Overcoming the Driver Shortage by Addressing Driver Detention

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ABSTRACT

In the United States, long-haul trucking is the main mode of transportation of goods. The trucking industry has been facing a shortage of drivers in the past few years and it is only increasing every year. Previous studies have found that multiple reasons are contributing to the driver shortage. These include underutilization of drivers' working hours, unfavorable working conditions leading to reduced driver retention, the inability to attract new drivers due to high costs in acquiring licenses, and lower income compared to other comparable jobs in the market. The current study focuses on addressing the driver shortage issue by studying factors causing underutilization. Driver utilization is calculated using the number of hours a driver drives on a typical working day and comparing it with the federal hours of service regulation. The data analyzed for this study was collected from a midsize U.S. transportation company. Specifically, this is the driver log data from the truck's Electronic Logging Devices (ELDs). Statistical data analysis showed that the driver detention time or dwell time at warehouses for loading and unloading contributed to the underutilization. More significantly, it was higher during the weekends than the weekdays. Through interviews, this capstone has identified the major factors affecting the dwell time during the weekends: having inexperienced personnel during weekends, lack of communication, training of personnel, and the scheduling of the trucks. By acting on these factors and improving warehouse operations, the industry can achieve valuable improvements in truck driver utilization. These improvements can help warehouses with efficient load operations and also address and alleviate the driver shortage problem by approximately 20%.

Capstone Advisor: Dr. David Correll
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1 Introduction

1.1 Motivation and Relevance

In the United States, trucking is estimated to account for 72.5% of freight tonnage and generates around $800 billion in revenue (American Trucking Associations, 2020). Trucking is the backbone of the freight transportation industry; however, it has been consistently facing an acute shortage of drivers over the years. Although there are about 3.36 million truck drivers (American Trucking Associations, 2020.), which includes around 1.8 million heavy and tractor-trailer truck drivers (U.S. Bureau of Labor Statistics, 2020) currently available, there was an estimated shortage of 80,000 drivers in 2021. By 2024, the shortage is expected to surpass 100,000 (American Trucking Associations, 2020.)

The mismatch between truck driver supply and demand has been continuous for the past 15 years. One of the "traditional" reasons for driver shortages is that the estimated average age of a truck driver is 55 years (Sheffi, 2021), which demonstrates the lack of appeal in this career for younger aspirants. Also, given that the minimum age for acquiring a commercial driver's license (CDL) is 21, many individuals have already chosen other career paths by this age or find the tuition for getting a CDL too costly for the average young learner. Furthermore, the lifestyle of a long-haul truck driver is known to be demanding. Long-haul truck drivers are commonly on the road for two or three weeks, followed by short periods at home before hitting the road again. In addition, truck drivers complain continuously about being disrespected by the warehouse employees when loading/unloading at the distribution centers (Sheffi, 2021).

The factors mentioned so far explain why there is no significant growth in the number of truck drivers. However, those are not the only reasons contributing to the driver shortage. The utilization of existing drivers can also impact the shortage crisis faced by the industry. To better understand how truck driver utilization relates to the shortage crisis, it is important to know various activities done by drivers and the time spent. Driving, Loading, and Unloading are three significant activities truck drivers perform in their day-to-day operations. It is essential that loading and unloading of the load are completed on time to maximize the driving time and move the load. Any interruption during loading and unloading can affect the driving time by increasing waiting time. This waiting at the shipper/receiver warehouses for loading/unloading is called "Dwell time." For the analysis of dwell time, it is important to understand how warehouses operate and how the data is collected.

1.2 Warehouse Operations and the effect on Driver Utilization

Warehouses or freight points operate as freight shippers and receivers. They act as key players in the supply chain as distribution centers and fulfillment centers. These warehouses use trucks in various capacities to move the freight across the country. They consolidate orders for long-haul movements and request the freight carrier to move the goods to the destination. The freight carrier and the warehouses agree on an appointment time. The trucking company would match a truck with relevant capacity and dispatch it to these warehouses for picking up the load. The responsibility of loading the truck with required goods lies with the shipper in most cases. Based on the relationship between the shipping company and the trucking company, these requests can be a part of annual contracts or spot bookings (Caplice, 2007). The loading activity can be categorized mainly

by when the trailer is loaded. A "live loading" happens after the truck driver reaches the warehouse, and a "drop and hook" loading, i.e., the trailer, is left at the warehouse for loading or unloading, and the driver will not be present at the location when the activity is performed.

A delay in loading the truck before the driver comes in a drop and hook loading or an exceeded waiting time during the live load affects the driver utilization. As the driver is considered on duty when they reach the warehouse, any additional waiting reduces their productive driving hours, thus contributing to the dwell time. So, to keep the trucks moving and appointments on time, it is crucial that the warehouses operate efficiently and reduce the driver dwell at their locations, thus contributing to improving driver utilization.

Typically, a focus on driver utilization is always considered in improving the on-the-road performance of drivers. However, this capstone will shift the focus to warehouses to study how we can reduce dwell time. This reduction in dwell time can eventually improve driver service hours and contribute to the 18 minutes of additional time required to alleviate the driver shortage problem, as mentioned by Dr. David Correll in 2021.

To analyze the average dwell time for drivers, the log data of various driving and non-driving activities performed by drivers on an average working day is essential. The Federal Motor Carrier Safety Administration (FMCSA) mandate of 2015 states that all trucks must be upgraded with electronic logging devices (ELD)s from the traditional manual paper logging. The data collected from the ELDs can be instrumental in understanding the dwell times faced by drivers.

1.3 Problem Statement

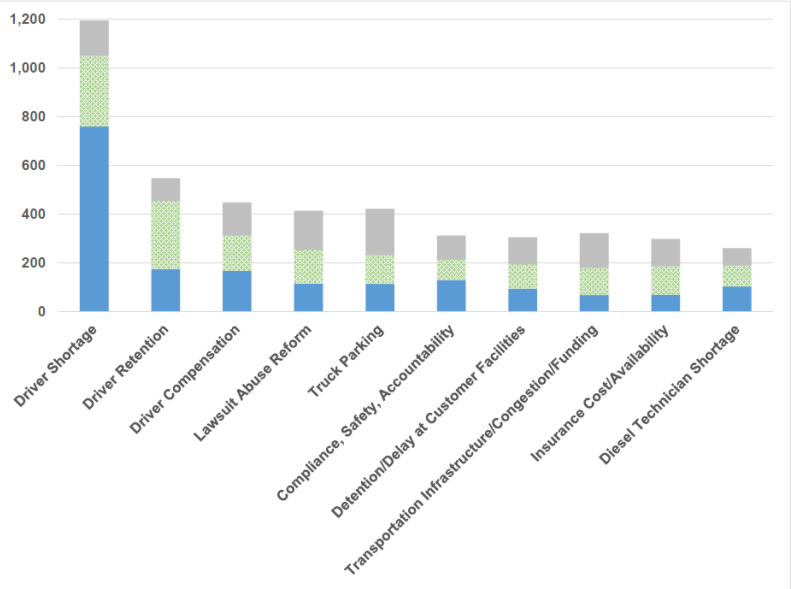
The American Transportation Research Institute (ATRI) has consistently ranked the truck driver shortage as one of the top problems the trucking industry is facing (ATRI, 2021), as explained in **Figure *1***. A detailed analysis of the ELD log data is required to understand and measure the dwell time.

The Hours-of-Service (HOS) regulation for long-haul truck drivers in the U.S. specifies that a truck driver is not allowed to exceed 11 hours of driving time per day, must have regular breaks, and should not exceed the 14-hour limit of being on duty (FMCSA, 2020).

The capstone will use the ELD data for driver stops, and HOS compliance data from a midsized U.S. trucking company collected over six months. The truck drivers drive for an average of ~6.5 hours a day, which is quite distant from the 11-hour HOS regulation limit (Correll, 2019).

Considering that the U.S. is facing a driver shortage problem, which is only expected to grow, analyzing the driver log data can help understand a pattern and contributing factors for the delays. Dr. David Correll, a research scientist at MIT Freight lab, in his testimony at the U.S. House of representatives in 2021, has quoted that an increase of 18 minutes in the average utilization of the American truck driver could reduce the shortage crisis with no need to increase the number of drivers or automating the industry. The question is: How?

Figure 1: Ranking of top issues faced by the American Trucking Industry



Note: Adapted from ATRI – Critical issues in the trucking industry – 2021

2 Literature Review

Supply chains across the globe rely on the essential aspect of transportation, which assures sub-product and finished goods transfer from suppliers to consumers. Over-the-road (OTR) or trucking is a common preference among all transportation options.

The trucking industry gains further importance every year due to a constant increase in demand, so do the challenges. A literature review study was carried out to understand one of the top challenges faced by the industry, i.e., the driver shortage problem.

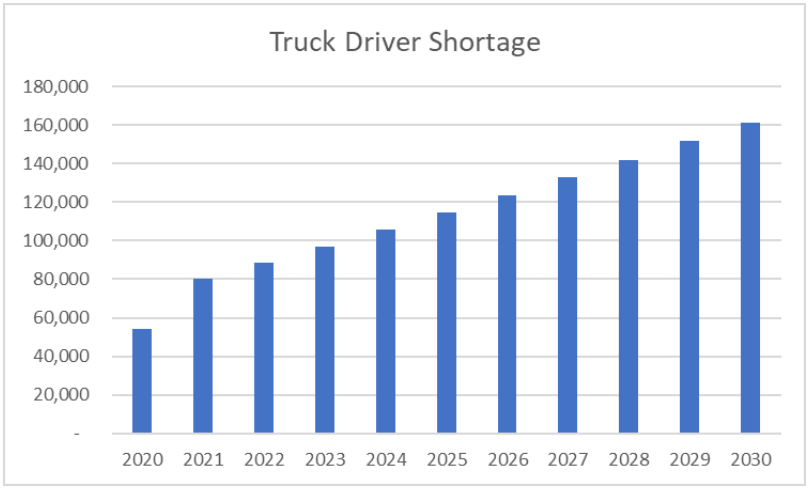
The resultant understanding from the study can be broadly categorized as below:

- Study of the Driver shortage
- Impact of COVID-19 on Driver shortage
- Understanding the Driver utilization
- Hypothesis

2.1 Study of the Driver shortage

The American Trucking Association has reported escalating driver shortages for the last 15 years; since this was first documented in 2005 with an approximate shortage of 20,000 drivers (ATA, 2019), it has reached 80,000 by the end of 2021 (ATA, 2021). With this current trend, the shortage is expected to surpass 160,000 drivers by 2030, as **Figure *2*** shows.

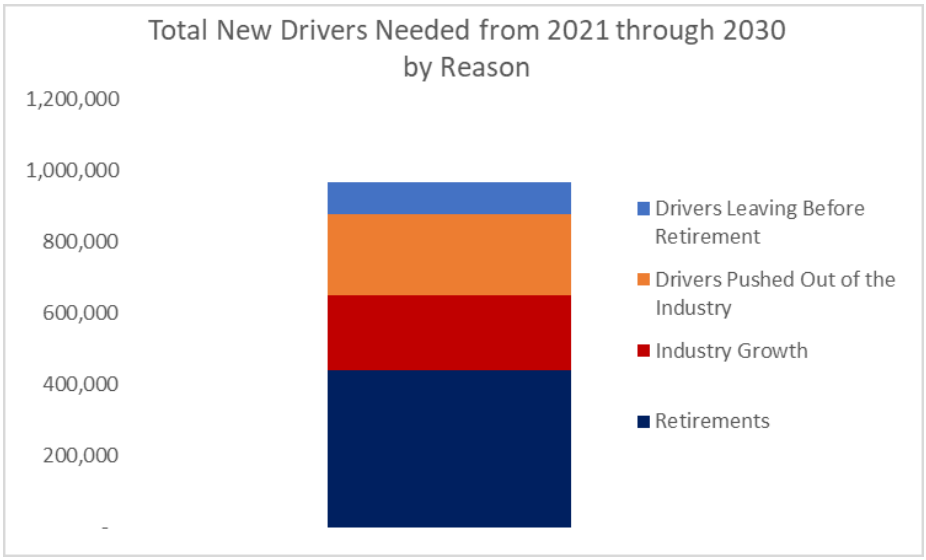
Figure 2 : Forecasted truck driver shortage for the next decade



Source: Adapted from ATA Driver Shortage Update 2021

With about 1.8 million heavy and tractor-trailer truck drivers (US BLS, 2020) currently operating, ATA estimates that the industry will have to recruit nearly 1,000,000 drivers by 2030. Retirements are the most concerning reason for driver shortage and the one that contributes the most to it, as **Figure *3*** illustrates.

Figure 3: Total New Drivers Needed from 2021 through 2030 by Reason



Source: Adapted from Driver Shortage Update 2021, ATA.

The three most common contractual arrangements for truckload services shippers use are private fleets, for-hire contract carriers, and for-hire spot markets (Caplice, 2007). The emphasis of this review is on the heavy and tractor-trailer for-hire carriers from trucking companies and independent operators. Though the shortages in the trucking industry cannot be attributed to a single cause, earlier studies have concentrated on improving the driver working conditions and addressing the high employee turnover rates faced by trucking companies. The "Truck Driver Shortage Revisited, 2002," by Min and Lambert (2002) studied the strategies and incentives used by trucking firms in recruiting and retaining drivers. They sent a questionnaire by mail to approximately 3,000 randomly selected trucking firms to understand driver shortage issues. This study concluded that carriers tend to believe that competitive pay for the drivers will reduce turnover rates; however, Min and Lambert found that this incentive tends to work only for drivers who are 45 years and older and have at least six years of experience.

A study conducted in 2011 interviewed many drivers at gas stations to understand their job satisfaction. It was demonstrated that 60% of the drivers would not recommend this occupation to their children due to the disproportionate amount of time away from home, the excessive work hours needed for a motivating income, and the lack of respect toward the occupation. (Johnson, James et al., 2011)

Another study done by Coyote Logistics in 2021 came up with the following challenges contributing to the driver shortage. The rate at which the industry attracts new talent is lower than the retiring rate. Younger people would rather work in a warehouse than become a driver. About 62% of warehouse jobs are being filled by people under 45 years old. When it comes to work/life balance, drivers prefer short-haul freight (short distance in a single day) over the long-haul. In addition, a CDL, which is costly and time-consuming to acquire, is required for this career, which can be contrasted to the lack of license needed to drive a forklift in a warehouse (Coffey, Clare et al., 2021).

These studies are showing that the availability of drivers is constantly decreasing. The demanding work conditions and being away from home are somethings that people are not attracted to anymore. For this reason, the industry needs to find a way to compensate for this shortage.

2.2 Impact of COVID-19 on Driver shortage

COVID has also contributed to the driver shortage. During the pandemic, online shopping increased considerably, and so did the demand for trucks. While some people had the chance to work from home, truck drivers had to keep working despite adversity. Truck drivers were facing closed rest stops, limited dining options, and no places to shower and refresh (Yang, 2021). In addition, the attractiveness of this profession had also decreased due to unemployment benefits, drivers with young kids at home with closed schools, and the fear of contracting the virus (Coffey, Clare et al., 2021).

Before the pandemic, there was an estimated shortage of 61,500 drivers (Spear, 2021). Now, the 80,000 drivers' shortage, translates to an increase of 30%. The pandemic has also impacted the deficit of drivers, increasing from 3.4% to 4.4% in less than two years. To attract more drivers, the ATA is supporting a piece of legislation that will allow people to drive the big rigs at the age of 18, shifting from the current 21 years minimum age. In addition, fleets of all sizes are raising wages and giving bonuses to attract more people to drive. Carriers will end up paying on average 8% more based on this effort (Smith, 2021).

As the pandemic is under control and economy starts to recover and the international trade is opening, companies are trying to catch up the lost market. With this peak in demand, the driver shortage is even more impactful. An example is the Port of Los Angeles, where the shortage of drivers has increased the accumulation of containers at the Port, creating a bottleneck for new vessels to unload additional containers (Healey & Masunaga, 2021). For this reason, on October 13, 2021, President Biden announced that Port of Los Angeles would begin operating 24 hours a

day, seven days a week (Littlejohn, 2021). While this is a logical solution, the implementation needs to be holistic. One of the main challenges is aligning the schedules for 24/7 operations with warehouse operators. The warehouse that operates with the Port would need to adjust its processes to be able to provide their service during the night shift. Most warehouses "traditionally operate during the daytime only" according to Gene Seroka, executive director at the Port of Los Angeles (Lopez, 2021).

2.3 Understanding the Driver utilization

In 2018, the Federal Motor Carrier Safety Administration (FMCSA) and Department of Transportation (DOT) incorporated the use of ELD in all trucks, replacing the traditional drivers' logbooks. The primary purpose of this mandate is to ensure truck drivers' safety while on the road and reduce accidents caused by drivers' fatigue by improving the Hours-of-Service (HOS) regulation compliance. By law, a truck driver can't drive for more than 11 hours or work for more than 14 hours a day, including non-driving activities. ELD records the driving time, HOS records, and off-duty data, as well as the miles driven. **Figure *4*** shows a summary of the hours-of-service regulations.

Figure 4: Hours of Service Regulations

PROPERTY-CARRYING DRIVERS
11-Hour Driving Limit May drive a maximum of 11 hours after 10 consecutive hours off duty.
14-Hour Limit May not drive beyond the 14th consecutive hour after coming on duty, following 10 consecutive hours off duty. Off-duty time does not extend the 14-hour period.
30-Minute Driving Break Drivers must take a 30-minute break when they have driven for a period of 8 cumulative hours without at least a 30-minute interruption. The break may be satisfied by any non-driving period of 30 consecutive minutes (i.e., on-duty not driving, off-duty, sleeper berth, or any combination of these taken consecutively).
60/70-Hour Limit May not drive after 60/70 hours on duty in 7/8 consecutive days. A driver may restart a 7/8 consecutive day period after taking 34 or more consecutive hours off duty.
Sleeper Berth Provision Drivers may split their required 10-hour off-duty period, as long as one off-duty period (whether in or out of the sleeper berth) is at least 2 hours long and the other involves at least 7 consecutive hours spent in the sleeper berth. All sleeper berth pairings MUST add up to at least 10 hours. When used together, neither time period counts against the maximum 14- hour driving window.
Adverse Driving Conditions Drivers are allowed to extend the 11-hour maximum driving limit and 14-hour driving window by up to 2 hours when adverse driving conditions are encountered.

Source: Federal Motor Carrier Safety Administration. Sept 2020

From the 11 driving hours available to truck drivers, merely 6.5 hours are being used on average (Correll, 2019). This analysis was concluded using the industry data provided by the ELDs. As the truck drivers are paid by the miles driven, by not being able to drive for 11 hours possible, they are driving less miles and earning less. On average, 4.5 hours are lost due to various events like loading, unloading, and drivers waiting to navigate through the ports and warehouses (Correll, 2019).

2.4 Conclusion from Literature Review

In 2020, a study conducted by Buttgenbach and Zhang, identified some of the reasons causing the underutilization of the drivers. They analyzed the data in terms of the dwell time at the freight points based on the arrival hour of the day and location frequency. By applying Ordinary Least Squares regression methodology to the HOS data available from ELD, it was identified that arrival time at freight point and the carrier frequency to a shipping location have statistically significant impact in reducing the driver detention.

Complementing Buttgenbach and Zhang's study, in 2021, the study by Roy and Sauter concentrated on identifying the nodes (shipper or receiver warehouse) causing higher dwell times. They hypothesized that if a driver is late to an appointment, the dwell time will increase. However, the data showed that lateness of arrival to a facility that operates 24 hours or if the load is drop-and-hook had no statistically significant impact on the drivers' dwell. Another hypothesis by Roy and Sauter concentrated on arrival at off-peak and peak hours at the node. It was statistically significant that drivers experienced less dwell time during the peak hours due to efficient operations. The third hypothesis was based on drivers' demographics such as age, gender, and its impact on the dwell. They found that it was statistically insignificant. The last hypothesis focused on drivers visiting the same node multiple times. It concluded that as the frequency of visits to a node increase, it reduces the dwell time as the drivers get familiarized with the paths and processes at the node.

Another study in 2021, by Proctor and Sousa Jr., highlighted the vital role played by the dispatchers in linking driver performance to carrier goals. The three metrics across which the study was done are driver utilization, efficiency, and retention. The utilization and efficiency were observed to be highly correlated, and retention was not. The study represented that those dispatchers who concentrated on maximizing productivity had lower driver retention. As the proposed solution to the driver shortage depends on improving the average hours driven rather

than increasing the number of individuals, it is justified if the maximum productivity is achieved while having a higher retention rate.

The truck driver shortage problem has been affecting the American supply chain for more than 15 years now, with American Trucking Association first reporting it in 2005 (Costello & Karickhoff, 2019). Instinctively, the shortage problem can be solved by hiring more drivers and retaining the existing workforce; but this approach has many challenges. Studies by Keller, Scott (2002) was conducted on employee satisfaction, turnover rates, retentions, encouraging youth to enrol in trucking jobs, among others. The existing literature by Procter and Sousa Jr (2021) and Zhang and Buttgenbach (2020) has studied the factors impacting drivers' performance. These studies provided useful insights in addressing the driver shortage problem from the carriers', dispatchers', and drivers' perspective.

The studies have understood how dispatcher and driver relationships, frequency of driver visits to a warehouse, time of visit to a warehouse and so on, can impact driver utilization. We aim to understand how the detention of drivers at warehouses is contributing to the driver shortage problem. By analysing the driver stop data from the partnering trucking company, we use data analytics to understand if the day of the week a truck arrives at a warehouse has an impact on driver detention. As this remains an unexplored area of the research on driver utilization, our capstone aims to study this and help improve the driver utilization and thus contributing to reducing driver shortage problem.

2.5 Hypothesis

The primary research hypothesis of this capstone is the opportunity to increase the drivers' utilization by increasing the number of days they can operate. If most warehouses can operate during the weekends, the utilization will increase. Another hypothesis is that the warehouses currently working during weekends are inefficient since most experienced staff will instead work from Monday to Friday and leave the weekends for the new and inexpert employees. We will compare the differences in the operational practice at warehouses with lower dwell versus higher dwell times during weekends and understand what causes these discrepancies.

3 Methodology and Data

3.1 Data Understanding

We have collected six months of ELD logs data (May 2019 – Oct 2019) from a midsized U.S. trucking company to analyze the dwell time from the logged driver stop data. The data contains stop times at various freight points during this period, as the snapshot in **Figure *5*** shows.

Figure 5: Freight point data format from Trucking Company

PLAN_NAME	Driver ID	CTRL_CUST	FREIGHTPOINT	FREIGHT_EVENT	DWELL	bdt_description	ARRIVAL_DT	ARRIVAL_TM	DEPARTURE_DT	DEPARTURE_TM
[redacted]		[redacted]		LPL	49.30	OTR - Southeast	2019-06-18	09:31:00	2019-06-18	10:20:18
				LPL	17.30	OTR - Southeast	2019-07-18	12:13:00	2019-07-18	12:30:18
				LPL	51.80	OTR - Southeast	2019-07-02	22:46:00	2019-07-02	23:37:48
				LPL	768.83	OTR - Southeast	2019-06-05	16:21:00	2019-06-06	05:09:50
				LLL	43.57	OTR - Southeast	2019-05-08	10:57:00	2019-05-08	11:40:34

The important fields in the initial data are described in **Table 1** and the different freight events that are used to identify the type of load are described in **Table 2**. The dataset focuses on the dwell time contribution during the "Loading" activities.

Table 1: Driver Stop Data Variables

FIELD	DESCRIPTION
PLAN	A unique identifier for the load carried by the driver
DRIVER ID	A unique identifier for the driver
TRIP_DIVISION	Internal classification of trip type
CONTROLLING_CUSTOMER	A unique identifier for the customer
FREIGHTPOINT	A unique identifier for the facility visited for the appointment (e.g., Warehouse, DC, or any other facility)
TIMEZONE	Time zone in which entry was recorded
FREIGHT_EVENT	Type of Freight Appointment (details in Table 2)
APPT_WINDOW	The opening and closing date of the appointment (Note, this includes re-schedules)
ARRIVAL	When the driver arrived at the facility (Gate In)
DEPARTURE	When the driver left the facility (Gate Out)
DIVISION	Another internal classification of the trip

Table 2: Driver Freight Event codes

FREIGHT EVENT	DESCRIPTION	ESTIMATED COMPLETION (HRS)
BEG	Pickup relay	0.5
CON	Continuous move, usually to pick up paperwork	0.5
END	Dropoff relay	0.5
LDA	Driver assists customer loading trailer	4.0
LLL	Customer loads trailer while the driver is present	2.0
LLM	Third-party (Lumper) loads while the driver is present	4.0

LPL	Trailer loaded when the driver arrives	0.5
UDA	Driver assists in unloading trailer	4.0
UDT	Dropoff loaded trailer	0.5
UDU	Driver unloads trailer alone	4.0
ULL	Third-party (Lumper) unloads while the driver is present	4.0
ULU	Customer unloads trailer while the driver waits	2.0

3.2 Data Cleaning

The raw data from the trucking company contains around 60,000 stop entries, as shown in **Figure *6***. The initial analysis focused on calculating the dwell time for each entry. The "ARRIVAL" and "DEPARTURE" fields hold the driver arrival and departure timestamps at the freight point. We used Python and Excel for our initial data cleaning. Any entry with a negative dwell time calculation is removed since it is not practical to leave with the load even before coming to pick the load. So, these can be considered as data errors and ignored from the analysis.

Figure 6: Data info after import into Python

```
<class 'pandas.core.frame.DataFrame'>
Int64Index: 59755 entries, 0 to 59754
Data columns (total 12 columns):
 #   Column           Non-Null Count  Dtype
---  ------           --------------  -----
 0   PLAN_NAME        59755 non-null  object
 1   Driver ID        59636 non-null  object
 2   Driver 2 ID      9847 non-null   object
 3   TRIP_DIVISION    59747 non-null  object
 4   CTRL_CUST        59755 non-null  object
 5   FREIGHTPOINT     59755 non-null  object
 6   TIMEZONE         38801 non-null  object
 7   FREIGHT_EVENT    59755 non-null  object
 8   ARRIVAL          59747 non-null  datetime64[ns]
 9   DEPARTURE        59747 non-null  datetime64[ns]
 10  DWELL            59747 non-null  float64
```

The data was then analyzed in Python on the "Dwell" field, which holds dwell time in minutes. To choose the upper and lower limits of the dwell time to proceed with the analysis, we considered the lower limit as 15 minutes, close to the 25th percentile, as shown in **Figure *7***. The

upper limit is considered as 1,440, which is 24 hours and can help us capture more important daily delays.

Figure 7: Dwell Time statistics

```
count    56197.000000
mean       133.485822
std        329.214012
min          0.020000
25%         19.250000
50%         40.550000
75%         95.000000
max      22016.420000
Name: DWELL, dtype: float64
```

3.3 Data Analysis

The cleaned data was used for exploratory data analysis that gave insights on difference between dwell times at various freight points. The data was then sorted by day of arrival at all the freight points or warehouses involved to do a day-wise plot of the dwell times. The **Figure *8*** and **Figure *9*** show the difference in dwell time patterns on weekdays and weekends. The pattern speaks that during the regular shift or between 6 AM to 2 PM the dwell time is more stable on weekdays and is less than 2 hours. However, the stability is less on the chart showing weekend data.

Figure 8: Dwell time by day/arrival hour on weekdays

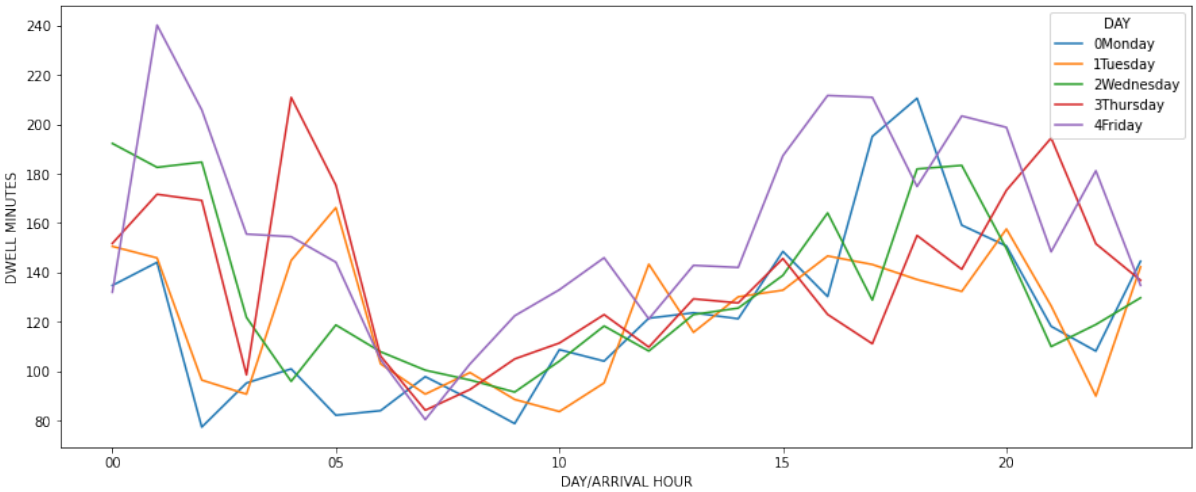


Figure 9: Dwell time by day/arrival hour on weekends

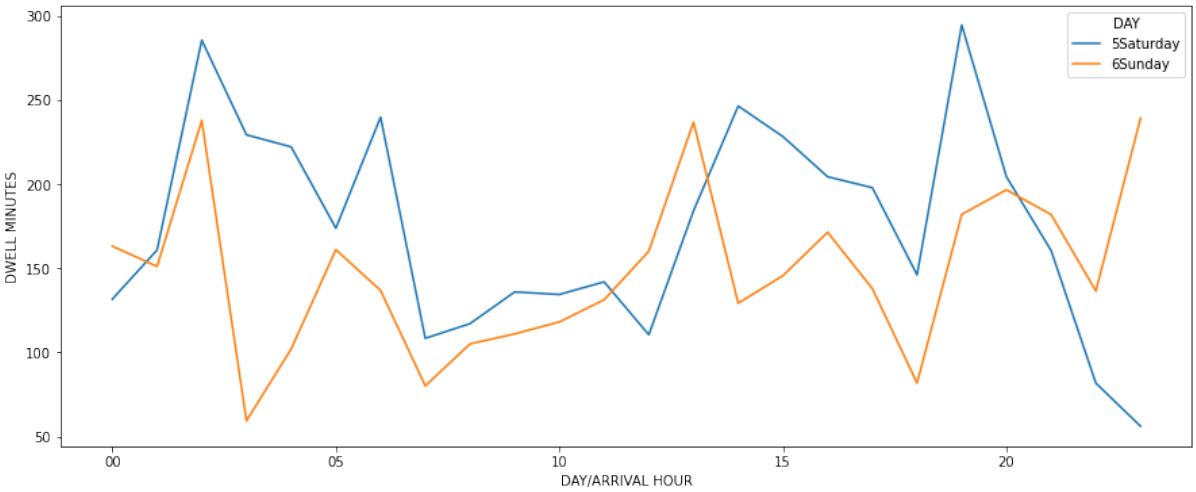


Figure *8* and **Figure *9*** show the difference between the dwell time contributions on weekdays and weekends. The instability in the dwell time patterns observed is a strong insight to dig deeper to see what impacts this behaviour.

We can also notice a sizeable instability when comparing weekday data to weekend data. This first insight made us focus on dwell times during weekends and weekdays and proceed with qualitative analysis by speaking with industry players (shippers).

4 Results

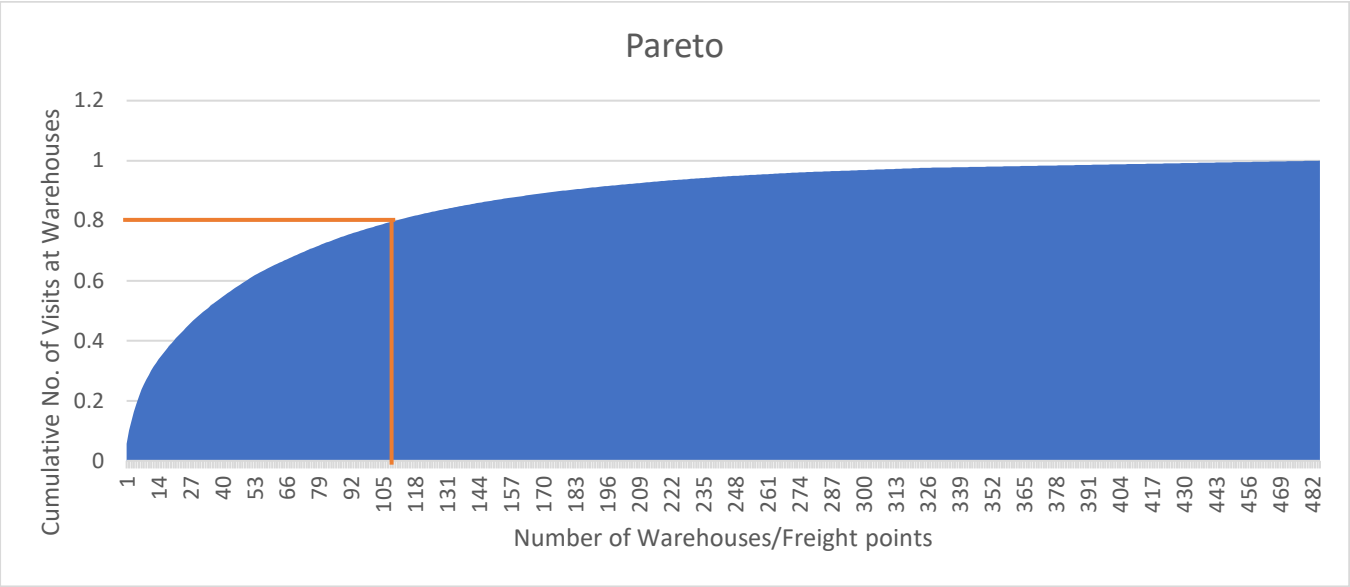
The statistical analysis performed in the data showed that there is an opportunity regarding the weekend operations of the warehouses. The results demonstrated that there are only a few warehouses that operate during the weekends. In addition, it revealed how for these warehouses, the weekend operations are inefficient comparing with their own weekday operations.

4.1 Weekends vs Weekdays

Using the initial six months of data (May 2019 – Oct 2019), we wanted to understand what percentage of the warehouses (freight points) worked during weekends. From the 2,509 unique warehouses in the data set, only 512 warehouses, or 20.41%, worked at least one day during the weekend. This insight tells us that about 80% of warehouses do not work during the weekends, so we can see that there is a sub utilization of the warehouses during these days.

Digging deeper into the 512 warehouses that work over the weekend is required. We first counted the number of truckloads' visits during weekends that each warehouse had during a six-month period. Using a Pareto, we observed that 110 (or 23%) warehouses received 80% of the visits during this period, as **Figure *10*** shows.

Figure 10: Pareto curve for the number of visits per location



As a reference, **Figure 11** shows the top 10 warehouses that worked during weekends by volume of visits.

Figure 11: Top 10 warehouses with most visits during weekends

Position	Location	# Visits
1	A	380
2	B	300
3	C	224
4	D	194
5	E	180
6	F	169
7	G	155
8	H	111
9	I	109
10	J	104

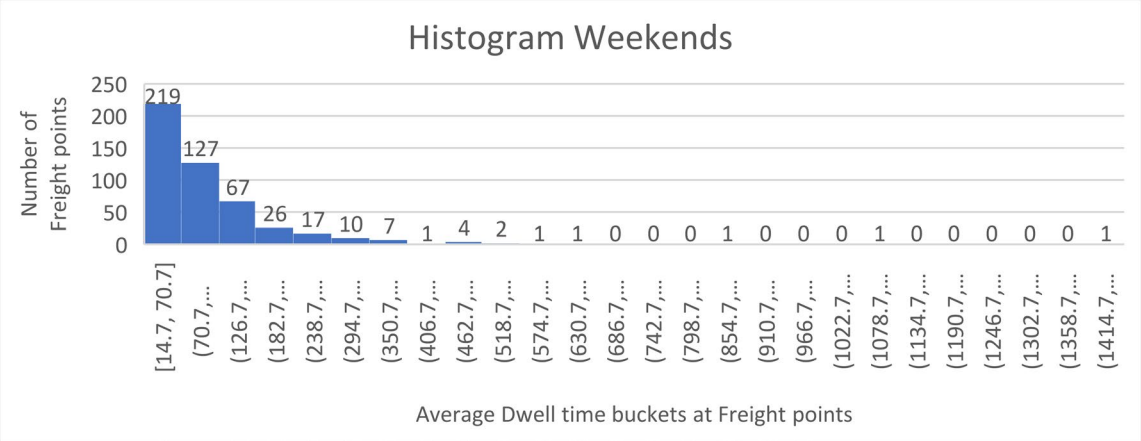
Before moving forward, we wanted to understand the dwell times during weekends. **Figure *12*** shows some simple statistics that will help compare the dwell times of weekends to weekdays.

Figure 12: Dwell time in minutes during weekends

Dwell Time (Weekends)	
Mean	116.2
Standard Deviation	125.4
25th percentile	48.3
75th percentile	138.8

The histogram in **Figure *13*** shows how the weekend dwell time is divided into different time buckets. Most of the observations have a dwell time ranging from 15 minutes to 70 minutes.

Figure 13: Histogram of dwell in weekends



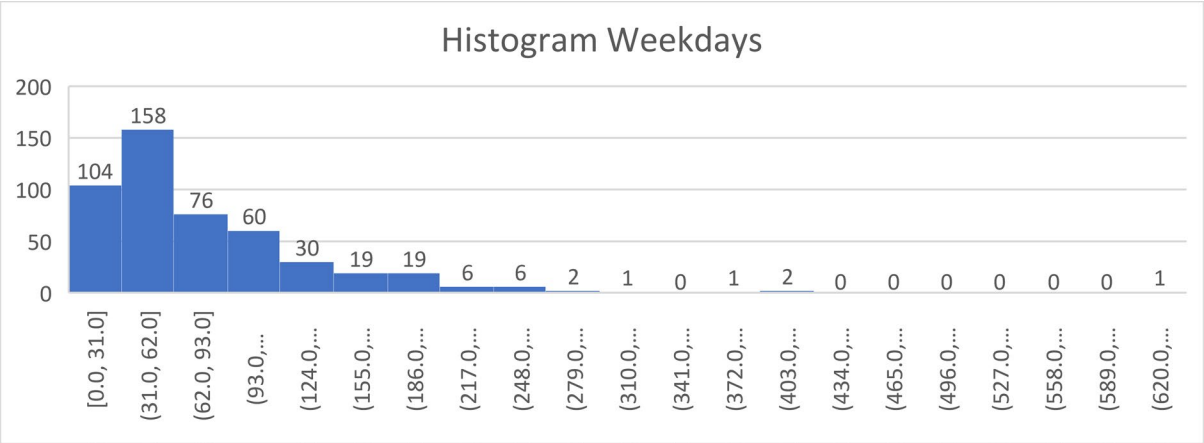
The next step was to compare the dwell times during weekends with weekdays. **Figure *14*** shows the mentioned statistics.

Figure 14: Dwell time in minutes during weekdays

Dwell Time (Weekdays)	
Mean	87.9
Standard Deviation	68.7
25th percentile	43.3
75th percentile	111.2

The Histogram in **Figure *15*** shows the weekdays' dwell time.

Figure 15: Histogram of dwell on weekdays



Comparing the dwell times between weekdays and weekends within the same warehouses, we see that weekends are 32% slower in fulfilling the loads than weekdays. This supports our initial hypothesis.

We then started to look at each warehouse individually. From the 110 warehouses in this analysis, 75% of them have longer dwell times during weekends. This shows that even if, on average, dwell time during weekends is slower, it is not the case for all the warehouses. For this reason, we have expanded our research to be able to capture and understand each warehouse. **Figure *16*** shows the individual comparison among dwell times.

Figure 16: Dwell time comparison between the top 10 warehouses with most weekend visits

Position	Location	# Visits	Avg Dwell (Weekend)	Avg Dwell (Weekday)	Difference in minutes	% slower weekends
1	A	380	132.8	65.8	67.0	50%
2	B	300	113.1	59.5	53.6	47%
3	C	224	110.6	72.0	38.7	35%
4	D	194	269.8	71.8	197.9	73%
5	E	180	210.2	54.4	155.8	74%
6	F	169	113.8	48.4	65.4	57%
7	G	155	97.8	46.8	51.0	52%
8	H	111	297.9	28.6	269.4	90%
9	I	109	119.4	54.0	65.4	55%
10	J	104	92.2	98.7	-6.5	-7%

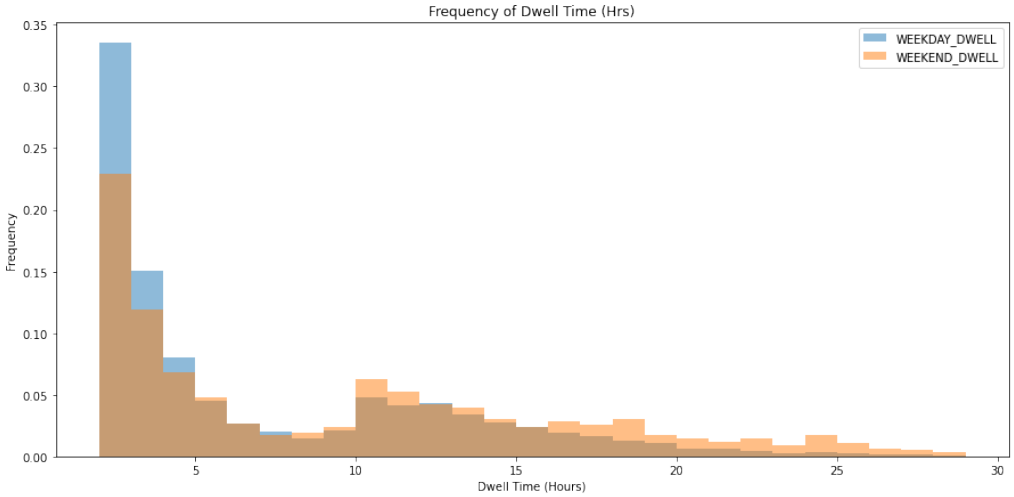
By observing this comparison, 9 out of the 10 warehouses are anywhere from 50% to 90% slower during weekends. It also shows how warehouse "J" in the 10th position has a lower dwell time during weekends than weekdays.

4.2 Dwell time variation for load type

The dwell time observed at the warehouses when plotted on frequency bar charts, are as shown in **Figure *17*** two peaks. The first peak represents the shorter dwell time which has higher frequency and is commonly observed in both weekday and weekend data. However, weekends have lesser frequency compared to the weekdays in the first peak.

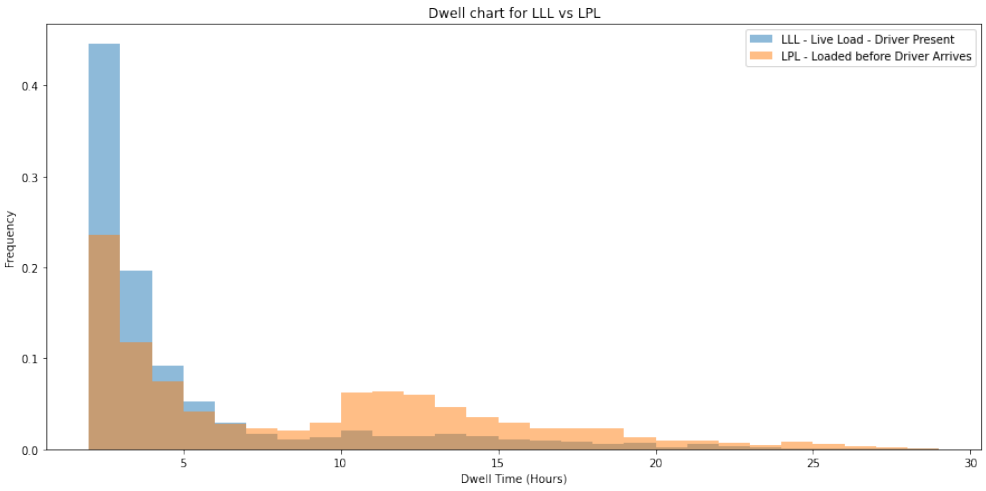
The second peak shows that the frequency of dwell time increases again after 10 hours. In contrast to the first peak, weekends have higher frequency in second peak over weekdays.

Figure 17: Frequency of Dwell Time (Hrs)



Further analysis of the frequency histogram to understand the dwell time patterns based on the loading activity was performed. It revealed that live load (LLL), where the driver is present at the location, has high frequency for shorter dwell times. On the other hand, drop and hook load (LPL), where the trailer is loaded when the driver arrives, has high frequency for dwell time above 10 hours. These peaks can be observed from the **Figure *18***.

Figure 18: Dwell time for Live load and drop and hook load



4.3 Qualitative Analysis

To understand the reason why weekend data was having high frequency of dwell time for hours above 10 and why drop and hook load, which is expected to reduce the dwell time, is showing higher frequency of dwell time above 10 hours, we interviewed some of the shippers and warehouse operators.

Our discussions with the industry representatives show that there are multiple factors that are contributing to these dwell times and they can be broadly categorized as below.

- Communication
- Scheduling
- Training

Communication

Lack of proper communication channels or having a standardized communication setup between drivers and warehouse operators is set to be as one of the troubling areas by shipping companies. Without an established communication channel, it is difficult for the warehouses to know of any delays from drivers due to unpredicted traffic conditions or delays from previous load. It is the same when it comes to delays from warehouse operators; drivers are not readily

informed of the delays on load preparation causing more waiting for drivers while on duty, essentially reducing the drivable hours. These issues from one delay at a warehouse can have a ripple effect on subsequent loads and unloads only exacerbating the waiting time and disruption in the schedules.

In a drop and hook scenario, a completely loaded trailer is expected when the driver arrives at the warehouse to start with the trip. A lack of communication in such case where the load is delayed or if the loading is not even started contributes heavily to high frequency in longer dwell times and thus the second peak in **Figure *18***.

Scheduling

Outbound and Inbound load scheduling is one of the crucial activities at a warehouse that can impact warehouse throughput and truck fleet utilization. Typically, operators tend to overschedule load bookings with tight timelines to increase the overall throughput of the operating facility. But with little or less consideration towards the unexpected delays and not coordinating with labor scheduling, it only adds to increased delays during peak hours. These tight schedules targeted to increase the throughput of the warehouse are causing a reverse effect in adding delays and an avalanche of delays in the subsequent loads for the trucks and warehouse.

Another reason for overscheduling is when the warehouse operations are closely linked with manufacturing or production facilities. When manufacturing units push the production schedules to meet their targets at the end of a time period, it can cause shipping congestion leading to more delays. For example, a production unit which has production targets for every work shift of 8 hours, if it pushes the loads for pickup at the end of the shift, there is an expected congestion at the end of the shift hours. When the same happens on weekly production schedules, the congestions increases over the weekends. This supports the data plots which show an increase in dwell time on weekends or in late evenings.

Training

Warehouses typically do not handle a single type of load. Some of the examples are palletized loads, non-palletized loads, and slip-sheet loads. Each of these loads have to be handling differently while moving, packing, unpacking, loading, and unloading. It is essential that warehouse staff are cross-trained across different handling equipment like forklifts, pallet jacks, automated equipment and so on.

Shipping companies usually have training schedules planned for staff to learn the necessary skills in operating the warehouse' equipment. Staff scheduling without consideration for necessary skillsets based on the scheduled load types will result in delays and increased dwell time.

Onboarding new staff into warehouses should have a definitive training period on the job where they can be familiarized with the warehouse layout and different type of equipment that are used in that facility. Warehouse staff scheduling should also consider having a mix of new staff under training along with experienced staff both over weekdays and weekends to train them quickly without causing disruptions to the operations.

5 Discussion

As shown in the results, there is a difference between the weekdays vs. weekend operations. In addition, most of the warehouses do not even operate during weekends. An underutilized warehouse facility or inefficiently operating facility when open will greatly impact driver utilization by causing severe delays.

This tends us to believe that the driver shortage problem cannot be solved just by hiring more drivers or introducing autonomous trucks, but rather the utilization of the existing driver force must increase. Operating warehouses over the weekends as efficiently as their weekday operations is one way to alleviate the problem. Having warehouses that do not operate during the weekends reduces the impact of this attempt. For this reason, this capstone is bringing this opportunity to light so the industry can focus their efforts.

There are two aspects to highlight: warehouses' internal operations and future applications.

5.1 Warehouse operations

It has been proven that within a warehouse, the average dwell time during weekends can be 50-90% higher than their own operations during weekdays. There can be several reasons that cause this issue such as personnel training, weekend employees with less expertise, and shipper's internal scheduling.

According to an industry expert, the workload during weekdays is usually the most demanding in terms of flow of trucks. For this reason, when a company needs to train their personnel regarding warehouse operations, they'll usually push these activities for the weekends. By doing so, during the weekend, most of the warehouse employees will be untrained to perform the activities. This is affecting the dwell time during the weekends, as it takes more time for them to load and unload a truck or operate the load handling equipment. In addition, they are prone to commit errors, which can cause re-work that needs even more time directly affecting dwell time.

For this reason, training sessions should be planned taking into account the impact and cross-train the staff.

In the warehousing industry, the "weekenders" are those people who are assigned to work during the weekends. Warehouse employees that have been working for several years for the same company, will be inclined to work from Monday to Friday and spend the weekends with their families. On the other hand, the new hires will be scheduled during the weekend for the simple reason that they are new and must work in the available schedule. For this reason, the weekenders are mostly employees with less expertise. This practice could generate higher dwell times during the weekends. To prevent this from happening, companies should consider a mix of experienced and trainee staff for their operations for weekdays and weekends.

When a shipping facility is associated with a production facility, any delays in the production schedules will directly impact the shipping facility operations. Unfortunately, the production schedules can be delayed for several reasons such as lack of raw material, issues with machinery, and lack of personnel. In such cases, the loads that the trucks are scheduled to pick up during the weekdays get pushed later into the week and even into the weekends. As issues like these happen over and over, more work gets pushed to weekends, and the workload for the weekend increases; this again requires a mix of experienced staff along with trainee staff to clear the backlogs during weekends. As the workload increases during the weekends, the dwell time also increases because the personnel are being overwhelmed with the number of trucks to load in a timely manner.

5.2 Future Applications

While this is study has showed very valuable insights regarding the weekend operations, further analysis is needed. It would be important to compare and contrast the operations between different warehouses by visiting them, measuring their dwell times, analysing their scheduling compliance, talking with personnel, among others. Studies should also focus on companies that

have inefficient weekend operations and also visit facilities which have their weekend operations as efficient as their weekday operations. It would be necessary to understand the reason of this behaviour to share it with warehouses that are struggling during the weekends.

As presented in the introduction of this capstone, drivers are on the road approximately 6.5 hours out of the 11 they can legally drive in one day. As mentioned, if on average this number increases by 18 minutes, then the driver shortage can be alleviated. Based on the findings of this capstone, weekends are on average 30 minutes slower that weekdays. If companies that operate during the weekends can improve their internal process and reduce these 30 minutes using the recommendations presented above, then this will generate two main contributions. The first, is that if the percentage of warehouses that operate during the weekend stays the same, then we've found the 18 minutes for 20% of the total loads. The second, is that if these warehouses have all their days equally efficient, then the workload during the week could balance out and warehouse can improve the flow of the trucks in their facilities. With all, by finding the 18 minutes for the 20% of the loads, this means that we've founds a solution to decrease the driver shortage from 80,000 to 64,000 drivers. This will help reduce the shortage problem trend in following years to come until the industry finds the 18 minutes for the remaining 80% of the loads.

6 Conclusion

The driver shortage has been a concern for the past 15 years. The industry is currently facing an 80,000-driver shortage and this shortage is expected to surpass 160,000 by 2030. One way to solve this problem is by hiring more drivers. The challenge here is that the current rate of people willing to become professional drivers is much lower than the rate of drivers retiring or resigning. The approach of this capstone has not focused on adding more drivers but suggesting that if drivers can be on the road on average for an additional 18 minutes, then the driver shortage problem could be reduced. Specifically, this capstone has demonstrated that there is a great opportunity to increase the driver utilization by having more efficient operations at warehouses during the weekends. By doing so, not only will the trucking industry benefits, but on a more granular level, the warehouses will also benefit. This is because they will reduce their costs since they do not have to pay detention fees to the carriers. At the end, improving weekend operations will be a holistic approach that will benefit the trucking industry and shippers eventually leading to better and efficient supply of goods around the country.

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