IBH	0%	15%	15%
Prob Core_FFP IBH	0%	15%	15%
Origin	WILM	WILM	WILM
Destination	WALM	WAKE	TOP
Distance	489.80	112.60	136.30
Duration(FH)_Dedi	2.16	0.65	0.75
Duration(FH)_Core	3.00	2.00	2.00
Start Day	0.50	0.50	0.50
Profit FP Backhaul	$ -	$ 45	$ 45
P(Domestic BH)	100%	20%	20%
Profit DBH	$ -	$ 40	$ 40
Exp_arrday_dedi	3.6592	1.4254	1.5202
Exp_arrday_core	3.5000	2.5938	2.5938
Expected arrival day	3.50	1.43	1.52

Exhibit 2: Snapshot of Part 2. Fronthaul Delivery Data

Part 3 (Container Availability for Fronthaul Delivery): This section of the model tracks the status of a container for each lane. It is broken down into two parts. The first part calculates what the container occupancy would be for both types of carriers. If the cell shows “1,” it means the container is either filled and waiting at the port, or on the way to the customer. Once it reaches the customer one of two things can happen. If it shows 0, it means that the lane has no chance of picking up backhaul. If it shows a decimal, that decimal is actually the probability of that lane picking up backhaul.

The second part of this Container Availability section is to convert the projected usage to actual usage. The first part gave projections for the container usage of both contract and dedicated carrier, but the optimization will only choose one. The second part is to show the actual container usage for the dedicated carrier, this will result in us knowing which lanes go contract (the whole column will show 0), and which column goes dedicated. Exhibit 3-11 below shows the second part of the container availability process, with the first lane (with all 0’s in the column) indicating that a contract carrier was used.

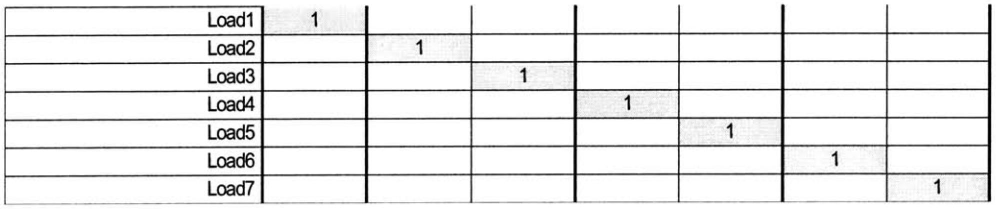


	0.375	0	1	1
	0.500	0	1	1
	0.625	0	1	1
	0.750	0	1	1
	1.375	0	0.15	0.2
	1.500	0	0.15	0.15
	1.625	0	0.15	0.15
	1.750	0	0.15	0.15
	2.375	0	0.15	0.15
	2.500	0	0.15	0.15
	2.625	0	0.15	0.15
	2.750	0	0.15	0.15
	3.375	0	0.15	0.15
	3.500	0	0.15	0.15
	3.625	0	0.15	0.15
	3.750	0	0.15	0.15
	4.375	0	0.15	0.15
	4.500	0	0.15	0.15
	4.625	0	0.15	0.15
	4.750	0	0.15	0.15

Exhibit 3: Snapshot of Part 3, Container Availability

Part 4 (Carrier Usage for Fronthaul Delivery): In this section (starting from cell A637 in sheet "1.Model"), the model creates seven tables for the purpose of showing the carrier usage for each lane. These seven tables distinguish between dedicated and contract carrier as well as fronthaul, DBH and Other IBH legs. The sum of the rows (each row is a time unit) across all lanes cannot exceed the total number of dedicated carriers. With this format, the user can review and inspect the usage of a specific carrier type and leg, or how certain lanes utilize its carriers.

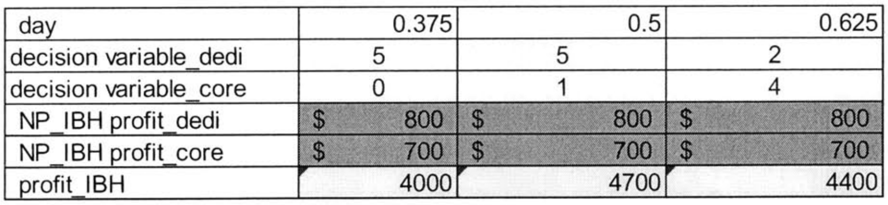
Part 5 (Check Loads): This part checks that loads are picked up once and only once with the model's optimization. It does this by summing the binary decision variables that indicate either dedicated or contract carrier usage from Part 2 of the model. All loads should show "1" to indicate that only one of the two carrier choices was chosen.



	Load1	1						
	Load2		1					
	Load3			1				
	Load4				1			
	Load5					1		
	Load6						1	
	Load7							1

Exhibit 4: Checking binary decision variables

Part 6 (International Backhaul): This section (starting from cell GV44 in sheet "1.Model"), is constructed similarly to the Fronthaul Delivery Data (Part 2), except that Part 6 focuses on the IBH profit and the carrier type to use to pick up Near Port IBH. The yellow highlighted area shows which carrier to use to pick up Near Port IBH at the different times (broken up into four 3-hour segments across each day). Exhibit 3-12 below is a snapshot of this section (showing only three lanes).

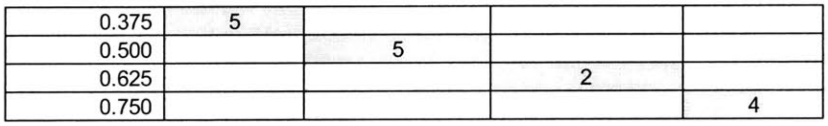


day	0.375	0.5	0.625
decision variable_dedi	5	5	2
decision variable_core	0	1	4
NP_IBH profit_dedi	$ 800	$ 800	$ 800
NP_IBH profit_core	$ 700	$ 700	$ 700
profit_IBH	4000	4700	4400

Exhibit 5: Part 6, Near Port International Backhaul Decision Variables

Part 7 (Container Availability for Near Port IBH): This section (starting from cell GV325 in sheet "1.Model) tracks the container occupied by Near Port IBH that were picked up by both dedicated carriers and contract carriers. We distinguish between contract and dedicated carriers because they have different profits from one another. Once a container is filled with goods, it remains occupied until it is loaded onto the upcoming vessel.

Part 8 (Dedicate Carrier Occupied for Near Port IBH): This section (starting from cell GV823 in the sheet "1.Model") tracks the dedicated carrier usage for Near Port IBH. It tracks how many dedicated carriers are being used for Near Port IBH at any given time unit. This lets us view where dedicated carrier resources are being used at. Exhibit 3-13 below shows a portion of that section.



0.375	5			
0.500		5		
0.625			2	
0.750				4

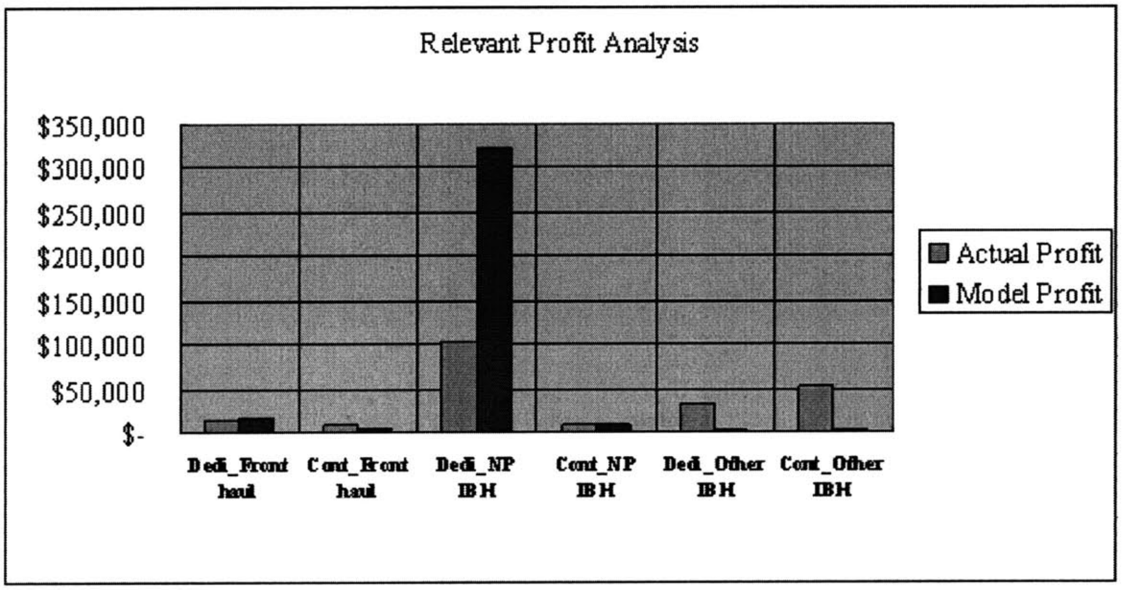
Exhibit 6: Snapshot of Part 8, Carrier Occupied

Appendix B. Results of sample runs

I. Feb 15 ~ Feb 23, 2006 Analysis

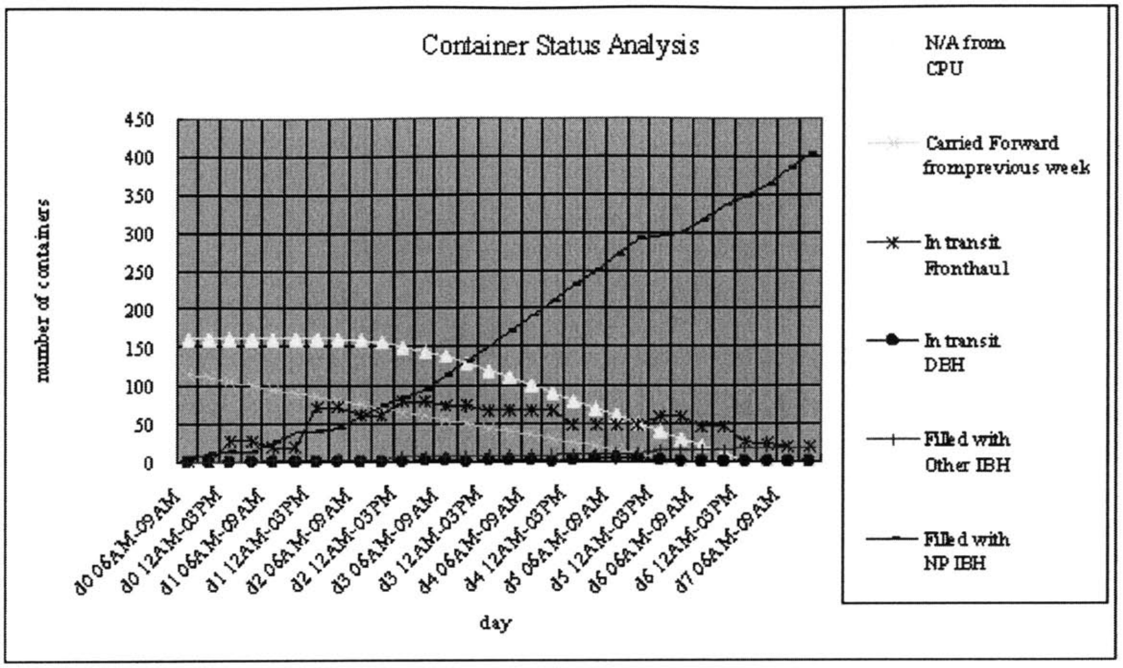
1. Profit Analysis

	Actual Profit	Model Profit	Profits Increase by	% increase
Dedi_Front haul	$ 14,342	$ 16,734	$ 2,392	17%
Cont_Front haul	$ 8,644	$ 5,893	$ (2,751)	-32%
Dedi_NP IBH	$ 103,200	$ 322,400	$ 219,200	212%
Cont_NP IBH	$ 8,400	$ 9,800	$ 1,400	17%
Dedi_Other IBH	$ 32,100	$ 1,680	$ (30,420)	-95%
Cont_Other IBH	$ 52,000	$ 4,325	$ (47,675)	-92%
Total	$ 218,686	$ 360,833	$ 142,147	65%



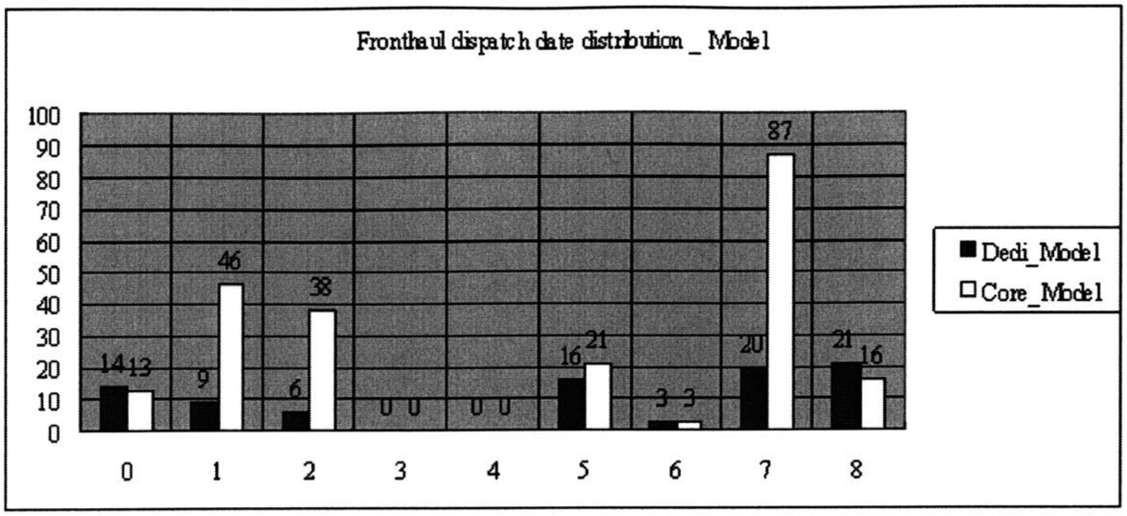
2. Container status analysis

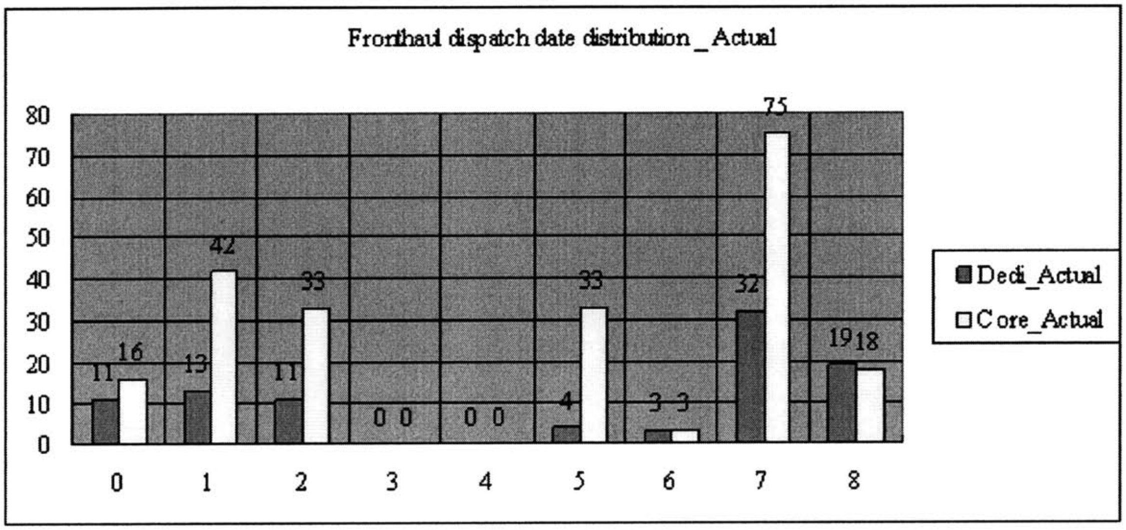
Time unit	N/A from CPU	Carried Forward from previous week	In transit Fronthaul	In transit DBH	Filled with Other IBH	Filled with NP IBH	Total Occupied	MAX
d0 06AM-09AM	162	115	0	0	0	5	595	595
d0 09AM-12AM	162	110	0	0	0	10	595	595
d0 12AM-03PM	162	105	27	0	0	12	592	595
d0 03PM-06PM	162	100	27	0	0	13	588	595
d1 06AM-09AM	162	95	18	0	1	25	587	595
d1 09AM-12AM	162	90	18	0	1	37	594	595
d1 12AM-03PM	162	85	71	0	1	40	590	595
d1 03PM-06PM	162	80	71	0	1	43	588	595
d2 06AM-09AM	159	75	60	0	3	58	586	595
d2 09AM-12AM	156	70	60	0	3	73	593	595
d2 12AM-03PM	150	65	80	1	7	83	582	595
d2 03PM-06PM	144	60	79	2	7	94	571	595
d3 06AM-09AM	138	55	73	2	7	113	573	595
d3 09AM-12AM	130	50	73	1	7	132	579	595
d3 12AM-03PM	120	45	66	2	7	151	579	595
d3 03PM-06PM	110	40	66	2	7	170	580	595
d4 06AM-09AM	100	35	66	2	7	190	585	595
d4 09AM-12AM	90	30	66	1	7	210	590	595
d4 12AM-03PM	80	25	48	2	10	230	585	595
d4 03PM-06PM	70	20	48	4	10	250	585	595
d5 06AM-09AM	60	15	48	4	10	270	590	595
d5 09AM-12AM	50	10	48	3	10	290	595	595
d5 12AM-03PM	40	5	58	3	15	295	573	595
d5 03PM-06PM	30	0	58	0	15	300	554	595
d6 06AM-09AM	20	0	46	0	15	317	548	595
d6 09AM-12AM	10	0	46	0	15	334	555	595
d6 12AM-03PM	0	0	25	0	19	348	543	595
d6 03PM-06PM	0	0	24	0	19	362	551	595
d7 06AM-09AM	0	0	19	0	20	382	565	595
d7 09AM-12AM	0	0	19	0	20	402	585	595
d7 12AM-03PM	0	0	122	1	20	403	586	595
d7 03PM-06PM	0	0	118	3	23	417	595	595



3-1. Front haul dispatch distribution analysis

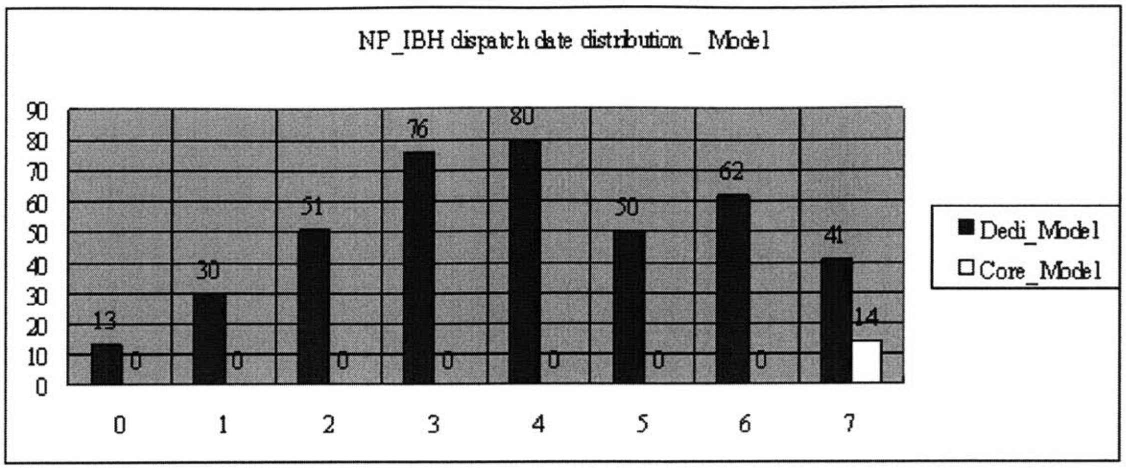
Dispatch Date	Dedi_Model	%	Core_Model	%	Dedi_Actual	%	Core_Actual	%
0	14	4.5%	13	4.2%	11	3.5%	16	5.1%
1	9	2.9%	46	14.7%	13	4.2%	42	13.4%
2	6	1.9%	38	12.1%	11	3.5%	33	10.5%
3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5	16	5.1%	21	6.7%	4	1.3%	33	10.5%
6	3	1.0%	3	1.0%	3	1.0%	3	1.0%
7	20	6.4%	87	27.8%	32	10.2%	75	24.0%
8	21	6.7%	16	5.1%	19	6.1%	18	5.8%
sub total	89	28.4%	224	71.6%	93	29.7%	220	70.3%
Total	313				313			

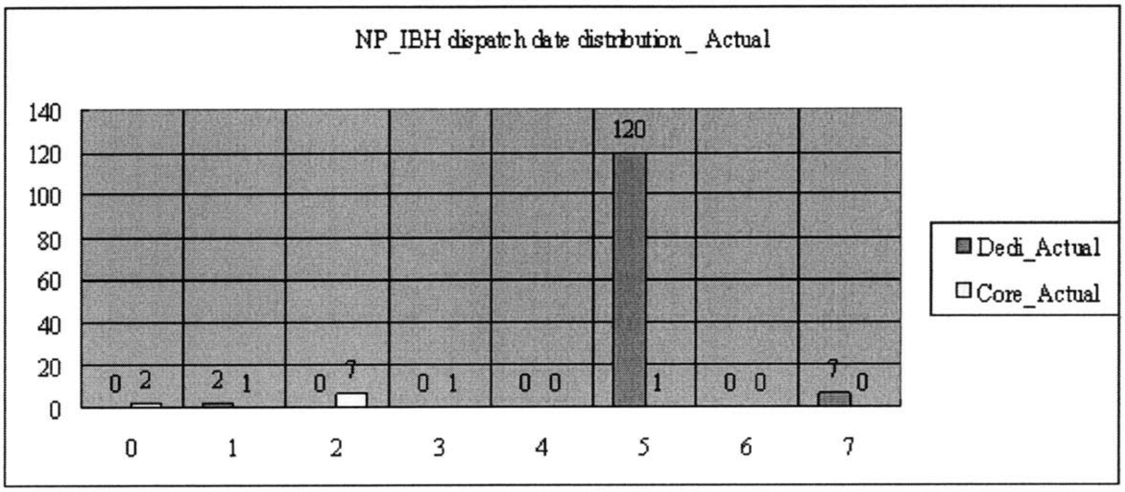




3-2. Near port IBH dispatch distribution analysis

Dispatch Date	Dedi_Model	%	Core_Model	%	Dedi_Actual	%	Core_Actual	%
0	13	3.1%	0	0.0%	0	0.0%	2	1.4%
1	30	7.2%	0	0.0%	2	1.4%	1	0.7%
2	51	12.2%	0	0.0%	0	0.0%	7	5.0%
3	76	18.2%	0	0.0%	0	0.0%	1	0.7%
4	80	19.2%	0	0.0%	0	0.0%	0	0.0%
5	50	12.0%	0	0.0%	120	85.1%	1	0.7%
6	62	14.9%	0	0.0%	0	0.0%	0	0.0%
7	41	9.8%	14	3.4%	7	5.0%	0	0.0%
Sub total	403	96.6%	14	3.4%	129	91.5%	12	8.5%
Total	417				141			





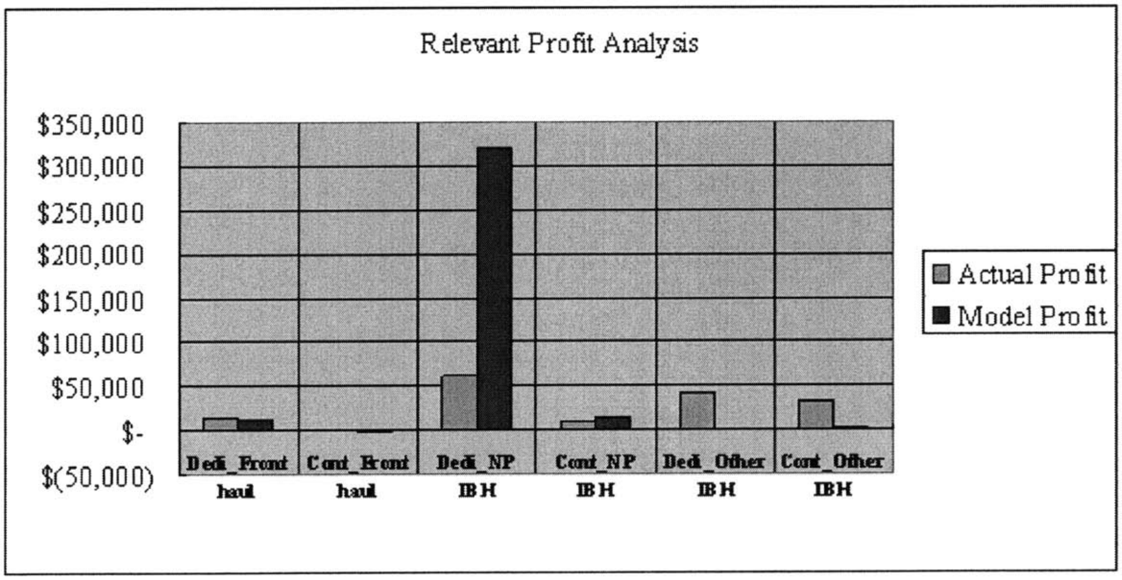
4. International backhaul analysis

1.Containers loaded_Actual	
Near port IBH	141
Other IBH	315
Empty	19
Total	475
2.Containers loaded_Model	
Near port IBH	417
Other IBH	23
Empty	35
Total	475

II. Mar 22 ~ Mar 29, 2006 Analysis

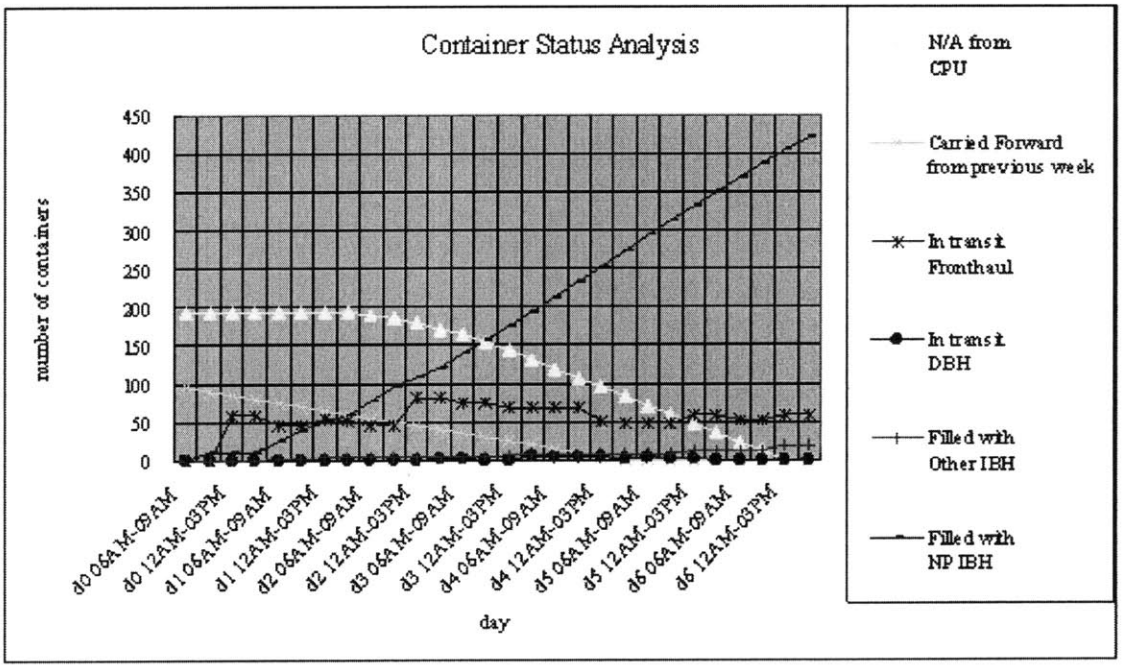
1. Profit Analysis

	Actual Profit	Model Profit	Profits Increase by	% increase
Dedi_Front haul	$ 14,376	$ 12,860	$ (1,517)	-11%
Cont_Front haul	$ 1,400	$ (3,178)	$ (4,578)	-327%
Dedi_NP IBH	$ 61,600	$ 320,800	$ 259,200	421%
Cont_NP IBH	$ 9,800	$ 14,000	$ 4,200	43%
Dedi_Other IBH	$ 40,500	$ 1,200	$ (39,300)	-97%
Cont_Other IBH	$ 32,250	$ 3,850	$ (28,400)	-88%
Total	$ 159,926	$ 349,532	$ 189,606	119%



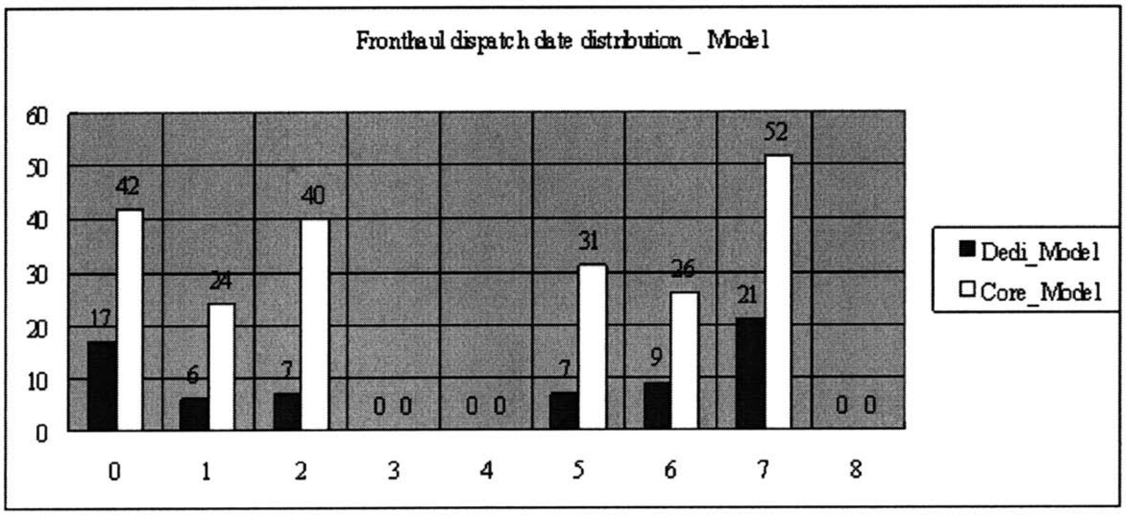
2. Container status analysis

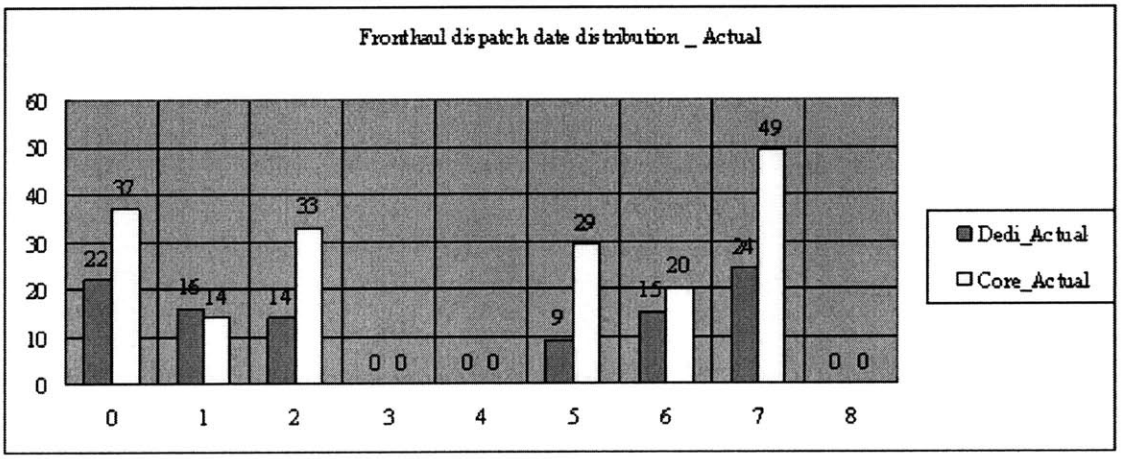
Time unit	N/A from CPU	Carried Forward from previous week	In transit Fronthaul	In transit DBH	Filled with Other IBH	Filled with NP IBH	Total Occupied	MAX
d0 06AM-09AM	193	95	0	0	0	0	570	575
d0 09AM-12AM	193	90	0	0	0	10	575	575
d0 12AM-03PM	193	85	59	0	0	10	570	575
d0 03PM-06PM	193	80	59	0	0	10	565	575
d1 06AM-09AM	193	75	45	0	2	25	563	575
d1 09AM-12AM	193	70	45	0	2	40	573	575
d1 12AM-03PM	193	65	54	0	4	49	563	575
d1 03PM-06PM	193	60	53	0	4	58	561	575
d2 06AM-09AM	189	55	45	0	4	77	564	575
d2 09AM-12AM	186	50	45	0	4	96	574	575
d2 12AM-03PM	179	45	81	0	5	109	567	575
d2 03PM-06PM	172	40	81	2	5	121	565	575
d3 06AM-09AM	164	35	76	2	5	139	565	575
d3 09AM-12AM	155	30	76	1	5	157	569	575
d3 12AM-03PM	143	25	69	1	6	175	563	575
d3 03PM-06PM	131	20	69	6	6	193	565	575
d4 06AM-09AM	119	15	68	5	6	213	567	575
d4 09AM-12AM	107	10	68	4	6	233	570	575
d4 12AM-03PM	95	5	49	4	8	253	562	575
d4 03PM-06PM	83	0	48	3	8	273	559	575
d5 06AM-09AM	71	0	48	4	8	293	567	575
d5 09AM-12AM	60	0	48	3	8	313	575	575
d5 12AM-03PM	48	0	59	3	13	332	569	575
d5 03PM-06PM	36	0	59	0	13	349	566	575
d6 06AM-09AM	24	0	52	0	13	368	566	575
d6 09AM-12AM	12	0	52	0	13	388	575	575
d6 12AM-03PM	0	0	59	0	19	405	563	575
d6 03PM-06PM	0	0	59	0	19	421	575	575



3. Front haul dispatch distribution analysis

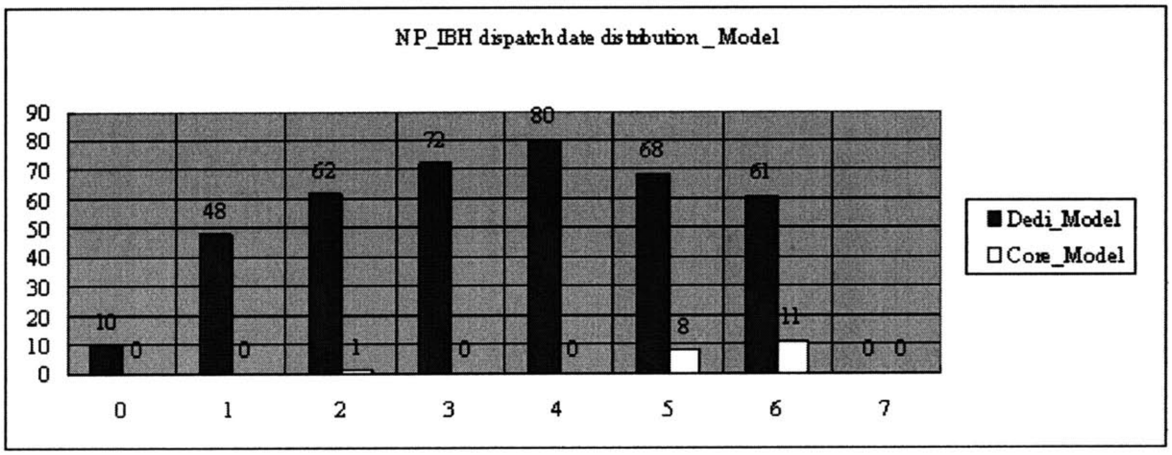
Dispatch Date	Dedi_Model	%	Core_Model	%	Dedi_Actual	%	Core_Actual	%
0	17	6.0%	42	14.9%	22	7.8%	37	13.1%
1	6	2.1%	24	8.5%	16	5.7%	14	5.0%
2	7	2.5%	40	14.2%	14	5.0%	33	11.7%
3	0	0.0%	0	0.0%	0	0.0%	0	0.0%
4	0	0.0%	0	0.0%	0	0.0%	0	0.0%
5	7	2.5%	31	11.0%	9	3.2%	29	10.3%
6	9	3.2%	26	9.2%	15	5.3%	20	7.1%
7	21	7.4%	52	18.4%	24	8.5%	49	17.4%
8	0	0.0%	0	0.0%	0	0.0%	0	0.0%
sub total	67	23.8%	215	76.2%	100	35.5%	182	64.5%
Total	282				282			

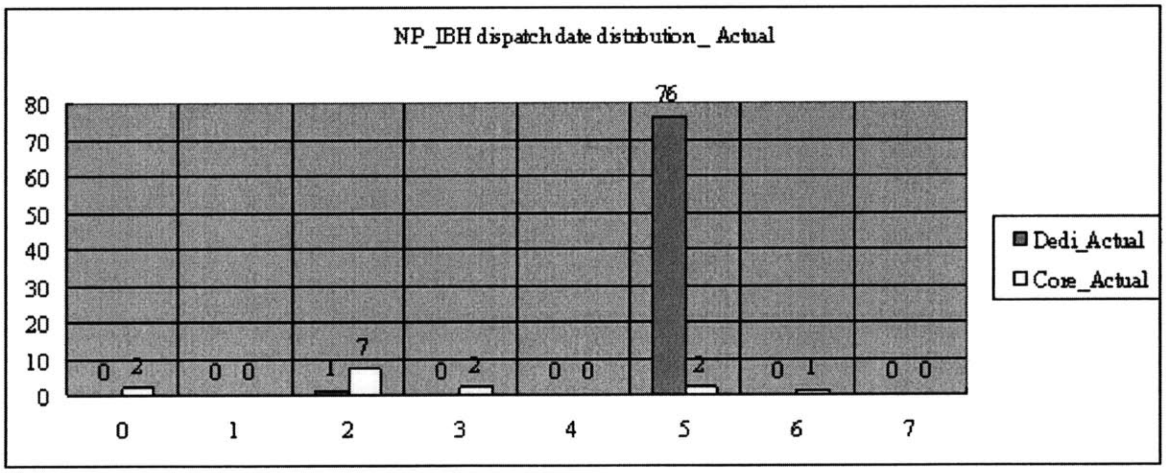




4. Near port IBH dispatch distribution analysis

Dispatch Date	Dedi_Model	%	Core_Model	%	Dedi_Actual	%	Core_Actual	%
0	10	2.4%	0	0.0%	0	0.0%	2	2.2%
1	48	11.4%	0	0.0%	0	0.0%	0	0.0%
2	62	14.7%	1	0.2%	1	1.1%	7	7.7%
3	72	17.1%	0	0.0%	0	0.0%	2	2.2%
4	80	19.0%	0	0.0%	0	0.0%	0	0.0%
5	68	16.2%	8	1.9%	76	83.5%	2	2.2%
6	61	14.5%	11	2.6%	0	0.0%	1	1.1%
7	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Sub total	401	95.2%	20	4.8%	77	84.6%	14	15.4%
Total	421				91			


NP_IBH dispatch date distribution _ Model


NP_IBH dispatch date distribution _ Actual

5. International backhaul analysis

1.Containers loaded_Actual	
Near port IBH	91
Other IBH	264
Empty	120
Total	475

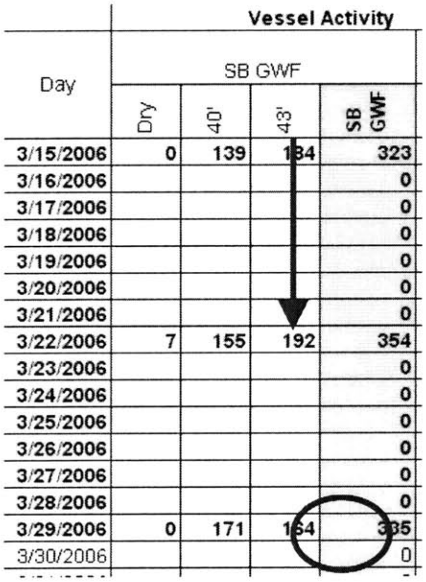
2.Containers loaded_Model	
Near port IBH	421
Other IBH	19
Empty	35
Total	475

Appendix C. Manual for using the Optimization Model

Three parts are required to update the model and obtain the optimized results; inserting input data, updating the *Model* tab, and adjusting report analysis tabs.

I. Inserting input data

1. Choose the target week and find the vessel's arrival and departure date from *vessel schedule* tab in *Wilmington Daily Activity Report_2006.EXL* file. For example, Mar 22 to Mar 29, 2006.



Day	Vessel Activity			
	SB GWF			
	Dry	40'	43'	SB GWF
3/15/2006	0	139	184	323
3/16/2006				0
3/17/2006				0
3/18/2006				0
3/19/2006				0
3/20/2006				0
3/21/2006				0
3/22/2006	7	155	192	354
3/23/2006				0
3/24/2006				0
3/25/2006				0
3/26/2006				0
3/27/2006				0
3/28/2006				0
3/29/2006	0	171	164	335
3/30/2006				0

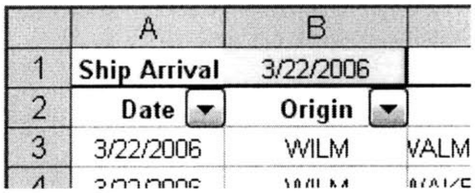
2. Also, two more information in this file is used in the model. First is number of days of previous week's operation cycle. In this case, it is 7 days, since a vessel arrived at Mar 15 and departed at Mar 22. Second is number of containers filled with international backhaul, which is 335 from Cell O93. This number is used in step 5.

3. Extract the front haul manifest data and international backhaul data from *2006 Wilmington_Delivery Data.EXL* file by filtering the range of date. The numbers of total deliveries for both front haul and backhaul in the period are input data of the model, so write those down.

4. Copy and paste the front haul manifest data into *0-2.Input_FH* tab in the model. Keep in mind that the size of the row might be different from the original file, so update it carefully.

5. Copy and paste the international backhaul data into *0-4.Input_IBH+Convert* tab in the model. The number of the rows of data should be same as actual number of containers filled with international backhaul, which is 335. Delete the rows starting from the last delivery, to match up with 335 international backhauls.

6. In tab *0-3.Converted_FH*, check the ship arrival day is correct.

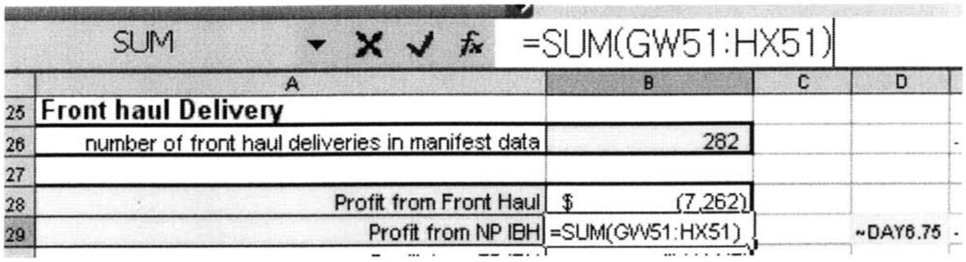


	A	B	
1	**Ship Arrival**	3/22/2006	
2	**Date**	**Origin**	
3	3/22/2006	WILM	VALM

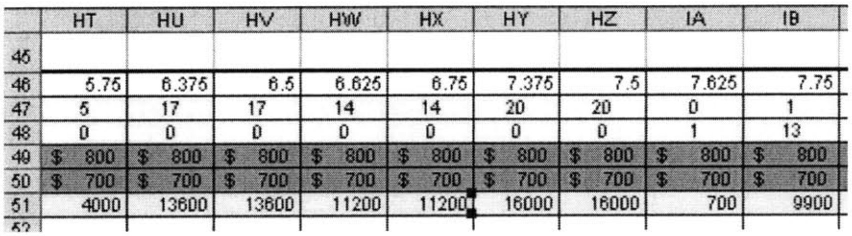
II) Updating the *Model* tab

7. Update the yellow cell in this tab. Update number of front haul deliveries in manifest data (cell B26) obtained from step 3(which is 282), and days of previous operation cycle in cell P9 (which is 7).

8. Check the end date of near port IBH in cell D29. Update the range of period available for near port IBH.

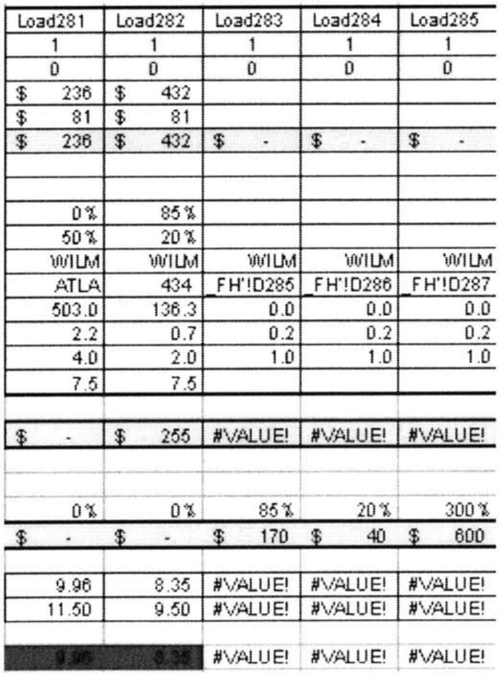


	A	B	C	D
25	**Front haul Delivery**			
26	number of front haul deliveries in manifest data	282		
27				
28	Profit from Front Haul	$ (7,262)		
29	Profit from NP IBH	=SUM(GW51:HX51)		~DAY6.75



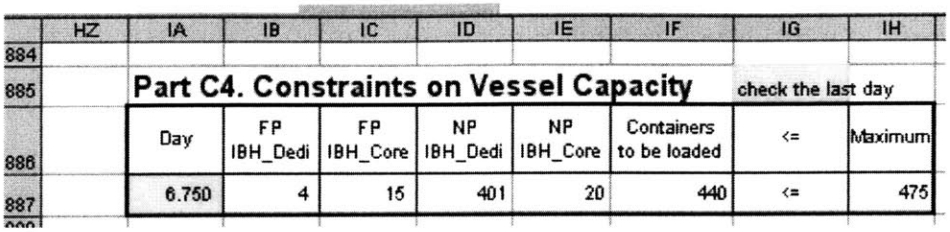
	HT	HU	HV	HW	HX	HY	HZ	IA	IB
45									
46	5.75	6.375	6.5	6.625	6.75	7.375	7.5	7.625	7.75
47	5	17	17	14	14	20	20	0	1
48	0	0	0	0	0	0	0	1	13
49	$ 800	$ 800	$ 800	$ 800	$ 800	$ 800	$ 800	$ 800	$ 800
50	$ 700	$ 700	$ 700	$ 700	$ 700	$ 700	$ 700	$ 700	$ 700
51	4000	13600	13600	11200	11200	16000	16000	700	9900

9. Update front haul delivery data by adjusting cells. In this case, remove all data starts from load 283, which contains no information. Also remove all the cells below this part.



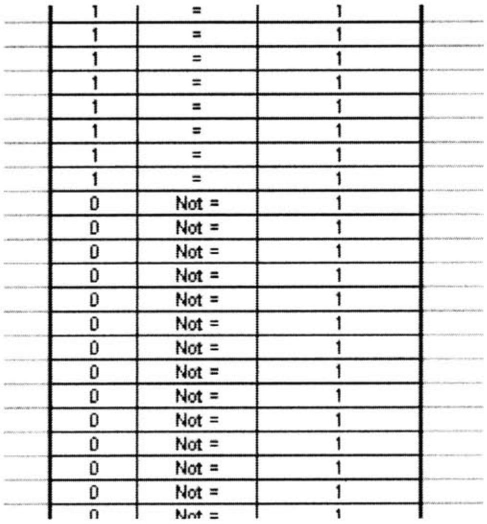
Load281	Load282	Load283	Load284	Load285
1	1	1	1	1
0	0	0	0	0
$ 236	$ 432			
$ 81	$ 81			
$ 236	$ 432	$ -	$ -	$ -
0%	85%			
50%	20%			
WILM	WILM	WILM	WILM	WILM
ATLA	434	_FH'!D285	_FH'!D286	_FH'!D287
503.0	136.3	0.0	0.0	0.0
2.2	0.7	0.2	0.2	0.2
4.0	2.0	1.0	1.0	1.0
7.5	7.5			
$ -	$ 255	#VALUE!	#VALUE!	#VALUE!
0%	0%	85%	20%	300%
$ -	$ -	$ 170	$ 40	$ 600
9.96	8.35	#VALUE!	#VALUE!	#VALUE!
11.50	9.50	#VALUE!	#VALUE!	#VALUE!
9.96	8.35	#VALUE!	#VALUE!	#VALUE!

10. Update Part C4. Check the last day of given week's operation. Update the formula in cell IB887~IE887.



	HZ	IA	IB	IC	ID	IE	IF	IG	IH
884									
885		**Part C4. Constraints on Vessel Capacity**						check the last day	
886		Day	FP IBH_Dedi	FP IBH_Core	NP IBH_Dedi	NP IBH_Core	Containers to be loaded	<=	Maximum
887		6.750	4	15	401	20	440	<=	475

11. Update Part C5.Binary check in cell GW2304. Adjust the range of data.

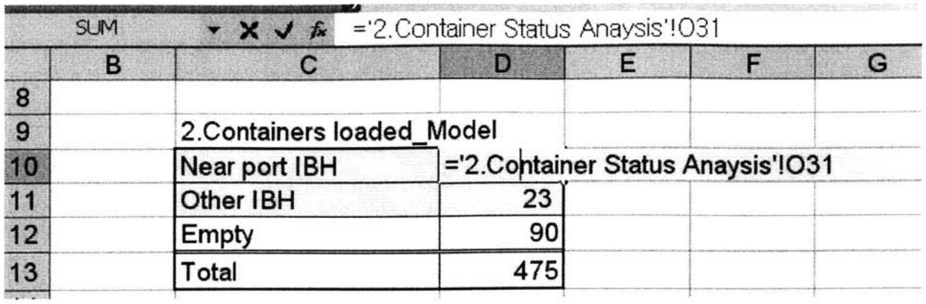


1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
1	=	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1
0	Not =	1

<u>III. Adjusting report analysis tabs</u>

12. Check if there are errors in report tabs. Update the range of days of operation.

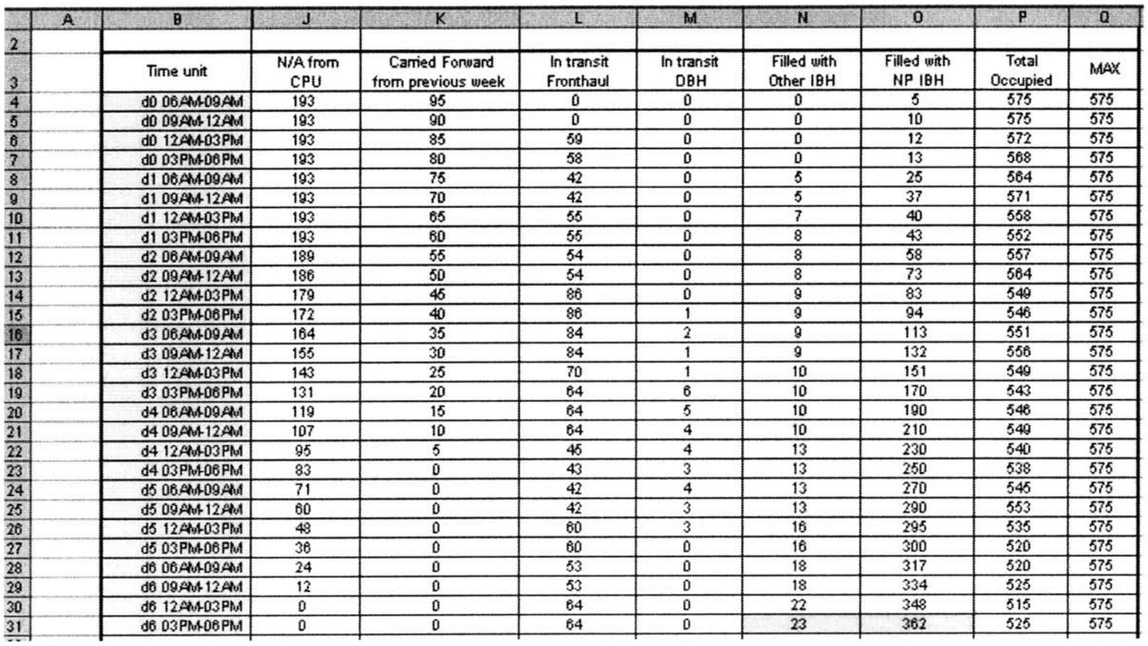
13. In 4.IBH_Cont analysis tab, check the value of cell D10. This number should be the number of cumulative containers filled with near port IBH at the last available day for near port IBH, which is day 6.75.



```
='2.Container Status Anaysis'!O31
```

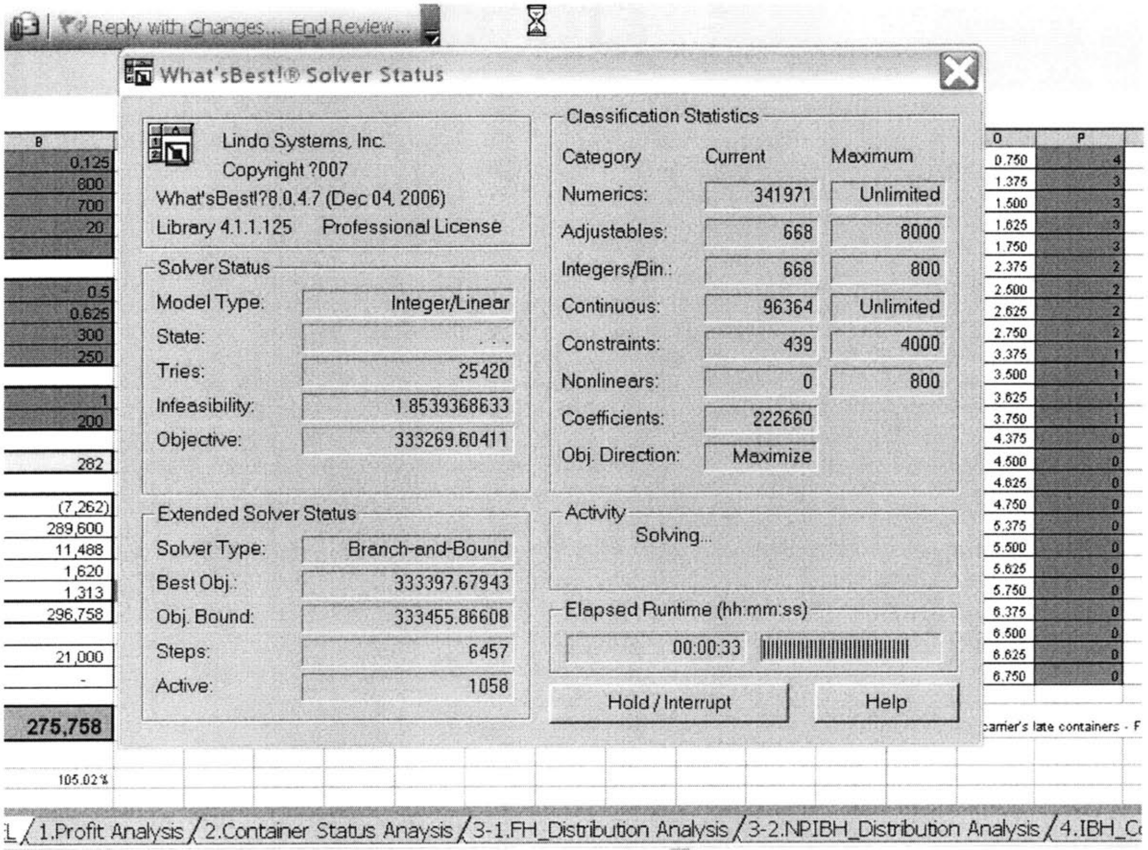
	C	D
9	2.Containers loaded_Model	
10	Near port IBH	='2.Container Status Anaysis'!O31
11	Other IBH	23
12	Empty	90
13	Total	475

This information is included the chart of *2.Container Status Analysis* tab.



	B	J	K	L	M	N	O	P	Q
3	Time unit	N/A from CPU	Carried Forward from previous week	In transit Fronthaul	In transit DBH	Filled with Other IBH	Filled with NP IBH	Total Occupied	MAX
4	d0 06AM-09AM	193	95	0	0	0	5	575	575
5	d0 09AM-12AM	193	90	0	0	0	10	575	575
6	d0 12AM-03PM	193	85	59	0	0	12	572	575
7	d0 03PM-06PM	193	80	58	0	0	13	568	575
8	d1 06AM-09AM	193	75	42	0	5	25	564	575
9	d1 09AM-12AM	193	70	42	0	5	37	571	575
10	d1 12AM-03PM	193	65	55	0	7	40	558	575
11	d1 03PM-06PM	193	60	55	0	8	43	552	575
12	d2 06AM-09AM	189	55	54	0	8	58	557	575
13	d2 09AM-12AM	186	50	54	0	8	73	564	575
14	d2 12AM-03PM	179	45	86	0	9	83	549	575
15	d2 03PM-06PM	172	40	86	1	9	94	546	575
16	d3 06AM-09AM	164	35	84	2	9	113	551	575
17	d3 09AM-12AM	155	30	84	1	9	132	556	575
18	d3 12AM-03PM	143	25	70	1	10	151	549	575
19	d3 03PM-06PM	131	20	64	6	10	170	543	575
20	d4 06AM-09AM	119	15	64	5	10	190	546	575
21	d4 09AM-12AM	107	10	64	4	10	210	549	575
22	d4 12AM-03PM	95	5	45	4	13	230	540	575
23	d4 03PM-06PM	83	0	43	3	13	250	538	575
24	d5 06AM-09AM	71	0	42	4	13	270	545	575
25	d5 09AM-12AM	60	0	42	3	13	290	553	575
26	d5 12AM-03PM	48	0	60	3	16	295	535	575
27	d5 03PM-06PM	36	0	60	0	16	300	520	575
28	d6 06AM-09AM	24	0	53	0	18	317	520	575
29	d6 09AM-12AM	12	0	53	0	18	334	525	575
30	d6 12AM-03PM	0	0	64	0	22	348	515	575
31	d6 03PM-06PM	0	0	64	0	23	362	525	575

14. Run the model. It may end up calculation with finding a globally optimal solution. However, if the deference of the value between Best Obj and Obj Bound is less than 100, which means the approximate tolerance is less than 0.03%, we can interrupt the calculation and use Best Obj value as the maximum value of total profit for the given week.



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Library 4.1.1.125 Professional License

Solver Status

Model Type:	Integer/Linear
State:	. . .
Tries:	25420
Infeasibility:	1.8539368633
Objective:	333269.60411

Extended Solver Status

Solver Type:	Branch-and-Bound
Best Obj.:	333397.67943
Obj. Bound:	333455.86608
Steps:	6457
Active:	1058

Classification Statistics

Category	Current	Maximum
Numerics:	341971	Unlimited
Adjustables:	668	8000
Integers/Bin.:	668	800
Continuous:	96364	Unlimited
Constraints:	439	4000
Nonlinears:	0	800
Coefficients:	222660	
Obj. Direction:	Maximize	

Activity

Solving...

Elapsed Runtime (hh:mm:ss)

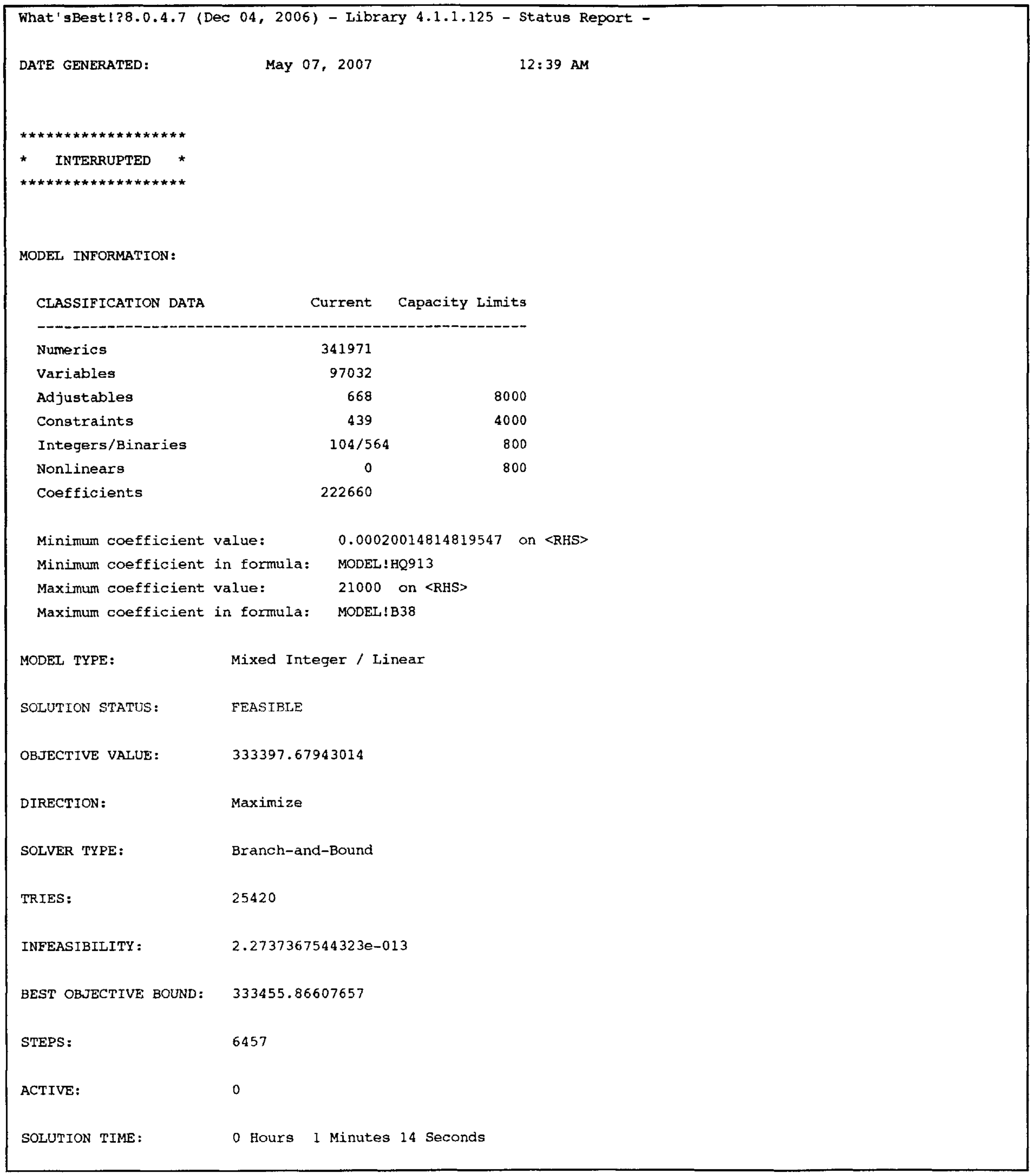
00:00:33

B
0.125
800
700
20
0.5
0.625
300
250
1
200
282
(7,262)
289,600
11,488
1,620
1,313
296,758
21,000
-
275,758
105.02%

O	P
0.750	4
1.375	3
1.500	3
1.625	3
1.750	3
2.375	2
2.500	2
2.625	2
2.750	2
3.375	1
3.500	1
3.625	1
3.750	1
4.375	0
4.500	0
4.625	0
4.750	0
5.375	0
5.500	0
5.625	0
5.750	0
6.375	0
6.500	0
6.625	0
6.750	0

carrier's late containers - F

Appendix D. Sample report from *What's Best!*



```
What'sBest!?8.0.4.7 (Dec 04, 2006) - Library 4.1.1.125 - Status Report -

DATE GENERATED:             May 07, 2007                 12:39 AM


*******************
*   INTERRUPTED   *
*******************


MODEL INFORMATION:

  CLASSIFICATION DATA           Current   Capacity Limits
  --------------------------------------------------------
  Numerics                       341971
  Variables                       97032
  Adjustables                       668              8000
  Constraints                       439              4000
  Integers/Binaries               104/564             800
  Nonlinears                          0               800
  Coefficients                   222660

  Minimum coefficient value:        0.00020014814819547  on <RHS>
  Minimum coefficient in formula:   MODEL!HQ913
  Maximum coefficient value:        21000  on <RHS>
  Maximum coefficient in formula:   MODEL!B38

MODEL TYPE:             Mixed Integer / Linear

SOLUTION STATUS:        FEASIBLE

OBJECTIVE VALUE:        333397.67943014

DIRECTION:              Maximize

SOLVER TYPE:            Branch-and-Bound

TRIES:                  25420

INFEASIBILITY:          2.2737367544323e-013

BEST OBJECTIVE BOUND:   333455.86607657

STEPS:                  6457

ACTIVE:                 0

SOLUTION TIME:          0 Hours  1 Minutes 14 Seconds
```