THE IMPACT OF TRUCK DRIVER HOURS-OF-SERVICE REGULATIONS ON RETAIL WAREHOUSE OPERATIONS

Valerie Maier-Speredelozzi
University of Rhode Island

August 2006

URITC PROJECT NO. 53000466

PREPARED FOR

UNIVERSITY OF RHODE ISLAND TRANSPORTATION CENTER

DISCLAIMER

This report, prepared in cooperation with the University of Rhode Island Transportation Center, does not constitute a standard, specification, or regulation. The contents of this report reflect the views of the author(s) who is (are) responsible for the facts and the accuracy of the data presented herein. This document is disseminated under the sponsorship of the Department of Transportation, University Transportation Centers Program, in the interest of information exchange. The U.S. Government assumes no liability for the contents or use thereof.
--- | --- | ---  
URITC FY05-466 | N/A | N/A

4. Title and Subtitle  
The Impact of Truck Driver Hours-of-Service Regulations on Retail Warehouse Operations

--- | ---  
August, 2006 | N/A

7. Author(s)  
Valerie Maier-Speredelozzi

8. Performing Organization Report No. | 9. Performing Organization Name and Address  
--- | ---  
N/A | Department of Industrial and Manufacturing Engineering, Gilbreth Hall, University of Rhode Island, Kingston, RI 02881, (401) 874-5187, vms@egr.uri.edu

10. Work Unit No. (TRAIS) | 11. Contract or Grant No.  
--- | ---  
N/A | URI 53000466

12. Sponsoring Agency Name and Address  
University of Rhode Island Transportation Center, Carlotti Administration Building, 75 Lower College Road, Kingston, RI 02881

13. Type of Report and Period Covered  
Draft

A study conducted in cooperation with U.S. DOT

15. Supplementary Notes  
N/A

16. Abstract  
Warehouse procedures affect productivity for the entire supply chain and transportation network. The revised hours-of-service regulations for highway safety require commercial truck drivers to include loading dock time in their on-duty hours. Retailers must help carriers meet schedules, ensure driver compliance, and improve warehouse efficiency so that transportation costs are minimized. The current state unloading process for a warehouse is analyzed and simulated and shown to exceed the desired times for the company and carriers. Lean manufacturing techniques are used to identify wastes in the process and a new procedure is proposed and modeled, generating a projected 46% time savings.

17. Key Words  
Hours-of-Service, Simulation, Distribution, Lean Logistics

18. Distribution Statement  
No restrictions. This document is available to the Public through the URI Transportation Center, Carlotti Administration Building, 75 Lower College Rd., Kingston, RI 02881

Unclassified | Unclassified | 20 | N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized (art. 5/94)
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES &amp; FIGURES</td>
</tr>
<tr>
<td>1- INTRODUCTION</td>
</tr>
<tr>
<td>2- BACKGROUND</td>
</tr>
<tr>
<td>3- LITERATURE REVIEW</td>
</tr>
<tr>
<td>4- DATA COLLECTION AND ANALYSIS</td>
</tr>
<tr>
<td>4.1- Facility 1, December, 2004</td>
</tr>
<tr>
<td>4.2- Facility 1, April, 2005</td>
</tr>
<tr>
<td>4.3- Facility 2, April, 2005</td>
</tr>
<tr>
<td>5- CURRENT RECEIVING PROCESS</td>
</tr>
<tr>
<td>5.1- Current Receiving Process Modeling</td>
</tr>
<tr>
<td>5.2- Current Receiving Process Problems</td>
</tr>
<tr>
<td>6- IMPROVED RECEIVING PROCESS</td>
</tr>
<tr>
<td>6.1- Improved Receiving Process Scenario 1</td>
</tr>
<tr>
<td>6.2- Improved Receiving Process Scenario 2</td>
</tr>
<tr>
<td>7- SUMMARY AND CONCLUSIONS</td>
</tr>
<tr>
<td>8- ACKNOWLEDGEMENTS</td>
</tr>
<tr>
<td>9- REFERENCES</td>
</tr>
</tbody>
</table>
LIST OF TABLES

TABLE 1. Summary of Statistics for 38 Trailers at Facility 1 .................................. 9
TABLE 2. Pallet Verification Times for 3 Receivers (in seconds) ............................... 19
TABLE 3. Current Process Model Resource Utilization (Average of 100 replications)........ 20
TABLE 4. System Cost, Process Time and Percent Utilization of Resources ............... 28
TABLE 5. Summary of Process Model Blocking .......................................................... 29

LIST OF FIGURES

FIGURE 1. Histograms of Trailer Unload Times, Case Count, Number of Items, Weight, Cases per Item, and Volume at Facility 1, December, 2004................................. 10
FIGURE 2. Correlation between Number of Cases and Unload Time, Facility 1.......... 11
FIGURE 3. Unloading Time Frequency at Facility 1 .................................................... 13
FIGURE 4. Number of Cases Received for 38 trucks at Facility 1............................... 13
FIGURE 5. Correlation between Number of Cases and Unload Time, Facility 1, April.. 14
FIGURE 6. Unloading Time Frequency at Facility 2 .................................................... 15
FIGURE 7. Number of Cases Received Per Truck at Facility 2 ................................... 16
FIGURE 8. Correlation between Number of Cases and Unload Time, Facility 2........... 17
1- INTRODUCTION

This report concludes a project that investigated the impact of the revised hours-of-service regulations for truck drivers on the warehouse operations of retail distributors. Warehouse procedures not only affect productivity at that facility, but also the performance of upstream and downstream activities in the supply chain, and their connecting transportation networks. The new federal hours-of-service regulations now require commercial truck drivers to include time spent waiting at loading docks as part of their on-duty hours, in an effort to reduce fatigue and fatality accidents, and thereby improve highway safety (1). This means that retail distribution centers need to be even more efficient in unloading procedures, so that deliveries can be accepted and drivers can be released quickly.

The specific areas targeted for waste reduction in this study are the receiving and sorting areas of a retail warehouse. Lean initiatives involve the reduction and elimination of waste and non-value added activities in a manufacturing facility. Non-value adding activities are those which add no value to the product from the perspective of the customer, such as defects, waiting, motion, over-processing, over-production, inventory, and inefficiency. At this distribution center, consumer products arrive on tractor trailers, are unloaded and sorted, received, and placed into inventory, which is later shipped to individual stores for order fulfillment in response to customer demand. Employees at the warehouse are responsible for checking the products that arrive, to verify that they match the purchase order, and to release payment to the vendor. Due to the fiscal importance of this task, the truck drivers are generally not released until the process is complete. This takes them away from their primary job responsibility of operating the tractor trailer vehicle and puts them in the position of waiting at loading docks until the cargo can be verified.
In the past, contracts between transportation carrier companies and this retail company were written with a specific unload time, often 2 hours. In many cases, unloading of a full trailer actually takes much longer than 2 hours, but both sides accepted this fact, or perhaps did not fully realize how prevalent the problem of extended unload times had become. Scheduling systems are based on expert knowledge but it is difficult to predict both arrival times and unload times accurately. Now, the transportation companies are facing labor shortages and fiscal implications of the changes in hours-of-service rules, and they are enforcing these contract times by charging more detention fees to the retailers. Contracts are being renegotiated with even shorter unload times, such as 1 hour and 45 minutes, or even 1.5 hours, and the retail companies are trying to respond.

In this project, operations at the receiving docks of a retail distribution center were modeled. Load/unload times, driver hours-of-service conditions, and wait times were collected to assess the impact of the new regulations, including a simulation model of the receiving operations. Recommendations were made for improved procedures that will reduce unnecessary driver wait times and thereby support compliance with the new hours-of-service regulations as well as lead to a more efficient overall distribution and transportation system. Ultimately, coordination and cooperation between the transportation carriers and retail warehouse operations will lead to improved highway safety.

2- BACKGROUND

Hours-of-service regulations are determined by the Federal Motor Carrier Safety Administration (FMCSA) in order to maintain safe highway conditions for everyone. These regulations were established in 1939 and modified in 1962. In 1985, Congress expressed concern about the effect
of commercial driver fatigue as a contributing factor in accidents and directed the FMCSA to review these rules, which were then implemented as of January 4, 2004 according to revisions announced in August 2003. By April, 2004, a coalition of safety advocates had filed a lawsuit challenging the new HOS regulations. The advocate groups include the Citizens for Reliable and Safe Highways (CRASH) and Parents Against Tired Truckers (PATT). In July, the Court of Appeals vacated the new regulations by stating that the FMCSA failed to fully consider driver health, but in August, the FMCSA requested a stay. In September, 2004, the safety advocate coalition filed a brief asking the court to reject the FMCSA’s request. Congress, however, passed a bill on September 30, 2004 that would keep the new rules in effect for one year, or until the FMCSA revised the new rules. By August, 2005, the FMCSA had announced the final rules which took effect on October 1, with a three month grace period for the benefit of the drivers, carriers, and all parties involved.

The revised regulations proposed in 2003 to take effect in 2004 require drivers to include time spent waiting at loading and unloading docks as part of their on-duty hours, which has had significant effects on retail distribution centers. Other changes were made, such as increasing the allowable driving time per day from 10 hours to 11 hours, and increasing the amount of required rest time in a 24 hour period from 8 hours to 10 hours. Drivers must still abide by a maximum of 60 work hours in a 7 day period, or 70 work hours in an 8 day period. This rule, however, was updated to say that the clock restarts after any 34 consecutive hours of rest. Exceptions exist that allow a driver to work a 16 hour shift if they have been dispatched from their home location for the past five tours and follow certain other restrictions. Another exception allows drivers with sleeper berths in their tractor cabs to use time spent resting there to count towards their 10 hour rest times, again while following certain restrictions. The changes regarding load/unload docks,
however, are most significant for analyzing the interface between the transportation providers and retail distribution warehouses. This change is listed as a reduction in the consecutive on-duty hours from 15 hours to 14 hours, with the important update that says breaks do not extend on-duty time. These breaks include time spent waiting at loading and unloading docks as part of their on-duty hours, as well as time during meals and refueling stops. Retail companies must coordinate with trucking companies to meet schedules, ensure driver compliance with the new hours-of-service regulations, and improve the efficiency of warehouse operations so that transportation and logistics costs for both parties will be minimized.

The position of the safety advocate groups that filed the lawsuit is that the new regulations did not go far enough in protecting highway safety. Evidence has shown that the risk of accidents increases between the 10th and 11th hours of driving time. In particular, they argue that the new rules do not promote 24 hour circadian cycles and equate two short rest periods in a sleeper berth to one longer rest. They oppose the fact that dispatchers are allowed to interrupt rest time and that driving times could expand up to 77 hours in a 7 day period or 88 hours in an 8 day period if drivers are forced by their companies to take full advantage of the 34 hour clock reset rule. They also do not apply to all drivers such as those arriving from Mexico. The new rules do not require electronic on-board recorders (OBRs), which is a technology that is in the future of the transportation industry, but which is also still quite controversial. The safety advocates recognize that drivers are already under significant pressure to meet schedules, particularly with the increase in Just-in-Time manufacturing and distribution systems that call for more frequent deliveries of smaller quantities of goods. Drivers are required to keep logbooks to track their on-duty and rest hours, and the OBRs would replace these books. The biggest change between the rules that the FMCSA announced in 2005 relative to those in 2003 was a
clarification to the sleeper berth exception which states that drivers must have at least one 8 hour rest period in the berth, and a 2 hour period of either sleeper berth or off duty time. In order for time spent at a terminal or warehouse to not count against the driver’s hours-of-service, the driver would have to be relieved of all duties and responsibility for the cargo, which is not the case at many retail facilities.

Many industry experts predicted that the new requirements for calculating hours-of-service would negatively impact transportation costs, but neither the trucking industry nor retail distributors had a clear understanding of how to mitigate these effects. The American Trucking Associations (ATA) responded to the proposed HOS changes by arguing that passenger seat riding should count as sleeper berth time under certain conditions, and that daytime and nighttime driving should be equivalent. They would prefer if rest periods were not mandated, and that the new rules should stay in effect while the FMCSA revised them once again to minimize confusion and expensive retraining for drivers. Finally, they would hope that employers can notify drivers of schedule changes, even during rest periods. Transportation carriers responded to the new regulations by increasing their fee structures, collecting detention fees that they previously tended to ignore, and renegotiating contracts, generally with shorter. They are hiring more drivers for long-haul connections and driver teams, because each individual driver can no longer work for as long of a shift once unload times are included. They are also using more drop trailer systems, where the distribution centers assume responsibility for unloading, sorting, and segregating the cargo without a driver present. An alternate solution is to force the distribution centers to sign-off on cargo loads without completing full verification, which does get the driver back on their way sooner, but exposes the warehouse to greater liability.
3- LITERATURE REVIEW

One supply chain management source supports the claim that logistics is the "last frontier" to explore as a "source of new profits for companies" in order to "maintain their competitive advantage (2)." This relates directly to retailers and transportation companies who are both currently concerned that the new government regulations regarding hours-of-service for drivers will negatively impact their costs. Transportation systems for retail distribution can be based on a variety of models such as hub-and-spoke or direct shipment and some researchers have sought optimal solutions to such problems (3, 4). Determining the best model involves a variety of factors, but the fact that more and more companies today are trying to arrange Just-in-time (JIT) manufacturing and distribution systems complicates the optimization process (5). Some transportation customers already impose fees when drivers fail to arrive at specific times, but at the same time some transportation providers may begin to impose fees for unexpected or extended loading dock delays that cause their drivers to exceed maximum on-duty time according to the new rules. Also, local or short-haul drivers have different scheduling issues than the long-haul trucking industry (6). Research has been conducted to support hours-of-service regulations by validating that fatigued drivers are involved in more accidents, but also shows that certain drivers face significant pressure to violate the regulations (7-10). A survey of more than 1,200 drivers at truck stops in 4 states found that 31% of drivers had exceeded the weekly limit on hours driven and that 19% reported falling asleep at the wheel at least once within the past month (11). In addition, many drivers regularly admit to falsifying their logbooks to the point that the call them "comic books." Pressures to falsify records may be economic, schedule driven, traffic related, or due to a lack of sufficient rest stops that allow large trucks to park for a full nights sleep as opposed to limits of just 1 or 2 hours. From a safety perspective, it
is estimated that the new rules will save 75 lives per year, in addition to preventing injuries and property damage insurance claims, saving $628 million in the American economy (12).

Many articles were written within the last several years commenting on the new hours-of-service regulations, but little research focuses on how the industries involved should adjust their operations in response (13-17). A series of articles in a weekly trucking industry newspaper during November and December of 2003 presents both supporting and opposing views on the new regulations. For instance, some carriers are predicting productivity losses of 2 to 19% and were thus warning customers that freight rates will be increasing. Consumers of the transportation industry, however, are claiming that the carriers are only using the new regulations as an excuse to raise rates and wanted additional studies and proof that the carriers truly experiencing higher costs which could not be offset by internal procedural changes (18). Regardless, if the availability of truck capacity for shipments decreases due to drivers requiring more rest time and the cost of remaining capacity increases (19), many retailers will shift to a transportation portfolio that includes both rail and highway carriers (20).

4- DATA COLLECTION AND ANALYSIS

Three periods of data collection were completed at two different retail warehouse facilities, in addition to information that was gathered from company employees and through transportation carriers and industry representatives.

The first segment of data collection looked at delivery records for the retailer. By early September, 2004, detention fees at 11 out of 16 distribution warehouses had already exceeded the 2003 totals at the same facility. The amount of detention charges across the distribution system represents a relatively small dollar figure, when compared to the total financial statement
of the large retailer. The percentage of increase, however, was at 42% and continues to rise due to the new HOS regulations as well as changes in the transportation industry such as higher fuel prices and labor shortages. In addition, these figures are only for cargo loads that are managed directly by the retailer, which represents a small percentage of the total number of trailers delivered. The majority of trailers are vendor-managed, meaning that the vendor continues to own the cargo and arranges for transportation and carrier payment, so data is less available. The retailer has an on-time delivery record of over 98% for self-managed loads and over 90% for vendor or supplier managed loads. This is good, however, any service level improvements for represents significant time and money savings. In addition, employees at the retail warehouse find “lost” pallets daily which were not properly entered into the inventory management system.

Operating procedures at the warehouses have not changed in response to the new HOS regulations, with one exception. The company is now allowing for more “sign-offs” than before. A “sign-off” is when the carrier driver is allowed to leave before the warehouse employees have completely checked in all of the cargo. This is a risky behavior for the retailer, since they are then responsible for paying for all goods that they sign for which may or may not have been inspected. In addition, the burden of proof for any problems that are discovered later is now placed upon them. Sign-offs are undesirable, but sometimes become necessary when drivers arrive late or loads take longer than expected to receive, which puts the driver at risk of exceeding their allowable hours-of-service.

4.1- Facility 1, December, 2004

Hundreds of delivery records were collected during a two week period from December 15-30, 2004. Receivers were asked to record a small amount of additional unload time information and
staple a data collection sheet to the set of purchase orders that they normally submit to the front office in the warehouse. Cargo is not paid for by the retailer until information from these purchase orders is manually entered into a computer system. Once this process was complete, researchers collected the data sheets and began the long process of entering some of the information into a custom database, due to the fact that information in the retailer’s computer was not accessible. Ultimately, 58 records for 3 days were entered manually, but 20 of those had incomplete data, and thus, were not included in the statistical analysis. Table 1 shows a summary of the statistics from these representative trailers of cargo. Figure 1 shows histograms of the different characteristics of cargo loads, such as weight or number of cases. The unload time histogram shows that for these trucks, only 18.4% were in fact unloaded in less than 2 hours, which is an industry standard for the contracts that transportation companies enter into with retail warehouses. All of the parameters passed a normality test, and thus, only 16% of trucks are statistically expected to unload in less than 2 hours given current procedures.

By looking at the receiving operations it is clear that the scheduling procedure has some inefficiency which increases the chaos and inefficiency throughout the rest of the material handling operations and cascades to the transportation carriers. Basically, schedulers do not know the duration of the unloading operations for different trucks in advance. Therefore, the

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Time</th>
<th>Case (QTY)</th>
<th>Volume (cubic meter)</th>
<th>Weight (Kg)</th>
<th>No.of Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>1h 10 min</td>
<td>350</td>
<td>1.21</td>
<td>377</td>
<td>3</td>
</tr>
<tr>
<td>Max</td>
<td>8h 30 min</td>
<td>3,940</td>
<td>51.53</td>
<td>18,514</td>
<td>114</td>
</tr>
<tr>
<td>Ave</td>
<td>3h 48 min</td>
<td>1742.58</td>
<td>23.60</td>
<td>7,630</td>
<td>30.55</td>
</tr>
<tr>
<td>STD</td>
<td>1h 50 min</td>
<td>902.749</td>
<td>13.04</td>
<td>5,033</td>
<td>26.76</td>
</tr>
</tbody>
</table>

1 cubic meter = 35.71 cubic feet
2 Kg = 2.2 lbs

9
FIGURE 1. Histograms of Trailer Unload Times, Case Count, Number of Items, Weight, Cases per Item, and Volume.

Schedulers assign one truck to each free gate at the beginning of the first shift. They approximately know the starting time (truck appointment), but do not know the finishing time. Figure 2 shows that there is no clear correlation between number of cases and unload time. The various factors and combinations of factors were checked for correlations with unload time, but no clear predictive model could be identified with the available data, which is unfortunate since this could greatly improve scheduling efficiency.
FIGURE 2. Correlation between Number of Cases and Unload Time, Facility 1.

On the other hand, uncertain truck arrival times at the gates causes more delays in unloading processes. The current receiving procedure at the retailer can be revised and re-engineered to decrease the time spent unloading each truck. In addition, the employees at the distribution facility need to be more aware of the time required to unload trucks with different cargo characteristics, such as number of cases, volume, weight, class, and types of freight, so that better schedules can be developed and implemented.

4.2- Facility 1, April 2005

The data collected in the first phase of the project led the research team to a better understanding of the operations throughout the system. However, there were some missing data and incorrect information which did not allow correlations to be made with any of the theoretical hypotheses. Therefore, facility 1 was revisited and the unloading operations were personally monitored to
collect additional data. The unloading time of 38 trucks was collected between April 20-22, 2005 and the results are partially different from the December results.

The collected data indicates that almost 80% of receiving operations take 4 hours or more, with an average of 4.6 hours, and a standard deviation of 2.53 hours. The range was from a minimum of 40 minutes and a maximum of 11.3 hours. Figure 3 shows the distribution of the receiving times for the 38 trucks. Also by looking at the amount of cases received in 38 appointments in Figure 4, it can be seen that 60% of the time the size of the cargo falls between 1500 to 3000 cases. This data also is comparable to the first set of data collected. Meanwhile, the data shows that there is a strong correlation between the unloading time and number of cases received. This fact could not be determined from the earlier phase one data but is now demonstrated through the use of Minitab software. The linear regression analysis and correlation test showed that R-square is 95.6% (more that 75%) and P-value is equal to 0 (less than 0.05). Figure 5 shows the trend line drawn based on the correlation between receiving time and number of cases in each truck.

**Regression Analysis: Cases versus Unloading Time**

The regression equation is

\[ \text{Cases} = -478.4 + 10.5 \times \text{Unloading Time} \]

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Coef</th>
<th>SE Coef</th>
<th>T</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-478.4</td>
<td>125.9</td>
<td>-3.80</td>
<td>0.001</td>
</tr>
<tr>
<td>Unloadin</td>
<td>10.5217</td>
<td>0.3751</td>
<td>28.05</td>
<td>0.000</td>
</tr>
</tbody>
</table>

\[ S = 402.6 \quad \text{R-Sq} = 95.6\% \quad \text{R-Sq(adj)} = 95.5\% \]

**Analysis of Variance**

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>127534620</td>
<td>127534620</td>
<td>786.72</td>
<td>0.000</td>
</tr>
<tr>
<td>Residual Error</td>
<td>36</td>
<td>5835905</td>
<td>162108</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>133370526</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unloading Time Histogram

FIGURE 3. Unloading Time Frequency at Facility 1.

Receiving Cases Histogram

FIGURE 4. Number of Cases Received for 38 trucks at Facility 1.
4.3- Facility 2, April, 2005

For comparison, facility 2 was also visited in April 2005. The purpose of this visit was mainly observing the agile receiving operations being performed at the facility. The facility has two 8 hour shifts starting at 5:00am and ending at 9:00pm. Based on the data collected in the visiting period, the facility has about 30 active gates with the purpose of receiving merchandises through truck delivery. A daily receiving schedule is made for about 65 appointments between 7:00am and 6:00pm. This schedule results in an average of two appointments (trucks) per receiving door. In other words, the expected time for unloading, sorting, and receiving operations for each appointment is somewhere between 6 and 8 hours. However, the data for 134 appointments in 3 days indicates that 66% of the trucks leave the facility in under 3 hours, which means the receiving area requires 3 to 5 hours to clean up and get ready for the next appointment. Figure 6 shows the distribution of unloading times for these 134 appointments.
Employees at facility 2 use utilize a bar-coding system with scanning guns, in order to expedite the receiving of the purchase orders and eliminate some of the human errors which usually occur in manual recording systems. Receiving records get updated in real time as soon as the barcodes on received items are scanned. Hence, there is no payment delay while waiting for records to be manually entered into the system. Although the bar-coding system makes the receiving operations appear to run smoother, the system by itself is not the main reason for the quick truck discharge. The receiving area at this facility is almost 1.5 times longer than the standard truck length. Therefore, there is enough room for the unloading crew to line all of the pallets up on the floor and provide adequate space for sorting the cases. Because of the wide receiving lines and quick receiving process, lift trucks can move the received pallets and open up floorspace for other unsorted pallets. Hence, in less than 3 hours pallets are received and checked and ready to be transferred to random inventory, allowing the truck driver to leave the facility.
By comparing similar unloading data between the two facilities, it can be observed that trucks mainly stay longer at the receiving docks of facility 1. This is mainly because of the limited receiving area facility 1 which does not allow the unloading crew to fully discharge and sort the whole cargo and release the truck. Data regarding the amount of cases received in both facilities shows that almost 60% of the time trucks carry 1500 to 3000 cases per delivery. Figure 7 presents the distribution of the cases received per truck in facility 2.

According to the facility 2 data analysis, no correlation was found between receiving time and number of cases per truck. This can be seen in Figure 8 where the graph does not show any pattern. The lack of correlation in the December 2004 data from Facility 1, and the April 2005 data from Facility 2 is explained by two factors. In both situations, the data was provided by the company, rather than collected by the researchers themselves. Consequently, in the first instance, this led to inaccurate data and unreported times from receiver logs. In the case of Facility 2, a great deal of data was available electronically, due to their more automated
information systems. This data, however, could not account for anomalies, or “special cause” variation. For instance, whenever either facility receives a cargo trailer with cosmetics, the unload time is disproportionately long. The sorting and segregating procedure takes much longer due to the high variety and small size of the items. Generally, whenever a truck with cosmetics or other small, high variety items such as bandages arrives, the facility gives this truck low priority and assumes it will take the remainder of the shift and possibly multiple shifts to unload. For this reason, drivers are released without full validation of the loads, and increasingly, these shipments are made using “drop” trailers. Drop trailers are those where the carrier leaves a full trailer in an adjacent lot, and picks up an empty trailer. Thus, the unload time for the driver is negligible. The facility tries to schedule these drop trailers to be unloaded during a time of lighter loads during the next 48 hours, generally during second or third shift.

FIGURE 8. Correlation between Number of Cases and Unload Time, Facility 2.
5- CURRENT RECEIVING PROCESS

Improvement efforts were concentrated on the smallest of the receiving areas in facility 1 which experiences higher utilization and blockage. The sequence of operations is as follows. The receiving process starts when a tractor trailer arrives at the unloading dock with an average load of 40 large pallets, and a pallet size of 101.6 cm by 121.9 cm (40 inch by 48 inch), with each pallet containing a mix of product cartons or SKU's. An operator utilizes a forklift to move approximately 8 to 12 pallets to the receiving area until the area is full. Collected data indicates a mean time of approximately 1 minute for unloading each large pallet. A temporary employee, known as a Lumper, then begins sorting the mixed cartons, and places them on smaller 76.2 cm by 91.4 cm (30 inch by 36 inch) pallets. Each small pallet can contain only one product SKU for assignment to Random Inventory locations. Collected data and observations indicate that large pallets may contain between two and eight different product SKUs which need to be sorted. Time study data indicates that sorting times for breaking down one large pallet into 4 to 6 small pallets are approximately 1 minute.

Once the cartons are sorted onto the smaller pallets by the Lumper, the Receiver checks the product against the purchase order to verify that the amount ordered is what was shipped to the distribution center. Typically, a Receiver is responsible for three doors, with a Lumper normally assigned to one door. Collected data for Receiver verification for each small pallet are shown in Table 2. The overall mean verification time for each small pallet is 46 seconds. The small pallets containing the sorted product are then cleared to be moved to Random Inventory queues by a material handler using a pallet jack. The material handlers remove the sorted pallets to the Random Inventory queues on an as needed basis, and are not dedicated to any particular door.
### TABLE 2. Pallet Verification Times for 3 Receivers (in seconds)

<table>
<thead>
<tr>
<th>Receiver</th>
<th>Collected operating times</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33, 29, 28, 80, 51, 18, 86, 44, 48, 47, 45, 23, 45, 50, 80, 36, 48, 76</td>
<td>48.16</td>
<td>20.3</td>
</tr>
<tr>
<td>2</td>
<td>25, 26, 41, 29, 38</td>
<td>31.8</td>
<td>7.3</td>
</tr>
<tr>
<td>3</td>
<td>15, 21, 37, 43, 28, 38, 66, 44, 72, 27, 30, 132, 55, 88, 19</td>
<td>47.66</td>
<td>31.3</td>
</tr>
</tbody>
</table>

### 5.1- Current Receiving Process Modeling

The collected data was converted into input for a simulation model that mimics the current state receiving process, built in ProModel software. The model uses an average trailer load of 40 large pallets, a forklift unloading time of 1 minute for each large pallet, a Lumper sorting time that is uniformly distributed between 1 minute and 2 minutes for each large pallet, and a Receiver verification time uniformly distributed between 0.5 and 1.5 minutes for each small pallet. Each large pallet was randomly split into between 2 and 8 small pallets.

Table 3 is the average results of 100 replications of the current state model for resource utilization. It can be seen that the average time required to unload and receive the product from a tractor trailer is 348.46 minutes (Scheduled Time column). This equates to 5.8 hours, almost three times the retailer goal of 2 hours receiving time per trailer. The 40 large pallets were split into an average of 180.15 small pallets (Number Times Used column in table 3). In addition, resource utilization for the Receiver is extremely low, at only 52.7%. Although this model simulates the Receiver dedicated to one door and trailer, in actuality they cover three doors. Actual Receiver percentage utilization may differ from the model, but observations during data collection show that once the receiving area is blocked with product, the receiver has significant idle time. However, this idle time was not recorded, and cannot be quantified from the collected data. The 5.8 hour unload time simulated is within the range of 1.16 hours to 8.5 hours actually observed at the facility, with an average of 3.8 hours and a standard deviation of 1.83 hours. The
current process model also indicates a high percentage of blocking occurring in the receiving area. With 100 model replications, the simulation shows the large pallets being blocked from unloading an average of 99.4% of the time and the small pallets blocked 67.7% of the time in the current process.

TABLE 3. Current Process Model Resource Utilization (Average of 100 replications)

<table>
<thead>
<tr>
<th>Resource</th>
<th>Units</th>
<th>Scheduled Time (MIN)</th>
<th>Number of Times Used</th>
<th>% Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forklift</td>
<td>1</td>
<td>348.46358</td>
<td>40</td>
<td>10.56949</td>
</tr>
<tr>
<td>Lumper</td>
<td>1</td>
<td>348.46358</td>
<td>180.15</td>
<td>78.65525</td>
</tr>
<tr>
<td>Receiver</td>
<td>1</td>
<td>348.46358</td>
<td>180.15</td>
<td>52.72088</td>
</tr>
<tr>
<td>Pallet truck</td>
<td>1</td>
<td>348.46358</td>
<td>180.15</td>
<td>10.46452</td>
</tr>
</tbody>
</table>

5.2- Current Receiving Process Problems

The current receiving process utilizes a batch processing method, where large quantities of product are unloaded from the trailers, to the point where the receiving area is blocked. The Lumper is unable to sort the cartons quickly enough to maintain a steady product flow. Observations conclude that blocking occurs within approximately one hour, at which point product flow ceases. The high percentage of blocking in the current process model verifies the observations made during data collection. The result is time wasted by the Receiver waiting for the sorting operations to be accomplished by the Lumper, and time wasted by the Lumper waiting for the sorted pallets to be verified and moved to the Random Inventory queues.

In addition, the current process requires movement of the Receiver and Lumper to the palletized products for the sorting and verification operations. This results in wasted movement throughout the receiving area. Once the receiving area is blocked, movement between the pallets
is extremely difficult, which prolongs the sorting and verification tasks. Repeated handling and movement of the pallets occurs in order to create space for additional pallets to be unloaded from the trailers.

Defects in sorting were also observed during data collection when Lumpers would mistakenly mix SKUs on the small pallets. During the verification process by the Receiver, the mistake is found, but by then the responsible Lumper may have left the area and needs to be called back to correct the error, resulting in wasted waiting time. Many times the mixed pallets are blocked between other sorted pallets, resulting in additional wasted movement and shuffling of other pallets to gain access to the ones containing defects.

Without a dedicated material handler to move verified pallets to the Random Inventory queues, there was also wasted time by the Receiver and Lumper waiting for the area to be unblocked. Observations conclude that there are no signals, or standardized methods, to alert the material handlers as to when verified pallets are available for transfer to the Random Inventory queues. Overall, the receivers are underutilized which is a significant financial problem, as they are the highest paid employees in the facility, and thus, a valuable resource. The retailer incurs detention charges assessed by the shipping companies for keeping drivers at the unloading docks for long periods of time while they wait for the load to be received. Extra costs can also be associated with the excess work-in-process inventory in the receiving and sorting areas, to the point where the areas are blocked and product flow ceases. This extends the leadtime between when products are ordered by the buyers to when they are actually received and stored in the warehouse inventory, both physically and electronically.

The current sorting process also has potential health problems associated with lifting cartons from the floor level. Lifting, in ergonomic terms, is defined as moving an object from a
lower level to a higher one. The result is stress in the lower back from work performed in transferring objects from one plane to another. The Lumpers must lift cartons from ground level during the current sorting operation. During lifting, they are also bending over and twisting in awkward positions. In a study conducted by the U.S. Department of Health and Human Services, there is a direct correlation between lower back disorders and work-related lifting and awkward positions (21). According to the Bureau of Labor and Statistics, overexertion was the leading cause of all worker injuries in the 1990's, at almost 28%, with almost 46% of these injuries leading to lost work time of 21 days or more (22). It is clear that the retailer should be very concerned with the current receiving and sorting process, and its tendency for causing worker injury. From the collected data it is concluded that the current receiving process contains wastes of waiting, movement, defects, inventory, and inefficiency, which should all be targeted for improvement through lean methods.

6- IMPROVED RECEIVING PROCESS

In order to move away from the current large batching process in the receiving area, an efficient process flow needs to be established. Flow is the continuous movement of material or product through a process. Improved flow leads to lower inventories, better quality, less floor space, better communication between work stations and employees, faster responses to problems, and shorter throughput (23). An improved process flow using lean methodology can greatly reduce the current receiving process time for each trailer of products delivered, and reduce the assessed detention charges. Two alternate improvements to the current receiving process were analyzed, both utilizing gravity fed conveyors to move pallets and improve flow.
6.1- Improved Receiving Process Scenario 1

The first solution incorporates three 20 foot sections of gravity fed conveyor in the receiving area. The conveyors are positioned approximately 3 feet from the floor, and sloped so that the pallets feed by the force of gravity. The large conveyor, located between the two smaller conveyors, is used to hold 5 large pallets for processing. A Receiver, utilizing a forklift, unloads pallets from the trailers and places them on the large conveyor. Located 0.915 meters (3 feet) away on both sides of the large conveyor are two smaller conveyors, each capable of holding 6 small pallets. Figure 9 is a view of this simulated conveyor system.

The two Lumpers and one dedicated Receiver perform their tasks at the end of the conveyor systems, allowing the pallets to flow to them. The Lumpers move between the large conveyor and the smaller ones, sorting the product SKUs onto small pallets, which are loaded onto the small conveyors. The Receiver verifies the contents of the sorted pallets against the

purchase orders, and moves between the two small conveyors at the end of the line. At the end of each small conveyor, there is a lift table equipped with a pallet positioner. The pallet positioners allow the sorted pallets to be turned by the Receiver during the verification process. The lift tables are then used to lower the sorted and verified pallets onto the floor. A ramp at the end of each lift table allows access to the small sorted pallets by a material handler utilizing a pallet jack. The material handler then moves the sorted and received pallets to the Random Inventory queues. The forklift operator places more large pallets on the large conveyor as space becomes available.

This processing system offers distinct advantages over the current process. First and foremost is the reduction in the chance for worker injuries due to lifting from an awkward and bent over position. Proper workstation height for situations involving forceful work aided by upper body weight is directly related to the operator’s elbow height (24). The proper height of a workstation involving forceful tasks, for the 50th percentile of the population, and averaging the female and male statistics, is 68.8-93.7 cm (27.1-36.9 inches). At this height, lower back strain and injury due to lifting is minimized. The conveyor for the proposed process will be elevated to a height of approximately 81.3 cm (32 inches) at the operator workstations, thereby reducing lower back strain.

The improved process also addresses the wastes present in the current receiving process. Utilizing conveyors for the process flow will reduce the amount of inventory and work-in-process. Large pallets will not be allowed to be unloaded from the trailers and placed on the floor, thereby blocking the receiving area. With reduced blocking, product flow will continue through the process, and not collect between processes or locations, and the Receivers and Lumpers will have less waiting time and less unnecessary movement. The repeated handling of
the same pallets, in order to create floor space for unloading additional pallets, is also eliminated. Waiting time by the tractor trailer drivers will also ultimately be reduced, since their loads will be processed and received much more quickly. The quality of sorted products will be improved. The Receivers and Lumpers will be working closely, enabling better communication between the operators. If a mixed pallet of sorted SKUs is found during verification, it can be corrected immediately, and will be confined to single pallets instead of large batches of inventory. In addition, the improved process will greatly reduce the amount of waiting time inherent in the current receiving process. The Receivers will not have to wait for batches of the large pallets to be sorted by the Lumpers. The sorted products can be verified as the small pallets become available at the end of the small conveyors.

The improved layout also reduces the inefficiencies that are present in the current receiving process. The Receivers will not have to wait for large batches of product to be sorted by the Lumpers before they can begin the verification process. This will result in an increase in Receiver utilization. Also, with the receiving area no longer becoming blocked, there will be no wasted effort by operators trying to move between the pallets in order to perform tasks.

The average time required to unload and receive the product from a tractor trailer dropped significantly from the current process model time. The current process model time is 348.46 minutes or 5.8 hours, and the scenario 1 model time is 187.04 minutes or 3.1 hours, an improvement of 46.6%. Although this solution does not meet the goal of 2 hours receiving time per trailer, set by both the retailers and transportation carriers, it is still a significant improvement over the current process. The 40 large pallets were split into an average of 180.31 small pallets. Also, resource utilization for the Receiver has appreciably improved to 97.22% from the current process model utilization of only 52.7%. The Receiver has become the bottleneck during the
process in this model. Adding a second Lumper to the process has dropped the single Lumper utilization slightly from 78.65%, but the utilization for both is over 73% for this solution. The blocking percentage for the receiving area in scenario 1 has also improved significantly over the current process model. Large Pallet blocking from the trailers has dropped from 99.4% in the current process model to 76.25% for the solution 1 model. Small pallet blocking has also improved from 67.7% to 16.52%. This is an indication that the product flow in the receiving area has greatly improved using the layout proposed in this solution. Results include the reductions in wastes of waiting time, movement, inventory, inefficiency, and process cycle time.

With this process design, there still exists one drawback and waste associated with the double handling of sorted pallets. At the end of the small conveyors, the sorted and verified products are lowered to the floor, where the material handlers move them to the Random Inventory queues. Once in the queues, they are then retrieved by the High-Rise material handlers for assignment to an inventory location. This results in the double handling of the sorted products. This can be eliminated by having the small conveyors feed directly into the Random Inventory queues. The improved receiving process scenario 2 addresses this wasted handling. In addition, scenario 1 has some drawbacks associated with the space requirements for the pallet lift table and dock plate ramp needed at the end of the small conveyors. This equipment is needed to lower the pallets to floor level and allow access by the material handlers using pallet jacks, and adds an additional 2.14 m (7 feet) to the conveyor cell. The result is an unloading lane at the end of each conveyor cell of only 1.53 m (5 feet), which may not be adequate for access by the pallet jacks.
6.2- Improved Receiving Process Scenario 2

The second solution to improve the current receiving process is similar to the first one, with the addition of 4.58 m (15 feet) of gravity fed conveyor at the end of each small conveyor section. This solution also incorporates three 6.1m (20 foot) sections of gravity fed conveyor, one large and two small width, with the smaller conveyors positioned approximately 83.9 cm (2 feet 9 inches) from the large conveyor on both sides. The smaller conveyors feed into pallet positioners, which then feed directly to the 4.58 m (15 foot) small width conveyor sections and Random Inventory queue. The large pallet trailer unloading process, Lumper sorting, and Receiver verification process would remain unchanged from scenario 1. The pallet positioners on each small conveyor line allow for manual turning of the sorted pallets during the verification process. The addition of the 15 foot conveyor sections, feeding directly to the Random Inventory queues at the end of the small conveyor lines, eliminates double handling of the sorted pallets.

The time for the receiving process of 315.93 minutes or 5.3 hours in the scenario 2a model increased drastically from the scenario 1 model time of 187.04 minutes or 3.1 hours. This is attributed to a shift in the bottleneck resource. In the scenario 1 model, the Receiver was the bottleneck, with a utilization of 97.22%. In the scenario 2a model, the Receiver is now at 57.36% utilization, and the High-rise lift is at 98.79%. This indicates that the High-rise lift resource and the process of moving the sorted pallets to Random Inventory locations is now the bottleneck. Lumper utilization dropped to approximately 43% in this model from over 73% in the solution 1 model. It is clear that an additional resource of a High-rise lift is needed in order to keep pace with the conveyor cell.
An alternate solution simulation, scenario 2b, was run with an additional High-rise lift resource. The resource utilization results from 100 replications of this model, having two High-rise lifts moving sorted pallets to Random Inventory locations. With the addition of a High-rise lift resource, the receiving process time has dropped dramatically to 185.76 minutes or 3.1 hours as compared to 315.93 minutes or 5.3 hours in the solution 2a model. The Receiver is once again the bottleneck in the process with a utilization of 96.45%. The High-rise lifts are both at approximately 84% utilization and the Lumpers are roughly at 73%.

Table 4 is a summary of results for 100 replications of ProModel simulation modeling statistics for solutions 1 and 2 compared to the current process. As compared to the current receiving process model time of 348.46 minutes or 5.8 hours as shown in Table 4, solution 2b has a significant reduction in time of 46.69%. In addition, the percentage of blocking in the receiving area that is present in the current process model has been drastically reduced, as seen in Table 5. The current process model results led to large pallets being blocked from unloading an average of 99.4% of the time, and the small pallets blocked 67.7%. The blocking percentages for the large and small pallets for the alternate solution 2b process model are 76.31% and 14.86% respectively. This indicates a significant decrease in the amount of blocking that occurs, and

<table>
<thead>
<tr>
<th>Process Model</th>
<th>System Equip Cost ($)</th>
<th>Receiving Process Time (MIN)</th>
<th>Forklift 1 (%)</th>
<th>Lumper 1 (%)</th>
<th>Lumper 2 (%)</th>
<th>Receiver (%)</th>
<th>Pallet Truck (%)</th>
<th>Highrise Lift1 (%)</th>
<th>Highrise Lift2 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Process</td>
<td>0</td>
<td>348.46</td>
<td>10.57</td>
<td>78.66</td>
<td>NA</td>
<td>52.72</td>
<td>10.47</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>13,139</td>
<td>187.04</td>
<td>20.48</td>
<td>73.97</td>
<td>NA</td>
<td>97.22</td>
<td>79.70</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Scenario 2a</td>
<td>11,018</td>
<td>315.93</td>
<td>12.79</td>
<td>43.08</td>
<td>42.87</td>
<td>57.36</td>
<td>NA</td>
<td>98.79</td>
<td>NA</td>
</tr>
<tr>
<td>Scenario 2b</td>
<td>11,018</td>
<td>185.76</td>
<td>21.88</td>
<td>73.61</td>
<td>72.50</td>
<td>96.45</td>
<td>NA</td>
<td>83.97</td>
<td>84.01</td>
</tr>
</tbody>
</table>

TABLE 4. System Cost, Process Time and Percent Utilization of Resources
TABLE 5. Summary of Process Model Blocking

<table>
<thead>
<tr>
<th>Process Model</th>
<th>Large Pallet % Blocked</th>
<th>Small Pallet % Blocked</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Process</td>
<td>99.40</td>
<td>67.70</td>
</tr>
<tr>
<td>Solution 1</td>
<td>76.25</td>
<td>16.52</td>
</tr>
<tr>
<td>Solution 2</td>
<td>76.31</td>
<td>14.86</td>
</tr>
</tbody>
</table>

indicates that the alternate solution 2b process model has a greatly improved product flow through the receiving process.

The alternate solution 2b process has reduced all of the same wastes that were addressed in solution 1, but also eliminates the double handling of sorted pallets. In this model, sorted pallets are no longer moved to Random Inventory queues by material handlers, only to be handled again by the High-rise lifts for assignment to Random Inventory. The sorted pallets are removed from the conveyor cell directly by the High-rise lift operators. As compared to the solution 1 process, alternate solution 2b is the preferred conveyor cell layout.

7- SUMMARY AND CONCLUSIONS

This study analyzes the impact of changes in the hours-of-service regulations on retail distribution, the current status of truck unloading and receiving processes at one company’s facility, and presents recommendations for improvement through the implementation of lean philosophies. The retailer’s current receiving process at the distribution center utilizes a batch processing method that is highly inefficient and contains many wastes, including waiting time of resources, movement of personnel and material, high inventory levels, receiving area blocking, sorted pallet defects, and resource inefficiencies. These wastes have led to an unloading procedure for tractor trailers that often takes longer than the two hour standard contract time specified by transportation carriers and forces the retail warehouse to keep drivers waiting.
Transportation safety advocates were concerned that the new hours-of-service regulations were increasing the allowable driving time from 10 to 11 hours. From a retailer's perspective, however, the more drastic effect was that a driver's on-duty time would now include time spent waiting at unloading docks. Given that current state unloading times during two different phases of data collection at facility 1 averaged 3.8 hours and 4.6 hours, respectively, the workday for truck drivers was effectively shortened. Now drivers with an average cargo are only able to transport goods for approximately 7 hours, rather than potentially up to 10 hours in the past, when time spent at the unloading dock was exempt from hours-of-service regulation. This means that they must hire more drivers and driver teams than before, which is difficult to do in an industry with high turnover, difficult working conditions, and an aging workforce. More fees are now being incurred when transportation companies pass their increased transportation costs on to vendors and retailers while following the new hours-of-service regulations.

Simulating the current unloading process using ProModel results in a receiving time of 348.46 minutes or 5.81 hours. For Solution 1, the conveyor cell's process time is 187.04 minutes or 3.12 hours, which is a decrease in time of 46.33%. For Solution 2b, the conveyor cell's process time is 185.76 minutes or 3.10 hours, a 46.69% improvement over the current process model. Resource utilization in the current process model is extremely low, with Receiver utilization at only 53%. Simulation results show an increase of Receiver utilization up to approximately 97%. In the current process, the Lumper is the bottleneck resource. In solutions 1 and 2b, the bottleneck has shifted to the Receiver, as determined from the utilization percentages. The implementation of Lean processing methodology by the installation of conveyor cells in the receiving areas can significantly improve the process cycle time, costs, and resource utilization. In addition, the conveyor cells will also improve throughput and reduce area
blocking. It is concluded from this report that the installation of the proposed solution 2b conveyor cells for the implementation of lean processing, with a cost for each cell of $11,018, will significantly improve the current receiving process which serves as the interface between the retailer and the transportation carriers, thereby reducing the retailer’s operating costs and the transportation costs.

The most important results from this project can be summarized with the following three statements, related respectively to the three areas of work: 1) background studies on the hours-of-service regulations and transportation industry, 2) current state data collection at a retail distribution center, and 3) simulation of current state and proposed future state designs for the receiving operations.

♦ Revised hours-of-service regulations now require time spent waiting at unloading docks to count towards driver time limits, and thus, retailers must respond with improved efficiency in their operations.

♦ The retail company was not fully aware of how long their unload processes required, which was measured with averages of 3.8 hours and 4.6 hours during two separate data collection periods at facility 1.

♦ Simulation of the current state yielded a process time of 5.81 hours, which was improved by approximately 46% with simulations of proposed new layouts and procedures in the receiving area, as well as many other benefits that can be seen in the new layout.

The changes in the hours-of-service regulations have greatly affected the transportation industry and carrier companies, but these effects have also cascaded to their upstream and downstream links in the supply chain, namely, vendors and retailers. Any improvement made to
the retail warehouse receiving process will improve the situation for transportation carriers, who are still in the process of adjusting to the new hours-of-service regulation, in addition to facing other pressures in the transportation industry such as its aging workforce and labor shortages. The proposed redesigns for the receiving area not only improve ergonomic work conditions and communication for the employees, but also reduce work-in-process, inventory, blocking, idle waiting time, and wasted motion. This will reduce transportation costs, which affect profits for both the retailers and carriers. Most importantly, pressure on drivers is relieved when retailers have a better sense of how much time unloading activities require and implement lean manufacturing philosophies to reduce these times. Waiting time for transportation carrier drivers will ultimately be reduced, since their loads will be processed more quickly, allowing them to be released for their next driving assignment sooner, and without being in danger of exceeding the limits set by the hours of service regulations to ensure highway safety.

8- ACKNOWLEDGEMENTS

The authors gratefully acknowledge financial support through the University of Rhode Island Transportation Center and the U.S. Department of Transportation. The authors also acknowledge the retail company for the motivation of this project and their openness to share data with the authors.

9- REFERENCES


