Full Issue

Journal of Transportation Management Editors

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The primary purpose of the JTM is to publish managerial and policy articles that are relevant to academics, policymakers, and practitioners in the transportation, logistics and supply chain fields. Acceptable articles could include conceptual, theoretical, legal, case, and applied research that contributes to better understanding and management of transportation and logistics. Saying that, our policy requires that articles be of interest to both academics and practitioners, and that they specifically address the managerial or policy implications of the subject matter. Articles that are strictly theoretical in nature, with no direct application to transportation and logistics activities, or to related policy matters, would be inappropriate for the JTM. Articles related to any and all types of organizations, and of local to global scope, will be considered for publication.

Acceptable topics for submission include, but are not limited to, broad logistics topics, logistics and transportation related legal issues, carrier management, shipper management of transportation functions, modal and intermodal transportation, international transportation issues, transportation safety, marketing of transportation services, transportation operations, domestic and international transportation policy, transportation economics, customer service, and the changing technology of transportation. Articles from related areas, such as third party logistics, purchasing and materials management, and supply chain management, are acceptable as long as they are related to transportation and logistics activities.

Submissions from practitioners, attorneys or policymakers, co-authoring with academicians, are particularly encouraged in order to increase the interaction between groups. Authors considering the submission of an article to the JTM are encouraged to contact the editor for help in determining relevance of the topic and material.

The Editor information is: Dr. John C. Taylor, Associate Professor of Supply Chain Management and Department Chairperson, Department of Marketing and Supply Chain Management, School of Business, Wayne State University, Detroit, MI 48202. Office Phone: 313 577-4525. Cell Phone: 517 719-075. Fax: 313 577-5486. Email: taylorjohn@wayne.edu

Publishing Data

Manuscripts. Submit manuscripts to the editor by email attachment at taylorjohn@wayne.edu. Manuscripts should be no longer than 30 double-spaced pages and 7000 words. Guidelines for manuscript submission and publication can be found in the back of this issue.

Subscriptions. The Journal of Transportation Management is published twice yearly. The current annual subscription rate is $50 domestic and $65 international in U.S. currency. Payments are to be sent to Laura Plizka, Delta Nu Alpha, 1720 Manistique Avenue, South Milwaukee WI 53172.
Welcome to the Winter 2018 issue of the Journal of Transportation Management, being Vol. 28 No 2! This issue of the Journal starts with an article on, includes a second trucking related article on legal issues related to truck safety, moves on drone usage in warehousing operations, and concludes with an article on the likelihood of scheduled ocean container vessel shipping into and out of the Great Lakes.

Our first article examines the influence of temporal factors on motor carrier crash severity. The results indicate that crashes resulting in property damage are more likely to occur during the day and on weekdays, however, that fatal and injury crashes are significantly more likely during nights and weekends. The second article is a law review style piece that looks at what the FMCSA is really measuring with its use of big data in safety fitness determinations, and the impact on due process. The author suggests that the successive efforts of FMCSA and its predecessor agencies to measure safety and fitness based on mass quantities of roadside inspection data are incapable of either accuracy or fairness. The third manuscript explores the feasibility of drone adoption and implementation in warehouses. The authors conclude that current unmanned warehouse drone technology offers the potential for significant efficiency gains both for inventory handling and inventory transparency. The fourth article studies the feasibility of ocean shipping container ships running scheduled services into and out of the Great Lakes. The article concludes that such services continue to be infeasible due to a number of factors that are reviewed.

At the Journal, we are continuing to make a number of changes that will improve the visibility of JTM, and improve its position in the supply chain publishing world. These include registering and updating journal information with several publishing guides, and placing the past and current content on services that provide visibility to Google Scholar.

I look forward to hearing from you our readers with questions, comments and article submissions. The submission guidelines are included at the end of this issue’s articles and I encourage both academics and practitioners to consider submitting an article to the Journal. Also included in this issue is a subscription form and I hope you will subscribe personally, and/or encourage your libraries to subscribe.
NOTHING GOOD HAPPENS AFTER DARK: THE INFLUENCE OF TEMPORAL FACTORS ON MOTOR CARRIER CRASH SEVERITY

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ABSTRACT

Motor carrier safety is a topic of great importance for both industry and makers of public policy. Regulatory agencies, such as the Federal Motor Carrier Safety Administration (FMCSA), regularly publish data detailing the circumstances surrounding roadway accidents. FMCSA’s Large Truck and Bus Crash Facts (LTBCF) data demonstrate an increase in accidents during daylight hours and on weekdays. Roadway risks are ever-present but differ by time of day and day of the week. These differences may potentially engender crashes of different severities at different times. This study analyzes FMCSA LTBCF data to determine when crashes of different severities are more likely to occur. Findings indicate that crashes resulting in property damage are more likely to occur during the day and on weekdays. However, fatal and injury crashes are significantly more likely during nights and weekends. Recommendations to improve safety outcomes are provided along with suggestions for future research.

INTRODUCTION

The trucking industry is crucial to US economic success. Over 70% of the nation’s freight moves by truck (Trucking.org, 2017) and trucking expenditures exceed that of the other four transport modes combined (CSCMP, 2017). Given trucking’s size and importance, it comes as no surprise that a great deal of past research has been devoted to the industry. This research can be summarized into three overarching areas: operations and technology, people, and regulatory compliance.

A review of the literature based on the operations and technology perspective indicates that the majority of the research in this area has focused on topics such as carrier management (Hada and Kleiner, 2000; Overstreet, Hanna, Byrde, Cegielski and Hazen, 2013); cost control (Grimm, Corsi and Jarrell, 1989; Thomas and Callan, 1992); carrier productivity (Weber and Weber, 2004; Han, Corsi, and Grimm, 2008; Boyer and Burks, 2009; Villarreal, Garza-Reyes and Kumar, 2016); survival techniques (Grimm, Corsi and Smith, 1993; Voss, Cangelosi, Rubach and Nadler, 2011); and the adoption of technology (Cantor, Corsi and Grimm, 2006; Keller, 2006; Cantor, Corsi and Grimm, 2009). People oriented motor carrier research has generally focused on truck driver management and retention (Mejza, Barnard, Corsi and Keane, 2003; Mello and Hunt, 2009; Nadler and Kros, 2014), driver ethics (Douglas and Swartz, 2017), workplace violence (Anderson, 2004), the use of medical marijuana (Stringham, Allard, Knapp and Minor, 2017); and driver health (Lemke and Apostolopoulos, 2015; Hilliard, 2016; Olson, Wipfli, Thompson, Elliot, Anger, Bodner, Hammer and Perrin, 2016).

Interestingly, regulatory aspects of the motor carrier industry have received little recent research attention. Research in this area can be further divided into two time frames: pre-2000 and the impact of deregulation (Daicoff, 1988; Corsi, Grimm, Smith and Smith, 1992; Jerman and
Anderson, 1994) and post 2000 (motor carrier safety/security). Safety/security studies of interest include hours of service (Saltzman and Belzer, 2002), regulatory compliance (Flatow, 2000), the adoption of safety processes (Huang, Jeffries, Tolbert and Dainoff, 2017); and motor carrier security (Chang and Wu, 2015; Boone, Skipper, Murfield and Murfield, 2016).

Given the breadth and depth of the motor carrier literature, most investigations of temporal factors associated with safety have been limited to Federal and state-level studies. No recent business logistics articles of which we are aware examine accident probabilities and the temporal factors associated with safety incidents. Studies exist related to the temporal dimensions of motor carrier safety but few academic articles in the business logistics space analyze available data or offer useful conclusions to motor carrier managers. For instance, the subject of motor carrier safety, as it relates to nights and weekends, was hotly debated during recent discussions related to federal hours of service (HOS) regulations (FMCSA, 2017). This debate centered around a 2013 update to HOS regulations that limited drivers’ ability to restart their 60/70 hour clock. This was accomplished by limiting drivers to one “34-hour restart” every 168 hours and dictating that this restart must include two nighttime periods including the hours of 1AM to 5AM. These provisions were eventually stricken in part due to trucking industry arguments that they forced drivers to operate in rush-hour traffic, which increases congestion and safety risk. Second order impacts with unintended consequences often occur when new regulations are implemented and the cost/benefits of these now repealed regulations are hotly debated.

Of course, risks occur more frequently when a subject is exposed to risk factors. In a roadway safety context, crash frequency is positively correlated with miles driven and traffic congestion (Knipping, 2009). Mileage and traffic congestion are greater during weekday, daylight hours (Hendrix 2002; ATRI 2014). However, other factors increase risk while driving on weekends and nights, when roadways are populated with a larger number of impaired automobile drivers (Knipping, 2009). The National Highway Traffic and Safety Administration (NHTSA, 2017) reported automobile drivers were impaired by alcohol in 27% of fatal light vehicle crashes.

Thankfully, most crashes are not fatal. Crashes are usually less severe and result in injury and/or property damage. However, no business logistics work of which we are aware assesses crash severity risk (e.g. fatal, injury, or property damage only) by time of day (e.g. day v. night) or day of the week (e.g. weekday v. weekend). This study draws from Federal Motor Carrier Safety Administration (FMCSA) data to explore the frequency and probability of fatal, injury, or property damage crashes by day of the week and time of day.

This study begins with a review of relevant literature related to motor carrier safety. The authors then discuss the methodology used to explore differences in crash severity by examining temporal factors. Results are subsequently presented. The authors then suggest implications for managers and how they may use study findings to improve safety performance. Limitations and implications for future research are presented followed by concluding remarks.

LITERATURE REVIEW

Motor vehicle crashes are an unfortunate reality in modern society. NHTSA (2017) reported that U.S. roadway accidents killed 37,461 people in 2016, an increase of 5.6% over 2015. Of those killed, only 4,317 (11.5%) resulted from an accident involving a large truck, and vehicles other than the truck are predominantly at fault in these fatal incidents (FMCSA, 2007). These statistics highlight the importance of government and private investments in roadway safety.

Investments in roadway safety are made in order to mitigate the severe economic, physical, and psychological harm caused by these incidents. NHTSA (2014) calculated that motor vehicle crashes cost the United States $871 billion a year. This includes $277 billion in economic costs and
$594 billion from death, pain, and suffering. The Federal Motor Carrier Safety Administration (FMCSA, 2008) found that the cost of an accident involving a large truck ranged between $334,892 and $7,633,600. Given the high cost of safety incidents, it is incumbent upon the motor carrier industry to understand the conditions under which most crashes occur. Most truck crashes occur on weekdays during daylight hours in clear conditions on dry roads (Knipling, 2009). There are three primary risk factors contributing to motor vehicle crashes: enduring driver characteristics (e.g. age, medical conditions, and susceptibility to fatigue), temporary driver characteristics (amount of sleep, illness, or moodiness that may lead to aggressive actions), and situational factors (e.g. traffic congestion, weather, and maintenance problems) (Knipling, 2009). These factors are important whether or not a truck is involved in the incident but, given the skill required to operate a commercial motor vehicle, their impact may be more pronounced when incidents involve a truck.

Time of day and day of the week are related to each of these factors. Driver fatigue more commonly manifests itself at night (Massie, Blower and Campbell, 1997) and may result from enduring or temporary driver characteristics. Some people are naturally more susceptible to fatigue and may have medical conditions, such as sleep apnea, that contribute to fatigued driving. Fatal fatigue related truck crashes generally involve only the offending truck, which frequently leaves the road (Massie, Blower and Campbell, 1997). Traffic congestion is more common during the day, particularly during weekday rush hours, and is positively related to the occurrence of safety incidents (Hendrix, 2002) as 85% of truck crashes involve other vehicles; overwhelmingly cars (Knipling, 2009). While night and weekend roads are less congested, they are more likely to be populated by impaired drivers. The Large Truck Crash Causation Study (LTCCS), undertaken as a collaboration between FMCSA and NHTSA, examined 1,000 large truck crashes between 2001 and 2003 and found that alcohol was used by 9.0% of car drivers but only 0.3% of truck drivers (FMCSA, 2007). Hendrix (2002) found the incidence of fatal light vehicle accidents begin rising at 10PM and peaked around 3AM.

Knipling’s (2009) motor carrier safety textbook posits that government and academic research have neglected the importance of exposure data (e.g. number and timing of miles driven) when assessing roadway travel risk. The aforementioned literature demonstrates that different risks occur at different times and on different days. Drivers choose the hours of day in which to drive and must decide when to expose themselves and their equipment to roadway risks. Knowing the likelihood that an accident of a given severity will occur might help them make more informed decisions. This work draws from FMCSA data to explore whether fatal, injury, or property only crashes are more likely to happen during the daylight or night and weekday or weekend. Conclusions are supported using the odds ratio, a technique advocated by Knipling (2009), to assess the likelihood a given risk will result in certain outcomes.

**METHODOLOGY AND RESULTS**

FMCSA was established within the Department of Transportation (DOT) on January 1, 2000 (FMCSA, 2014). At that time, the FMCSA was tasked with commercial driver licensing, data and analysis, regulatory compliance and enforcement, research, technology, and safety assistance activities. Ultimately, the FMCSA’s stated mission is to prevent commercial motor vehicle related fatalities and injuries (FMCSA, 2014). In an effort to educate the public, the FMCSA has published the Large Truck and Bus Crash Facts (LTBCF) analysis annually since 2010. LTBCF compiles descriptive statistics pertaining to truck crashes of different severities and draws from four major sources of information: NHTSA’s Fatality Analysis Reporting System (FARS), NHTSA’s General Estimates System (GES), FMCSA’s Motor Carrier Management Information System (MCMIS), and Federal Highway Administration’s (FHWA) highway statistics (FMCSA, 2017). This study utilizes LTBCF data from 2011 – 2015, which is the most recent year available. FMCSA requires accidents to be reported that involve a truck, bus, or any
vehicle displaying a hazardous materials placard, if one of these vehicles was involved in a crash while operating on a roadway customarily open to the public, or if the accident resulted in fatality, injury or tow-away (FMCSA, 2015). When attempting to understand why these accidents occur and how to prevent them one must first understand when they occur. LTBCF data from 2015 are provided in Tables 1 and 2 below as an example. The information contained in Table 1 provides a comparison of the time of day in which accidents occurred and the severity of those accidents.

Table 1 demonstrates that fatal, injury, and property damage only accident rates are not uniformly distributed throughout the day. Rather, the occurrence of each type of accident is more or less normally distributed with the majority occurring between peak driving hours of 6AM and 6PM. Each year from 2011-2015 exhibited similar characteristics. Table 2 compares days of the week in which accidents occurred and the severity of those accidents.

Table 2 demonstrates that accident rates are not uniformly distributed throughout the week. Accidents of all severities occur more frequently during the work week and less frequently on the weekends. Each year from 2011-2015 exhibited similar characteristics. LTBCF data demonstrate a directional difference, with more of each accident severity category occurring during daylight hours and during the week. This would lead one to believe that accidents of any severity are more likely to occur on weekdays during daylight hours. However, this may be deceiving as it does not control for exposure. More people are driving during the day and during weekdays. More accidents occur as more people are driving. This is true for two basic reasons. First, as roads become more crowded, more vehicles are compressed into a given space. As compression increases, proximity between vehicles decreases, and the chance of contact between vehicles increases. Second, each driver has a given risk of being involved in an accident based on skill, mechanical factors, and other issues. For example, driver skill and accident risk would be inversely proportional. Even the most skilled drivers with the most mechanically sound vehicles bear some accident risk. As more people drive, more accidents will occur due to exposure to the accident risks of all drivers with whom the road is shared. Therefore, more people on the road leads to more accidents due to 1) greater compression and 2) more driving participants, which leads to more accidents due to exposure.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Fatal Crashes</th>
<th>Injury Crashes</th>
<th>Property Damage Only Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>12am - 3am</td>
<td>279</td>
<td>3,000</td>
<td>7,000</td>
</tr>
<tr>
<td>3am - 6am</td>
<td>352</td>
<td>4,000</td>
<td>10,000</td>
</tr>
<tr>
<td>6am - 9am</td>
<td>578</td>
<td>16,000</td>
<td>55,000</td>
</tr>
<tr>
<td>9am - 12pm</td>
<td>569</td>
<td>15,000</td>
<td>71,000</td>
</tr>
<tr>
<td>12pm - 3pm</td>
<td>643</td>
<td>19,000</td>
<td>75,000</td>
</tr>
<tr>
<td>3pm - 6pm</td>
<td>552</td>
<td>16,000</td>
<td>66,000</td>
</tr>
<tr>
<td>6pm - 9pm</td>
<td>324</td>
<td>7,000</td>
<td>29,000</td>
</tr>
<tr>
<td>9pm - 12am</td>
<td>295</td>
<td>4,000</td>
<td>16,000</td>
</tr>
<tr>
<td>Daytime (6am - 6pm)</td>
<td>2,342</td>
<td>65,000</td>
<td>267,000</td>
</tr>
<tr>
<td>Nighttime (6pm - 6am)</td>
<td>1,256</td>
<td>18,000</td>
<td>61,000</td>
</tr>
<tr>
<td>Total</td>
<td>3,598</td>
<td>83,000</td>
<td>328,000</td>
</tr>
</tbody>
</table>
Focusing on fatal accidents in 2015, Table 1 indicates that 2,342 fatal accidents occurred in the daytime compared to 1,256 at night. However, more daytime traffic engenders more accidents. The question remains, if you are involved in an accident, is this accident more likely to be fatal (injury, or property damage only) during the day or night? To answer this question, we must control for exposure.

Optimally, we would control for exposure by comparing the number of accidents per million miles driven (for example) on each day of the week/at each time of day. LTBCF does not provide this data. Given this, we chose to control for exposure by comparing a) the percentage of daytime fatal (injury, property damage only) accidents as a percentage of total daytime accidents to b) the percentage of nighttime fatal (injury, property damage only) accidents as a percentage of total nighttime accidents. Given that more of all accident types occur in daytime, comparing percentages affords a standardized measure to determine whether the likelihood of a fatal (injury, property damage only) accident is greater in day or night.

Summing all accident severity types in Table 1 across all daytime hours reveals 334,342 total daytime accidents; 2,342 of which were fatal (7%). Following the same procedure for nighttime crashes reveals 80,256 nighttime crashes; 1,250 of which were fatal (16%). Percentages were derived in a similar fashion for daytime and nighttime injury and property damage only crashes as well as weekday v. weekend fatal, injury, and property only accidents.

Percentages from 2011 – 2015 were combined, coded, and analyzed using ANOVA to determine if significant differences exist in the number of fatal, injury, and property only accidents that occur in the day v. night. Observations were coded as DAY if the accident occurred from 6AM – 6PM. Observations were coded as NIGHT if the accident occurred from 6PM – 6AM. This yielded a total of 20 DAY and 20 NIGHT observations (n = 40) for each accident severity type. Results for time of day x accident severity type are presented in Table 3.

Results indicate significant differences for all three types of crash severity. The mean column represents the percentage of all crashes during that time period that resulted in a given crash severity outcome. Of all the nighttime crashes, 2.16% resulted in a fatality. Fatal crashes make up a significantly larger percentage of all nighttime crashes than they do daytime crashes. (F = 42.317; p £ 0.01). Of all the nighttime crashes, 24.20% resulted in injury. Injury crashes comprise a significantly larger percentage of all nighttime crashes than they do daytime crashes (F = 11.135; p £ 0.01). Of all daytime crashes, 78.48% result in

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Fatal Crashes</th>
<th>Injury Crashes</th>
<th>Property Damage Only Crashes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunday</td>
<td>245</td>
<td>4,000</td>
<td>14,000</td>
</tr>
<tr>
<td>Monday</td>
<td>560</td>
<td>15,000</td>
<td>61,000</td>
</tr>
<tr>
<td>Tuesday</td>
<td>605</td>
<td>15,000</td>
<td>64,000</td>
</tr>
<tr>
<td>Wednesday</td>
<td>606</td>
<td>13,000</td>
<td>53,000</td>
</tr>
<tr>
<td>Thursday</td>
<td>631</td>
<td>16,000</td>
<td>58,000</td>
</tr>
<tr>
<td>Friday</td>
<td>598</td>
<td>13,000</td>
<td>56,000</td>
</tr>
<tr>
<td>Saturday</td>
<td>353</td>
<td>7,000</td>
<td>22,000</td>
</tr>
<tr>
<td>Total</td>
<td>3,598</td>
<td>83,000</td>
<td>328,000</td>
</tr>
</tbody>
</table>
property damage only. Property damage only crashes make up a significantly larger percentage of all daytime crashes than they do nighttime crashes ($F = 16.520; p \leq 0.01$).

Following the same procedure utilized in the day vs. night comparison, percentages for 2011 – 2015 were combined, coded, and analyzed using ANOVA to determine if significant differences exist in the number of fatal, injury, and property only accidents that occur on weekdays vs. weekends. Observations were coded as WEEKDAY if the accident occurred from Monday to Friday. Observations were coded as WEEKEND if the accident occurred from Saturday – Sunday. This yielded a total of 25 WEEKDAY and 10 WEEKEND observations (n = 35) for each accident severity type. Results for day of the week x accident severity type are presented in Table 4.

Results indicate significant differences across all three types of crash severity. Of all the weekend accidents, 1.49% resulted in fatality. Fatal accidents make up a significantly larger percentage of all weekend accidents than they do weekday accidents ($F = 47.528; p \leq 0.01$). Of all the weekend accidents, 23.94% result in injury. Injury crashes comprise a significantly larger percentage of all weekend accidents than they do weekday accidents ($F = 8.112; p \leq 0.01$). Of all the weekday crashes, 78.15% result in property damage only. Property damage only crashes comprise a larger percentage of all weekday crashes than they do weekend crashes ($F = 10.082; p \leq 0.01$).

Given the small sample size utilized in the analyses presented heretofore, we utilized the odds ratio technique to further support our findings. Knipling (2009, p. 50) advocates the use of odds ratios and

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### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Day or Night</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>Day</td>
<td>0.83%</td>
<td>0.14%</td>
<td>20</td>
<td>42.317</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>2.16%</td>
<td>0.90%</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury</td>
<td>Day</td>
<td>20.68%</td>
<td>1.77%</td>
<td>20</td>
<td>11.135</td>
<td>0.002*</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>24.20%</td>
<td>4.37%</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property</td>
<td>Day</td>
<td>78.49%</td>
<td>1.84%</td>
<td>20</td>
<td>16.520</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Night</td>
<td>73.64%</td>
<td>5.01%</td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant difference at $p \leq 0.01$

---

### Table 4

<table>
<thead>
<tr>
<th></th>
<th>Weekday or Weekend</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
<th>F</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatal</td>
<td>Weekday</td>
<td>0.97%</td>
<td>0.16%</td>
<td>25</td>
<td>47.528</td>
<td>0.000*</td>
</tr>
<tr>
<td></td>
<td>Weekend</td>
<td>1.49%</td>
<td>0.30%</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Injury</td>
<td>Weekday</td>
<td>20.88%</td>
<td>1.73%</td>
<td>25</td>
<td>8.112</td>
<td>0.008*</td>
</tr>
<tr>
<td></td>
<td>Weekend</td>
<td>23.94%</td>
<td>4.72%</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Property</td>
<td>Weekday</td>
<td>78.15%</td>
<td>1.82%</td>
<td>25</td>
<td>10.082</td>
<td>0.003*</td>
</tr>
<tr>
<td></td>
<td>Weekend</td>
<td>74.56%</td>
<td>4.96%</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Significant difference at $p \leq 0.01$
describes them as, “…a derived statistic that estimates the relative risks of a crash [severity type] based on some other factor of interest [day v. night or weekday v. weekend].”

Knipling (2009, p. 50) provides an example of an odds ratio in use. Suppose a motor carrier with 100 drivers wishes to determine the impact of sleep apnea on accident frequency. Over a period of time, 11 company drivers were involved in accidents. Out of these 11 drivers it was determined that 6 had sleep apnea and 5 did not. Computing the odds ratio of crash involvement in this scenario requires comparing the odds of being in a crash for those who have sleep apnea to those who do not. The company is said to have 26 drivers with sleep apnea, 6 of whom were involved in an accident. This leaves 74 drivers without sleep apnea, 5 of whom were involved in an accident. Knipling (2009) structures the aforementioned scenario as follows:

\[
\text{Sleep apnea odds ratio} = \frac{6}{20} = \frac{0.30}{0.07} = 4.1
\]

In this example, the odds of an accident given that a driver has sleep apnea is 4.1. Values greater than 1.0 indicate greater risk is associated with the factor. Values less than 1.0 indicate less risk associated with the factor. Greater deviations from 1.0 indicate more/less risk.

Tables 3 and 4 indicate that accidents are more likely to be fatal or injurious on nights and weekends. Therefore, we placed night and weekend data in the numerator indicating it is the risk factor for which the odds ratio is quantifying. The odds ratio calculation for 2015 weekend v. weekday fatal crashes is provided below as an example.

Results for 2011 – 2015 are presented in Table 5.

Results presented in Table 5 indicate that fatal accidents are more likely to occur on nights and weekends for each year from 2011 – 2015. Injury accidents were more likely to occur on nights and weekends in 2015, 2013, and 2012 as well as weekends in 2011. Injury accidents were less likely to occur on nights and weekends in 2014 and less likely to occur on nights in 2011. Property damage was less likely to occur on nights and weekends in 2015, 2013, 2012, and 2011. Property damage was more likely to occur on nights and weekends in 2014.

**IMPLICATIONS**

Results presented in this study indicate statistically significant differences between the likelihood of different accident severities across nights v. days and weekends v. weekdays as a function of the total accidents that occur in each time period. As a percentage of total accidents during a respective time period, accidents involving a fatality or injury are more likely to occur on nights and weekends. Accidents involving property damage only are more likely to occur on days and weekdays. These results may have important managerial implications.

Roadway traffic congestion is greatest during weekday daylight hours and especially in peak, rush hour drive time (ATRI, 2014). Over the road commercial motor vehicles are often compensated on a per mile basis. Congestion reduces the number of miles a truck can travel in a given period of time.

**2015 Weekend v. Weekday Fatal Accident**

\[
\frac{\text{Total Fatal Weekend Accidents}}{\text{Total Weekend Accidents} - \text{Total Fatal Weekend Accidents}} = \frac{\text{Total Fatal Weekend Accidents}}{\text{Total Weekend Accidents} - \text{Total Fatal Weekend Accidents}}
\]

\[
= \frac{598}{47,598 - 598} = 1.54
\]

\[
= \frac{3,000}{367,000 - 3,000}
\]
Sharing the road with fewer drivers is also perceived to improve safety. Therefore, drivers’ common sense often dictates a preference to operate on nights and weekends in the interest of maximizing compensation and perceived safety performance.

Raw FMCSA data demonstrate that a larger number of accidents, regardless of severity, occur on weekday days. A disproportionate number of these accidents result in property damage without injury or fatality. However, outcomes differ when controlling for exposure (e.g. the total number of accidents). In this context, our results indicate that accidents occurring at night or on weekends are significantly more likely to result in death or injury compared to accidents that occur during the day. Accidents occurring during the day or on weekdays are significantly more likely to result in property damage only.

Counterintuitively, traffic congestion may actually reduce accident severity. Newton’s second law states that force is a function of mass and acceleration. Force increases as the speed of an object with a given mass increases. Greater force increases accident severity. Congestion slows traffic (ATRI, 2014) and, therefore, reduces the force involved in accidents that occur. Therefore, congestion may also reduce accident severity during day and weekdays as demonstrated in our study.

Decreased congestion allows trucks to travel at higher average speeds. Higher speeds allow trucks to increase daily revenue. However, should an accident occur, higher speeds increase accident severity. Increased speed may contribute to the increased severity of night and weekend accidents.

The population of inebriated drivers also increases on nights and weekends. Commercial truck drivers are not often found to be under the influence of alcohol when a fatal accident occurs. NHTSA reported that 2.7% of commercial truck fatal crashes involved alcohol use by the truck driver. Car drivers were impaired by alcohol in 27% of fatal light vehicle crashes (NHTSA, 2017). Blower (1998) studied driver error in accidents involving cars and large trucks. Results indicate that the car driver was at fault in 71% of accidents. The increased presence of impaired car drivers during night and weekend hours likely increases truck accident severity.

Drivers should consider these results when planning their trips. Drivers should not take advantage of decreased congestion and travel at unsafe speeds. Caution should be taken to maintain speeds that are safe for conditions. Drivers should also more carefully weigh the tradeoffs of exposure as it relates to day v night and weekday v weekend driving. Reduced congestion inherent to night and weekend driving increases profitability, but there is also a

<table>
<thead>
<tr>
<th>Year</th>
<th>Night/Day</th>
<th>Weekend/Weekday</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>2.24</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>1.18</td>
<td>1.23</td>
</tr>
<tr>
<td></td>
<td>0.86</td>
<td>0.80</td>
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<tr>
<td>2014</td>
<td>2.29</td>
<td>1.43</td>
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<tr>
<td></td>
<td>0.93</td>
<td>0.76</td>
</tr>
<tr>
<td></td>
<td>1.02</td>
<td>1.27</td>
</tr>
<tr>
<td>2013</td>
<td>2.12</td>
<td>1.56</td>
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<td></td>
<td>1.20</td>
<td>1.47</td>
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<td></td>
<td>1.27</td>
<td>1.21</td>
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<tr>
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<td>2.39</td>
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</tr>
<tr>
<td></td>
<td>0.74</td>
<td>1.30</td>
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<td>0.71</td>
<td>0.76</td>
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significantly increased risk of fatal or injurious accident during these times when compared to days and weekdays.

Safety managers should also consider exposure when setting company policy. Any safety incident is detrimental. However, insurance carriers often dictate safety managers reduce certain types of incidents (e.g. property damage, injury only, or catastrophic fatality losses). Safety managers may use the principals of exposure explained heretofore as a lever to influence safety outcomes. Given an overabundance of past property damage or injury only incidents, safety managers may wish to control for excess exposure to other vehicles and encourage drivers to operate at night or on weekends. However, if faced with the need to reduce catastrophic losses, safety managers may encourage drivers to operate during the day or on weekdays.

LIMITATIONS AND FUTURE RESEARCH

This study is faced with several limitations. First, real-time information cannot be gleaned from the FMCSA LTBCF data due to the two-year delay in its release. However, given the relative stability of accident severity odds ratios presented in Table 5, it is likely that our findings remain applicable today.

Next, secondary data was used in this study. The validity of our results is subject to the practices of those who collect and code the LTBCF data. Finally, small sample sizes employed in our analysis inhibit generalizability. Future investigations should seek to collect more data or obtain larger datasets.

Future investigations should also uncover reasons behind increased night and weekend accident severity. We posit that increased speed and impaired light vehicle drivers play a significant role. However, LTBCF data do not contain information that would allow us to substantiate this theory.

Data limitations also prevented the examination of covariates. Our results would imply that accidents are most severe on weekend nights. Future research should examine this possibility.

Motor carrier safety research is relatively lacking in the business logistics literature. The large volume of available, secondary data makes this a potentially fruitful area for further inquiry. Researchers wishing to collect primary data may wish to define a new “driver deviance” construct and assess its impact on safety performance. Deviant behavior (e.g. such as speeding, poor maintenance practices, and log book violations) have been shown to influence safety outcomes. This research should seek to uncover characteristics of drivers that are more likely to result in bad behavior, and how these drivers can be avoided in the hiring process.

CONCLUSIONS

Safety is of paramount importance to motor carrier operations. However, safety is multi-faceted and not easily achieved. Drivers must operate in a safe manner. Management must put drivers in a position to operate safely by, for instance, scheduling delivery appointments that can be legally achieved in accordance with posted speed limits and Federal HOS regulations. Drivers must also be aware and wary of those with whom they share the road.

Our results demonstrate that safety outcomes differ by time of day and day of the week. However, the clock and calendar do not determine roadway safety. Safety outcomes are primarily determined by human choices. These choices differ by the temporal factors examined herein. These temporal factors are but a small subset of those contributing to the thousands of deaths that occur annually on American roads. Safety is a shared responsibility and one that is equally important at every hour on every day.

REFERENCES


BIOGRAPHIES

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SAFETY FITNESS DETERMINATIONS:
WHAT IS FMCSA MEASURING?
Big Data and Regulatory “Improv” are Drowning Due Process

Mark J. Andrews
Clark Hill Strasburger

INTRODUCTION
This article reports on a topic assigned to a recent legal conference panel that discussed safety fitness determinations for motor carriers. The assigned topic, focused on safety fitness determinations, big data, and due process, begs the question of whether the Federal Motor Carrier Safety Administration (FMCSA or the Agency) is measuring anything that’s really relevant to the “safety” or “fitness” of a motor carrier of passengers or property to operate on the Nation’s highways. Even if FMCSA thinks it is measuring safety or fitness, the more important question is whether those measurements are accurate or fair. I submit that the successive efforts of FMCSA and its predecessor agencies to measure safety and fitness based on mass quantities of roadside inspection data are incapable of either accuracy or fairness. This is true of the methodology known as Compliance, Safety, Responsibility (CSA) and was true of its SAFESTAT predecessor before 2010. The same will be true if FMCSA ever tries to implement the recommendations of the National Academies of Sciences (NAS) for vastly expanded data collection as envisioned in the Item Response Theory (IRT).

The Agency’s history of data mismanagement has been well-documented in the context of the Safety Measurement System (SMS) developed under CSA. But if we look beyond past history with SMS, the same problems threaten to cripple the Agency’s future response to other regulatory issues in the supply chain. FMCSA is still struggling with the basic task of writing computer code to support the Unified Registration System (URS) it unveiled as a “final rule” in 2013. It has yet to comply with literally dozens of mandates under the Fixing America’s Surface Transportation Act, Pub. L. 114-94 (FAST Act) for procedural reform in areas that include but are not limited to SMS. Thus it is ill-equipped to analyze emerging regulatory issues ranging from crash preventability to the safety of “last mile” delivery operators. Instead, the Agency too often flounders from one issue to the next, substituting evanescent “guidance” for predictable rules. These issues of poor data quality, small sample sizes, data mismanagement, institutional “innumeracy” (look it up) and regulatory improvisation pose existential threats to administrative due process, as will be developed in more detail below.

ANALYSIS OF THE ISSUE

Big Data ≠ Good Data
By now an ample body of evidence has been presented to FMCSA, to the United States Department of Transportation (USDOT) and to Congress regarding the defects of SAFESTAT and SMS methodology. This evidence comes from federal watchdog agencies, from academic studies and even from NAS in its review of SMS under the FAST Act. The major shortcomings of roadside inspections as a surrogate for safety fitness are detailed in Attachment 1.

Those shortcomings include:

- State by state disparities in safety enforcement policies mean that SMS scores largely depend on
where a carrier operates, not on the inherent safety of those operations.

- The Governmental Accountability Office (GAO) has stated that the roadside inspections undergone by small motor carriers typically fail to yield sufficient sample sizes to reflect the overall safety of such fleets over time.

- The “law of large numbers” ensures that an occasional bad inspection will cause much more severe fluctuations in the SMS score for a small fleet than for a larger one.

- The impact of a bad inspection is magnified by widespread under-reporting of “clean” inspections.

- The Agency’s 800-plus “enhancements” of SMS methodology since its launch in 2010 detract from the predictability and usefulness of its performance standards, and have ignored established procedures for due process in rulemaking.

- Most importantly, the percentile scores generated by SMS from roadside inspection data fail to predict the actual crash history of individual motor carriers. Numerous crash-free carriers within the artificial peer groupings created under SMS suffer from guilt by association due to “averaging of averages” with regard to aggregate performance levels.

### Bigger Data ≠ Better Data

Although the NAS report recognizes many of the SMS statistical problems described above, its proposed solution is essentially “more of the same.” The proposed IRT model would vastly expand the amount, type and complexity of data gathered from motor carriers, to include competitively sensitive data such as method and amount of compensation, type of cargo transported, and driver turnover. The additional costs of gathering and analyzing such additional data are likely to be compounded by industry resistance to providing it in the first place.

In addition, fundamental legal issues are raised by two recommendations in the NAS Report (at p.5), to the effect that an IRT model should “allow for the addition of new safety measures as they become available, without having to start from scratch” and should “adapt to changes in safety over time.” These recommendations would exacerbate the worst feature of SMS from a due-process standpoint – the constantly moving targets resulting from its endless “enhancements” of the scoring system. With or without the IRT overlay, SMS cannot become the basis for definitive safety fitness determinations as long as its criteria are subject to constant revision without prior notice and opportunity for comment. While it may be understandable that the statisticians authoring the NAS report were not aware of the due process requirements for making and changing rules under the Administrative Procedure Act, FMCSA has no such excuse.

### Can FMCSA Handle Big Data?

When FMCSA requested public comments on the NAS report last year, it targeted a December 2017 release date for a “Corrective Action Plan” in response to NAS. At this writing in April 2018, we’re still waiting – but this observer is not surprised. With due respect and regret, it must be said that FMCSA is barely able to maintain the data bases and IT systems supporting its current activities, let alone address the complexities or IRT.

The five-year debacle that is URS already has been mentioned. Last summer, two federal watchdogs renewed their criticisms of data management by FMCSA. The USDOT Inspector General stated in Report No. ST2017065 (July 25, 2017) that the Agency needed “to address its quality assurance processes and compliance review data limitations.” Similarly, a GAO report (No. GAO-17-488, July 13, 2017) called on FMCSA to modernize legacy IT systems, including development of “well-defined goals, strategies, measures and timelines.” More recently, the Agency’s online registry of certified medical examiners for drivers was hacked on December 1, 2017 and remained out of service more than three months later (Transport Topics, March 19, 2018, pp. 1, 47). Perhaps it is time for FMCSA to borrow IT staff from sister agencies such as the Bureau of Transportation Statistics in order to upgrade its data management.
The above background casts serious doubt on the feasibility of implementing the abstruse IRT model. In all likelihood, that model would turn out to be an even costlier and more data-intensive version of SMS. Considering that SMS is still riddled with statistical, logical and legal defects after eight years of “enhancements,” adding an IRT overlay would amount to throwing good money after bad. Isn’t it time for FMCSA to consider alternative ways of fulfilling the statutory mandate (see 49 U.S.C. § 31144(a)) that actual safety fitness determinations be assigned to all 532,000 truck and bus fleets it regulates? One such alternative would be to expand desktop audits, now used by FMCSA for “new entrant” carriers, into a fee-based program linked to the periodic MCS-150 updates now required for all fleets. Details of this proposal, including follow-up site visits as warranted, have been spelled out for FMCSA in comments repeatedly filed for coalitions represented by myself and my co-panelist Hank Seaton, whose contributions to the analysis underlying this paper have been significant and are valued by the author.

CONCLUSION:
BEYOND SMS, NAS, IRT AND THE FAST ACT

FMCSA’s unfinished business under the FAST Act is not limited to dealing with the NAS report. Wholly aside from the FAST Act mandates still facing FMCSA with regard to safety fitness issues and administrative procedures generally, the industry is facing many other regulatory challenges necessitating improved IT and data management at FMCSA. These issues include:

- Whether and how to modify Part 395 in view of the increasing economic toll of vehicle detention and the onset of electronic logging.
- Whether the emerging issue of salvage for food shipments should be jointly addressed by FMCSA and the Food & Drug Administration (FDA). in view of shipper claims that the “actual loss” standards of the Carmack Amendment (49 U.S.C. § 14706) are changed by “adulteration” provisions in new FDA regulations on sanitary food transportation (21 C.F.R. Part 1).
- And finally, how to reform FMCSA procedures to allow independent administrative review of safety fitness determinations to at least the extent now available for civil penalties with less severe commercial impacts.

Attachment 1:
Excerpt from Comments of MCRR Coalition in Docket FMCSA-2017-0226

1 Editor’s Note

– This article is written in a law review style and advocates a particular positon as is common in law review articles. The article has been formatted for the journal’s style but the references are not in JTM’s typical style. The Journal does not take a position on the points made by the author.

(Footnotes)

1 See, e.g., comments filed with FMCSA on September 27, 2017 by a coalition (for which your author and co-panelist Hank Seaton served as counsel) in response to the NAS study of SMS. A full copy of that filing can be viewed at https://www.regulations.gov/document?D=FMCSA-2017-0226-0014. An excerpt from it is reproduced in Attachment 1 to this paper.
BIOGRAPHY

Mark J. has practiced law in Washington, D.C. since his admission to the District of Columbia bar in 1970. He became the Partner-in-Charge for the Washington, D.C. office of Dallas-based Strasburger & Price, LLP when that office was opened on October 1, 2001, and recently became a Member of Clark Hill PLC when that law firm and the Strasburger firm completed a combination. Among other things, Mark assists clients in resolving conflicts between U.S. federal and state laws; complying with U.S. federal licensing and safety rules for surface, air and ocean carriers; obtaining regulatory clearances for transportation mergers and acquisitions, and drafting and negotiating complex agreements for management of U.S. domestic and international supply chains. A holder of undergraduate and law degrees from Harvard University, Mark is a past co-chair of the International Transportation Committee within the American Bar Association’s Section of International Law, a past President of the Transportation Lawyers Association, a recipient of that association’s Lifetime Achievement Award, and an elected member of the American Law Institute. E-Mail: Andrews (mark.andrews@clarkhillstrasburger.com)
ATTACHMENT

BEFORE THE FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION WASHINGTON, D.C.

Docket No. FMCSA-2017-0226
Fixing America’s Surface Transportation Act Correlation Study

COMMENTS AND AFFIDAVITS OF THE MOTOR CARRIER REGULATORY REFORM (MCRR) COALITION, INCLUDING

Air & Expedited Motor Carrier Association (AEMCA)
Alliance for Safe, Efficient and Competitive Truck Transportation (ASECTT)
American Home Furnishings Alliance (AHFA) / Specialized Furniture Carriers
Apex Capital Corp.
Auto Haulers Association of America (AHAA)
National Association of Small Trucking Companies (NASTC)
Tennessee Motor Coach Association (TMCA)
The Expedite Alliance of North America (TEANA)
Transportation and Logistics Council (TLC)
Transportation Loss Prevention & Security Association (TLP&SA)

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Date Due and Filed: September 27, 2017

IV. Responses to Federal Register notice
In the following discussion, Commenters will address the NAS recommendations set out in the Agency’s August 28 Federal Register notice. In doing so, Commenters will point out that no corrective action plan can be confined to these recommendations in light of the analysis of the FAST Act and the limitations of the systemically flawed SMS.
A. Recommendation 1 – Item Response Theory Model

Systemic flaws that undermine SMS methodology would plague any statistical model based on the same data – even the NAS panel’s proposed IRT approach.

After spending 10 years in its development, FMCSA has made more than 800 changes to its safety weighting procedures and its convoluted algorithms in an effort to “improve” the accuracy of its system. Yet the Agency has failed to address systemic flaws that Commenters have consistently presented but that have been ignored.

The NAS Report expresses a belief that introducing more types of data and using a more rigorous mathematical formula to interpret and normalize the data will result in more accurate and reliable scoring among the carriers than is currently available under SMS. In particular, Chapter 2 of the NAS Report acknowledges many current deficiencies of SMS and concedes that most of them are not readily fixed. The report fails to recognize, however, that similar flaws would pervade its proposed IRT model, which would try to predict crash risk by crunching even more gargantuan amounts of data using algorithms even more complex than those of SMS.

Although the MCRR Coalition will not explore the systemic flaws of SMS in detail at this point, we believe a brief recap is necessary to show issues not fully addressed in the NAS Report’s support of the IRT Model. As we have established in previous submissions to FMCSA\(^1\), SMS suffers from at least seven systemic flaws:

- Insufficient Data
- The law of small numbers
- Misuse of average crash rates
- Misuse of crash data
- State-by-State enforcement inconsistencies
- Peer group creep
- Profiling
- Enforcement biases

Evidence of insufficient data is extensive, but just a few points will suffice here: Based on our analysis of the 24-month SMS snapshot for August 2017, among the 532,000 active U.S. interstate motor carriers:

- 39.6% had no inspections
- Just 7.5% had 20 or more total inspections – the minimum threshold of data sufficiency recommended by GAO for individual BASICs
- 83.7% do not have the minimum number of inspections with violations to be considered in any of the five public SMS BASICs even under FMCSA’s inadequate data sufficiency thresholds\(^2\)

The Driver Fitness and Controlled Substances/Alcohol BASICs each capture fewer than 1 percent of active U.S. motor carriers. Meanwhile, the Unsafe Driving and Hours-of-Service Compliance BASICs have seen and will continue to see major declines in data sufficiency. The Unsafe Driving BASIC suffers from the huge decline over the past decade in traffic enforcement (“TE”) inspections, which are the sole source of data for this BASIC. As seen in Figure APP-1 these inspections peaked in 2006 and have since dropped 59.6%. TE inspections are down 37.4% since the year FMCSA implemented CSA. The drop in TE inspections has leveled off, but there are no signs of a rebound.

Likewise, the growth in popularity of electronic logging among larger carriers apparently has starved the HOS Compliance BASIC of many data points previously collected at roadside, and this trend should become even more pronounced once the electronic logging device mandate is fully implemented. The ELD mandate could help correct a different systemic flaw in SMS – enforcement bias.
– and of course should improve compliance with the HOS regulations. But it could also render the HOS Compliance BASIC obsolete.

Given these trends, even under FMCSA’s clearly inadequate current standards of data sufficiency, the Vehicle Maintenance BASIC – in which just 12% of carriers meet the minimum threshold – could become the only BASIC with anything remotely approaching a meaningful amount of data, albeit with a preponderance of low-value violations. (See “Enforcement biases” below.) However, applying the data sufficiency standard recommended by GAO, SMS basically disappears except, arguably, as a tool for monitoring large carriers. This is a systemic flaw that FMCSA is powerless to rectify and that would plague any statistical model.

**Law of Small Numbers**

The law of small numbers is in large part a function of data insufficiency. As has been widely recognized, SMS metrics become extremely volatile as the number of data points drops. This is the same phenomenon – small sample size – that leads baseball fans to pay little attention to early-season batting averages. As noted above, GAO concluded that SMS metrics could be reliable only at a higher data sufficiency standard of at least 20 observations.

Although the NAS Report does not refer explicitly to the law of small numbers, it is quite clear regarding the impact of the phenomenon. We quote the following again for emphasis:

There is no getting around the point that providing BASIC measures to carriers that have very infrequent inspections will result in highly variable assessments of such carriers. This is simply because not much is known about the frequency of violations for small carriers. Such high variance measures can result in mischaracterizing the nature of a carrier—the high variability could result in the carrier being given alerts more or less often than what would be warranted given its behavior. On the other hand, the industry is highly skewed, being comprised of a very large number of small carriers. If the data sufficiency standards were raised, a high percentage of the industry would be excluded from measurement by SMS and therefore monitoring by FMCSA. We believe that this issue should be further investigated. (NAS Report, p. 46)
A similar problem relates to how FMCSA misuses the data in formulating regulatory and enforcement policy. Our Coalition has consistently challenged the Agency’s use of average carrier performance to make sweeping claims that do not describe the reality of individual carriers. We submitted the following graphs (Figure APP-2) as part of our comments filed in July 2012 in Docket No. FMCSA-2012-0074 and again in May 2016 in response to the SFD Proposal (Docket No. FMCSA-2015-0001). These graphs show FMCSA’s regression of average crash rates for carriers in the Fatigued Driving (now HOS Compliance) and Unsafe Driving BASICs compared to a plot of the individual carriers’ crash rates.

**FIGURE APP-2**

**FMCSA REGRESSION OF AVERAGES – FATIGUED DRIVING**

**PLOT OF 35,933 CARRIERS – FATIGUED DRIVING**

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The upshot is that SMS is not remotely predictive of individual carriers’ safety performance where it matters most – i.e., crashes. As discussed earlier, this flaw lies at the very heart of what Congress wanted to address in the NAS correlation study. Both the Agency and the NAS panel have been presented with this study and have not addressed the issue. In fact, in their response to the Agency’s NPRM in 2016, Commenters demonstrated this regression of averages when applied to peer group percentiles misidentified 53% of profiled carriers who had no crashes during the review period as “bad actors” warranting unfit ratings.

**Crash Data**

The SMS structure traditionally has depended upon counting all reported accidents without any scrubbing for “preventability,” let alone for causation or – even more appropriate – for absence of carrier compliance with safety regulations resulting in causation. DataQ simply does not work since the Agency insists on publishing data under a “presumed guilty until proven innocent” basis. And it does not determine causation, nor can it at less than prohibitive cost. The light scrubbing the Agency now offers for preventability determinations – in very limited scenarios as part of its two-year pilot program – cannot possibly offer a remedy for small carriers unlucky enough to be caught up in accidents that were not their fault.

Multiple studies have shown that most fatal car-truck crashes are not the result of actions by the commercial motor vehicle driver.\(^3\) FMCSA’s annual Large Truck and Bus Crash Facts publication consistently shows essentially the same breakdowns with around 84% to 86% of passenger vehicle drivers being cited for driver factors and only 26% to 35% of truck drivers cited with driver factors.\(^4\)

Regarding crash preventability, the NAS Report is equivocal. It lists (at pp. 48-50) several factors that would complicate a proposal to set aside non-preventable crashes. On the other hand, the report acknowledges that including non-preventable crashes is potentially misleading because any carrier placed in the same situation would have crashed, meaning that the crash is simply a consequence of circumstances, not carrier or driver misdeed. “This is an important issue, especially for small carriers, since such events can be extremely damaging, possibly putting some small carriers out of business.” NAS Report, p. 48. As is evidenced elsewhere in the report, the NAS panel seems willing to shrug off the problem, and live with a system that it acknowledges is grossly unfair to small carriers.

**Inconsistent Enforcement**

A system that compares carriers operating under different state regimes cannot be justified, particularly when the evidence shows significant variation in enforcement prerogatives by state. For example, commenters have long demonstrated that enforcement anomalies distort any effort to normalize or compare speeding violations among carriers that operate in different areas. Consider Figure APP-3 below, which shows that Indiana – accounting for about 3% of commercial vehicle miles each year – writes up 10% of all reported commercial vehicle moving violations nationwide.\(^5\) Neighboring state Michigan accounts for slightly more than 5% of the moving violations but less than 2% of the miles. Among the top 10 states in moving violations, five – Indiana, Michigan, Illinois, Pennsylvania, and Ohio – are in the Great Lakes region. Carriers that operate in western states inevitably have better Unsafe Driving scores than carriers that operate in the Midwest.

Disparate enforcement also is evidenced by differences in the number of inspections. Together, Texas and California represent more than 40% of inspections conducted by state personnel, excluding federal inspections at the border. While those two states are by far the nation’s largest in terms of commercial vehicle miles traveled, their share of inspections far exceeds their share of vehicle miles, which combined is about 20%.

While it is true that the high level of freight activity in these two states naturally calls for more inspections than in, say, the Plains or Mountain West, SMS methodology does not consider regional differences. For example, in 2016, Maryland ranked fifth in the number of state inspections at 3.28% of the total, but only 30\(^{th}\) in the number of commercial vehicle...
miles traveled. New Mexico is seventh in inspections but only 19th in the number of commercial vehicle miles. On the other hand, Ohio ranks fourth in commercial vehicle miles but only 13th in inspections. And Louisiana is 13th in commercial vehicle miles but 27th in inspections.

The NAS report suggests that an IRT-based model could help adjust for enforcement disparities. Maybe a model could be created to simulate a more even distribution of enforcement activities, but the result would be just that: a model. The potentially devastating impact on carriers of relative metrics – especially if made public – is too great to be based on complex calculated projections rather than actual on-road results. Once again, the NAS Report effectively shrugs off an existential threat to small carriers who find themselves in the wrong
place at the wrong time – especially when crash causation and the law of small numbers are factored in.

**Peer Group Creep**
Commenters have long pointed out the distortions of SMS metrics that can result from carriers’ shifts among safety event groups, especially as small carriers with volatile metrics ease into a slightly larger peer group. We are heartened, therefore, by the NAS report’s recognition of this phenomenon and even somewhat encouraged by FMCSA’s initial response on the topic. See 82 Fed. Reg. at 40831.

However, Commenters contend that peer group creep is a bigger problem than FMCSA concedes. We believe FMCSA’s suggestion “that the methodology should be revised so that a safety event that is not a violation or a crash is not the sole reason for an increased measure or percentile” is too narrow. Even if an inspection that includes a violation kicks a carrier into a more stringent safety event group, that carrier could instantly appear significantly less safe than is justified by a single violation.

**Profiling**
As Commenters have shown in past proceedings, anomalous reporting results from the assignment of inspection values to carriers; the availability of weigh station bypass systems like PrePass; and a failure to report clean inspections uniformly throughout all states.

As members of the MCRR Coalition noted in response to FMCSA’s SFD Proposal, the Agency’s use of inspection profiling and the Inspection Selection System (“ISS”) program are inherently biased against small carriers. An unwarranted “negative feedback loop” is created when the system relies primarily on past inspections to target current inspections. Inspection profiling undoubtedly explains why small carriers receive far more scrutiny than their larger brethren. Power units operated by motor carriers with 1 to 4 trucks are inspected nearly three times as often as those operated by carriers with 1,000 or more trucks.⁶

At the outset, Commenters take issue with the statement of Joseph DeLorenzo, director of the FMCSA Office of Enforcement and Compliance, at the September 8 public meeting in this docket regarding clean inspections. While DeLorenzo’s comment that 40% of reported inspections do not involve a violation is factually correct, it is misleading because once again there is a wide disparity among states. California, which reports more inspections than any other state, had a clean inspection rate in 2016 of 56.2%, behind only Mississippi, Montana, West Virginia, and Alaska. On the other hand, Texas, which reports the second-largest number of inspections, had a clean inspection rate near the bottom at 26.1%. Ten states had clean inspection rates below 25%.

Moreover, the above figures are based on situations when an inspection is actually reported. Another major concern is situations when inspectors choose not to report inspections at all because no violation was unearthed in a walk-around. Analyzing this problem obviously is thorny because it involves quantifying the extent of non-existent data. However, there is data beyond extensive anecdotal reports of missing clean inspections. For example, in a survey conducted in 2016 by Overdrive and research firm TransAdvise, 48% of carriers reported that clean inspections are not consistently recorded in their experience.⁷

**Enforcement Biases**
Analysts and regulators tend to ignore the fact that the data feeding their models and databases originate with state agencies and individual inspectors. Commenters have already referred to this phenomenon in the discussion of inconsistent enforcement. For example, Midwestern states such as Indiana and Michigan have focused much of their enforcement efforts in the Unsafe Driving BASIC, while Texas and California have placed relatively more emphasis on the Vehicle Maintenance and Driver Fitness BASICs. Once again, the NAS Report (at p. 51) seems to shrug off state-by-state enforcement differences as being “not something that FMCSA can unilaterally change.”
Another bias lies in the types of violations that inspectors report within individual BASICs. It is much easier to catch a driver on a reporting oversight than it is to painstakingly compare supporting documents to log grids in order to prove a false log. And it is easier to cite a vehicle for an inoperative lamp than it is to crawl under the chassis to inspect brakes caked with dirt and grease.

The effectiveness of the two most important BASICs in terms of carriers covered – Vehicle Maintenance and HOS Compliance – is undermined by a dominance of minor violations. For example, about half of the HOS Compliance violations are form and manner infractions. The Vehicle Maintenance BASIC is heavily skewed toward violations, such as inoperative marker lights, that standing alone are insufficient to signify that equipment is unfit to operate. Also, profiling of units for vehicle maintenance inspections is particularly high and prejudicial to intermodal carriers, to owner-operators that operate older equipment, and to oilfield carriers that frequently operate off-road.

If the proposed IRT model does not completely resolve the state-by-state inspection and violation distribution discrepancies, or if individual states are not forced into uniformity in inspection and data-collection methods, the same systemic flaws will continue to plague the new model. But even if those systemic flaws somehow could be resolved, no statistical model can veto or repeal the law of small numbers. The NAS Report essentially advocates an enormous investment of time and money to create a highly opaque set of algorithms that – because of these systemic flaws – at best would be only marginally more effective than SMS.

(Footnotes)
1 Members of this coalition have explored SMS flaws exhaustively in multiple proceedings, most recently in the docket concerning the now-withdrawn SFD Proposal. See https://www.regulations.gov/document?D=FMCSA-2015-0001-0184
2 Although percentiles and alerts currently are withheld for property carriers, FMCSA now publishes absolute measures on these carriers, which are not subject to any data sufficiency thresholds. These measures are subject to misinterpretation and are potentially even more damaging than the relative metrics published previously.
3 For example, see The Relative Contribution of Truck Drivers and Passenger Car Drivers to Two-Vehicle, Truck-Car Traffic Crashes, D.F. Blower, Publication No. UMTRI-98-25, UMTRI, 1998.
5 A substantial number of moving violations likely go unreported to FMCSA’s Motor Carrier Management Information System because of a change in SAFETEA-LU that allowed states to receive grant funds for issuing moving violation citations on motor carriers without reporting an associated inspection. Many consider this to be the principal reason for the huge drop in traffic enforcement inspections since the mid-2000s.
6 See the Vise affidavit in the Coalition comments on the SFD Proposal: https://www.regulations.gov/document?D=FMCSA-2015-0001-0184
7 See id.
FEASIBILITY OF WAREHOUSE DRONE ADOPTION AND IMPLEMENTATION

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ABSTRACT
While aerial delivery drones capture headlines, the pace of adoption of drones in warehouses has shown the greatest acceleration. Warehousing constitutes 30% of the cost of logistics in the US. The rise of e-commerce, greater customer service demands of retail stores, and a shortage of skilled labor have intensified competition for efficient warehouse operations. This takes place during an era of shortening technology life cycles. This paper integrates several theoretical perspectives on technology diffusion and adoption to propose a framework to inform supply chain decision-makers on when to invest in new robotics technology.

INTRODUCTION
Unmanned drones have been described as “on the verge of blowing a big hole in the supply-chain” (Bamburry, 2015) - an assertion supported by a predicted global market of $22.15 billion by 2022 representing a compounded annual growth rate (CAGR) of 20.7% from 2015 to 2022 (Statistics, 2016). The military and consumer markets drove much early growth, and recent commercial usage has ballooned from 102,600 units in 2016 to a projected 805,000 units in 2021, representing a five-year CAGR of 51% (Meola, 2017).

Defined as “robot vehicles” that are remotely or unmanned piloted, tethered, or autonomous (Rys, 2016), aerial unmanned drones captured headlines after Amazon made the first unmanned aerial vehicle delivery to a customer in England on December 7, 2016 (Bort, 2017). Regulatory challenges have slowed unmanned aerial drone use in open skies for delivery by companies including Amazon and Domino’s Pizza. At the same time the pace of adoption in warehouse drones has accelerated, conducting infrastructure monitoring and inventory management using bar codes, QR codes, and RFID in combination with industrial Internet of Things technologies, and wheeled unmanned drones working both autonomously and in tandem with humans to pick-and-pull (Appelbaum and Nehmer, 2017). Preliminary results suggest paradigm-shifting improvements for inventory management, with Walmart reporting that unmanned warehouse drones cut the warehouse inventory count process from 30 days using manual processes to one day (Bose, 2017), and Amazon’s 2012 acquisition of robotics powerhouse Kiva for $775 million is cited as the cornerstone to its ability to provide even more efficient and effective next-day and two-day shipping (Kim, 2016; Nichols, 2016).

The process of adoption of technology has resulted in a media cycle of exaggerating the promise of a new technology in the short-run while underestimating its importance over the long run—dubbed the “hype cycle” by Gartner and more generally known as Amara’s law (PC Magazine, n.d.)—renders suspect most of the prognostications in mainstream media. Given the importance of warehousing in global supply chains (Frazelle, 2002a) and that warehousing constitutes 30% of the cost of logistics in the US (AT Kearney, 2016), the time is right for a reasoned inquiry regarding the factors that supply chain decision-makers should use to decide when to invest in the new robotics technology.
This paper compares models of technology diffusion in order to develop a hybrid model that combines the insights of several empirically supported perspectives. Warehouse operations are reviewed for the purpose of applying this knowledge to the domain of warehouse drone robots. Next, the thoughts of several supply chain professionals are presented based upon exploratory conversations, followed by a brief conclusion regarding the applicability of technology diffusion models and the hype versus reality of warehouse drone robots in the near future.

**Drone Technology**

The term “drone” may include a number of different characteristics. In general, “drone technology” involves using unmanned robotic vehicles. There is a tendency to immediately conclude drone technology only involves the multi-rotor or quadcopter aerial devices touted by firms such as Amazon (unmanned aerial vehicles or UAV); however, drone technology may also involve (Drone, n.d.):

- unmanned aerial vehicles (UAV) including multirotor or quadcopter which is a type of unmanned aerial vehicle
- unmanned combat aerial vehicle (UCAV)
- unmanned spacecraft both remote controlled (“unmanned space mission”) and autonomous (“robotic spacecraft” or “space probes”)
- Unmanned ground vehicles (UGV) such as autonomous self-driving automobiles
- Unmanned surface vehicle (USV) for operation on the surface of water
- Autonomous underwater vehicles (AUV) or unmanned undersea vehicles (UUV) for operation underwater

For this paper, we investigated wheeled unmanned ground vehicles (UGV) utilized for warehouse operations and specify them as “warehouse drones”. These include driverless trucks, aerial delivery drones, wheeled, warehouse drones, and warehouse robots.

**Technology Diffusion Model**

There are several models of technology diffusion, for example, “product life cycle management (PLC)” dominates in marketing, the technology acceptance model (TAM) developed in information technology research, and the spiral life cycle (SLC) model developed to manage risks in software development. Since unmanned warehouse drones represent a unique combination of mainstream product, information technology systems, and software, each model is compared, with insights distilled into a new “spiral cost implementation model.”

**Product Life Cycle Model**

The product life cycle management model was originally developed by Everett Rogers (1962), a communications professor who defined diffusion as the process by which an innovation is communicated over time among the members of a social system through certain channels, with system saturation modeled using a logistic curve (Figure 1). Theodore Levitt (1965) brought the PLC into the mainstream for general business use by matching each stage of diffusion with marketing and product management advice. Subsequently, Frank Bass (1969) published the most widely used forecasting model that describes the PLC mathematically based upon the coefficients of innovation and imitation.

Based upon the rapid growth in market demand of 20-50% (Statistics, 2016; Meola, 2017), unmanned warehouse drone demand demonstrates the inflection point that transitions from the “introduction” to the “growth” stage of the PLC. The PLC provides some basis for distinguishing customer segments based on their adoption process—they either adopt based on written communications such as technical reports, or they await word of mouth regarding the product or technology’s promise. Disadvantages of the PLC are its simplification and aggregation of the complex processes of innovation, diffusion, and adoption—the PLC looks strictly at the aggregate adoption behavior for a new product or technology, and does not incorporate considerations such as technical capabilities, costs, or risks. The next model, the Technology Acceptance Model, incorporates some of these factors.

**Technology Acceptance Model**

The Technology Acceptance Model (TAM) was
originally developed by Fred Davis (1989) as an extension of the theory of reasoned action (Fishbein and Ajzen, 1975; Ajzen and Fishbein, 1980). TAM’s advantage to managers considering adopting warehouse drone technology is that it is the most empirically applied and validated model of users’ acceptance and usage of technology (Venkatesh and Davis, 2000; Maranguniæ and Graniæ, 2015), incorporating the external variables of perceived usefulness and ease of use to explain the adoption process. These variables provide insights into the drivers for humans to adopt a new technology or product, with greater levels of perceived usefulness and ease of use predicting a greater probability of technology acceptance.

TAM offers the advantage of using easily measurable characteristics to predict the likelihood of adoption at the level of the individual user. The model’s measurement instruments have been widely validated (e.g., Adams, et al., 1992) and extended to include additional social and cognitive factors (Venkatesh and Davis, 2000). TAM’s disadvantages include failure to consider cost and structural factors that obligate or prevent technology adoption (Lunceford, 2009), and the potential lack of meaning for an individual technology user trying to assess “perceived usefulness” due to its broad and dynamic nature. These disadvantages both diminish the applicability of TAM in the warehouse environment which is cost-sensitive, demonstrate fixed structural factors (at least in the short run), and the issue of deciphering usefulness of a new technology that may require several iterations to optimize. Both of these disadvantages may be addressed using the spiral life cycle model proposed next.

Spiral Life Cycle Model
Supply chain managers considering drone adoption often consider the risk and cost involved. Barry Boehm (1986, 1988) originally developed the spiral life cycle model for defense software development in order to shift project decisions from a coding or document-driven process to a risk-driven approach. In the words of Boehm (2000), the spiral model is a “process model generator” because its output prescribes the appropriate process for managing a project based upon a four-step iterative process that incorporates risk assessment and cost (see Figure 3).

The spiral life cycle model starts in the middle of the diagram with the four basic activities performed during every cycle: determining objectives (planning), followed by identifying and resolving risks (risk analysis), development and testing (engineering), and planning the next iteration (evaluation). At the very beginning of the model, the concept of operations, the concept of requirement, and the operations plan are developed. Cost accumulates as iterations or prototypes are produced, and the spiral model advises how to minimize the level of risk by scaling the level of effort and degree of details. The spiral life cycle model incorporates other extant process models such as incremental, waterfall, and prototyping as special cases depending on the risk patterns of certain projects (Boehm, 2000).

The spiral life cycle model offers advantages for minimizing risk, especially for large projects, and for managing and controlling documentation and approval processes; these features make the model conducive to development of new product lines rather than implementation of a new supply chain operational technology. The model may be costly to implement and not very suitable for small projects, such as implementing drones in a single warehouse. Additionally, while the spiral life cycle determines a project process and incorporates cost, it depends heavily upon identifying risks, which may vary widely depending upon the project. A framework that specifically incorporates supply chain and unmanned warehouse drone risk factors would prove advantageous for managers and researchers assessing incorporation of unmanned warehouse drone, robots, and related digital economy advances.

Spiral Cost Implementation Model (SCIM)
The spiral cost implementation model (SCIM) represents a hybrid framework that combines the previous models in order to encompass their salient positive aspects while compensating for reduced parsimony by reducing the negative aspects. The
framework modifies the spiral life cycle model by focusing on costs at every stage and repeating the evaluation stages. The model assumes adoption of an existing technology available on the market, which is an important difference from the spiral life cycle model that focuses on innovating a new product or technology, and renders the model particularly appropriate for the warehouse drone adoption decision.

The SCIM framework incorporates a constant review phase in response to the intensely dynamic technology and regulatory environments. A cost review at every stage of the model reflects the rapid changes and the shift of purpose from developing new product lines to on-going supply chain operations. As a visual enhancement, the spiral grows larger or smaller based on the cost in each phase. SCIM incorporates the TAM’s perceived usefulness into the planning and evaluation stages. The model loses in its application to creating a new technology, but gains from greater depth of analysis when adopting a new offering available on the open market—a circumstance currently confronted by warehouse managers considering drone adoption.

THE WAREHOUSING ENVIRONMENT

Warehousing represents close to 30% of US supply chain costs (AT Kearney, 2016), with 55% or more resulting from order picking costs which would respond readily to automation (van den Berg and Zijm, 1999; De Koster, et al., 2007). [Warehouse] drone implementation should address current inefficiencies in warehousing most amenable to automation including inventory accuracy, inventory locating, space utilization, redundant processes, and picking optimization (Garcia, 2013; van den Berg
The key drivers for modern warehouse management is the reduction of inventory due to heightened financial risks, shorter response times, and increased productivity (van den Berg and Zijm, 1999).

Warehousing increasingly relies upon “smart” technologies that incorporate information tracking technologies such as bar coding, electronic data interchange (EDI), and radio frequency identification (RFID) into data processing systems designed to aid decision-making (Autry, et al., 2005)—unmanned warehouse drones represent the logical extension that integrates the virtual information processes with the physical warehouse processes.

The rate of growth of industrial robots provides evidence of this integration. Overall world supply of industrial robots hit an annual record increase for the fourth year in a row in 2016, and increased 84% from 2011 to 2016 compared to the 2005 to 2008 timeframe (IFR World Robotics, 2017). The world population of industrial robots is projected to increase from 1.8 million in 2016 to over 3 million by 2020. Industry reports predict warehouse robotics compound annual growth rate varies from 7.6% through 2024 (Goldstein Research, 2017) up to 11.5% through 2021 (Mordor Intelligence, 2017) and 11.6% through 2023 (Dasyam, 2017).

Warehouse robotics has gone from novelty to mainstream for larger companies seeking competitive advantage in an era of labor shortages and highly demanding customers (Futch, 2017).

Practical considerations mean that warehousing offers a particularly compelling application for unmanned warehouse drones compared to oft-hyped direct-to-customer delivery drones. The co-founder of Kiva—the warehouse drone company acquired by Amazon in 2012—identified three major challenges that will delay use of unmanned warehouse drones for direct-to-customer delivery that will take several technology iterations to overcome: vehicle design, localization and navigation, and vehicle coordination (D’Andrea, 2014). Once the technological challenges are
overcome, issues such as public reactions, privacy concerns, and government regulation will offer further challenges. Warehouses provide protected and controlled environments that obviate these concerns, and the future of direct-to-customer delivery drones may be extensions of warehouse drones. The SCIM model implies that as market offerings of drone technology continue to evolve, they should diminish the risk of direct-to-customer deliveries while simultaneously reducing the cost per delivery until such a point that the cost and risk become acceptable.

Unmanned warehouse drones may greatly improve warehouse operations. As previously noted, warehouse drones may be aerial or wheeled. For difficult to reach places unmanned aerial warehouse drones facilitate inventory management using bar codes, QR codes, and RFID in combination with industrial focused Internet of Things technologies, and wheeled unmanned warehouse drones work both autonomously and in tandem with humans to pick-and-pull, with Wal-Mart reporting that the switch from manual to warehouse drone-based processes cut warehouse inventory time from 30 days to one day (Bose, 2017). Warehouse operators have relatively low profit margins (3-6%), which impedes their ability to invest in technological capital, a fact which accentuates competitive advantage for those who do (AT Kearney, 2016).

Unmanned aerial warehouse drones perform tasks other than moving product. The cost of inventory auditing with aerial warehouse drones is approximately half the annual cost of a live employee and eliminates most of the need for humans to climb warehouse racks and perform other dangerous work (Appelbaum and Nehmer, 2017; PwC, 2016). Amazon has already reduced “click to ship” time from 60-75 minutes with a human to 15 minutes with warehouse drones; additionally, Amazon’s drone enabled warehouses carry 50% more inventory per square foot and have 20% lower operating costs, a savings of $22 million per warehouse for 13 warehouses so far (Bhattacharya, 2016). Other companies report costs as low as 10 cents per order for automated picking versus 80 cents for the typical order pick (Banker, 2017). Incorporating low-light, infrared, and other capabilities these unmanned warehouse drones may often observe more with high resolution video or still cameras, useful for temperature controlled items, monitoring vermin, seeing items in dark corners, and identifying signs of leaking roofs or faulty wiring. Unmanned aerial warehouse drones may also provide auditability details such as geo-locational, RFID, and other sensor data. Unmanned aerial warehouse drones may reinforce the auditability of other inputs, such as verifying that RFID tags are attached to the correct product; overlapping of technologies may provide hitherto unachievable inventory accuracy on an hour-by-hour basis.

Warehouse drones hold the promise of taking inventory and facility management to greater heights of efficiency and effectiveness. As one example, in collaboration with two important research sponsors, MIT believes that warehouse drone technology could have saved $3 billion in lost revenue for Walmart, and prevented the US Army from losing track of $5.8 billion in assets (Hardesty, 2017). Determining where warehouse drones may best contribute requires first enumerating the types, activities, and functionalities of warehouses.

Types, Activities, and Functionalities of Warehouses
Warehouses fall into three categories (van den Berg and Zijm, 1999). A distribution warehouse collects and sometimes assembles products from different suppliers for subsequent customer delivery. A production warehouse localizes in a production facility and stores raw materials, semi-finished products, and finished products in a production facility. A contract warehouse discharges the warehousing operation on behalf of one or more customers.

All types of warehouses conduct four primary functional activities (Coyle, et al., 2017):

- Accumulation: receipt of goods from a variety of locations
- Sortation: assembling like products for storage or transfer to customers

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Allocation: matching available inventory to customer orders (break-bulk)

Assortment: product mixing capability

Picking constitutes in excess of 60% of warehousing costs and represents the greatest opportunity for unmanned warehouse drones to generate efficiencies (van den Berg and Zijm, 1999; De Koster, et al., 2007).

Locus Robotics is an example of how a modern unmanned warehouse drone can work side-by-side with humans, doing most of the 12-16 miles per day that warehouse workers walk but still requiring humans to pick and place products on the robot’s tray (Garfield, 2016). Locus Robotics forecasts up to 800% productivity improvements since the robots move faster than humans, can work 24 hours straight, and take no breaks; freeing humans to provide a personal touch to the shipments that are craved by consumers of e-commerce parcel goods, such as personalized notes or fancy wrapping paper.

Optimizing Warehouse Flows for Unmanned Drones

Warehouse layouts generally fall into two styles (Figure 5), the U-flow and the through-flow (Frazelle, 2002b). The U-flow design locates fast moving products on the inner side of a U-shaped flow so that product moves less distance at all stages of warehouse operations. This improves use of dock resources since inbound and outbound occur on the same or proximate docks, improves efficient lift truck utilization since fast-moving product is located close to the docks, and improves security since entry and exit occupy the same side of the building.

Through-flow warehouses move all product in a straight line from one side of the building to the opposite, locating fast-moving items along the center aisle of the warehouse and slower items along the walls of the warehouse (Frazelle, 2002b). This layout requires all product to move the length of the building and is less flexible. It provides advantages for avoiding confusion regarding product flowing in and out, and when different material handling equipment is used for in-flows vs. out-flows. Factory warehouses often use the flow-through layout.

The interest in warehouse drones by companies like Wal-Mart and Amazon focuses on leveraging drone strengths primarily to maintain inventory accuracy and to shorten response times for picking in response to consumer orders—an environment conducive to U-flow warehouse layouts. In addition to greater speed of picking, warehouse drones reduce losses to shrinkage—especially relevant for high value finished goods—and the U-flow layout results in shorter trips to recharging stations, a
critical consideration with current battery technology (D’Andrea, 2014). Other factors that suggest that consumer finished goods warehouse drones will initially establish themselves in U-flow warehouses are based on the assumption that U-flow warehouses are more likely to be the design of choice for finished consumer goods, the potential to standardize packaging for consumer goods, improved product identification (barcodes, RFID), and the greater value (and profitability) of finished goods to pay for the early investments in technology.

Through-flow warehouses are often attached to production facilities, and the product more often changes shape and form, which presents a challenge for warehouse drone technology for the near future. Cross-dock facilities represent the application of the through-flow layout to finished goods—the bulk nature of the entering goods diminishes the productivity advantage for warehouse drones vs. human labor. Other challenges to the current state of warehouse drone technology include the ability to move increased product weight and travel further, factors which increase time spent at charging stations. Warehouse drone technology exists with the potential to facilitate through-flow work such as the Automated Ground Vehicles described in the next section, yet it does not demonstrate the rapid growth of smaller, lighter warehouse drones, and additionally appears in U-flow warehouses.

Best Approach for Warehousing with Unmanned Warehouse Drones
Warehousing is a labor-intensive industry, and has become even more so with the strong growth of e-commerce which requires picking more “eaches”, or single units of product, in response to consumer order size. This trend has driven part of the 53% increase of warehouse employment from 622,000 in January 2017 to 950,000 in July 2017¹, and has increased wages for warehouse workers 6% in the past year (Smith, 2017) E-commerce warehouses tend to locate near population centers, and offer a better value proposition than retail, an even more labor-intensive industry (Gebeloff and Russell, 2017), even when e-commerce related warehouse jobs command a 26% premium over traditional retail jobs (Mandel, 2017).

Goods-to-picker, also known as goods-to-person, automate warehouses by bringing goods to humans to pick. Kiva is the goods-to-picker warehouse drone used by Amazon that resembles an automated warehouse drone vacuum (e.g., a Roomba) that goes beneath a set of shelves, lifts it, and brings it to the human picker. Industry leaders indicate expect to adopt commercially viable unmanned warehouse drones in about a year (Baskin, 2017).

The current generation of unmanned warehouse drones performs material transport, acting as a shuttle between humans who pick and pack the goods. The greatest impact of implementing warehouse robotics remains the ability to perform the human tasks of identifying product on the shelf, picking product in non-standardized packaging, and

¹ Source: U.S. Bureau of Labor Statistics
understanding the human context of the goods in order to properly package it for presentation to a human customer. Amazon launched a $250,000 competition, now in its third year to develop a robot that can perform the human portion of order picking reliably; commercial application could occur as soon as next year (Baskin, 2017), albeit the competition focuses on stationary robots and does not require unmanned warehouse drones.

Primary uses for unmanned warehouse drones include inventory audit, infrastructure and security surveillance. Warehousing competitive advantage relies strongly upon data integration in real time, a capability that unmanned warehouse drone use reinforces (Gresham, 2017; Waller and Fawcett, 2013), yet picking represents the greatest need for labor savings. Commercially available unmanned warehouse drones may lift up to 10 kilograms (22 lbs.) (Dronelli, 2017), perfect for e-commerce, and the incentive for labor savings which should drive robotic picking technology to unmanned warehouse drones. Unmanned warehouse drones promise productivity improvements, do not require breaks, improve accuracy, maximize use of 3D space utilization, and alleviate injury, repetitive task, and other worker quality of life issues related to what the warehousing industry calls the 3D’s category: dirty, dangerous, and difficult (Fiveash, 2016).

Exploratory research suggest that executives may be unaware of the impact of unmanned warehouse drone technology even over the next few years as discussed in the next section.

Motives for Intransigence
Despite the advantages of warehouse drones and robotics, certain issues create intransigence when it comes to adopting the new technology. Positive leadership support represents the single most important factor for bringing a knowledge or data-related initiative successfully to fruition (Patil and Kant, 2014). While 75% of executives assert the importance of digital transformation across the supply chain, 48% still use non-digital (phone, fax, email) communications; only 15% can access the majority of needed data from trading partners, and 23% have the ability to analyze the data to make better supply chain decisions (Dougados and Felgendreher, 2016). When the same group of 337 executives from across multiple industries were asked to forecast five years into the future, 68% expected that data from across the majority of trading partners in the supply chain will be available to be analyzed and 54% expect to have access to the majority of needed data from their trading partners—indicating that technology is expected to advance rapidly throughout supply chains.

While supply chain executives exhibit knowledge and optimism about information supply chains, the literature suggests that they have relatively little knowledge or optimism about the physical supply chain. The traditional view of the supply chain looks at the information, financials, and product moving in essentially a straight line; but increasingly, supply chains may be divided into support supply chains—those nodes through which the physical product does not flow but which support the physical movement—and the physical supply chain, which encompasses the traditional view of the product accompanied by its information and financials (Carter, et al., 2015).

EXECUTIVE’S STATE OF AWARENESS ON DRONE TECHNOLOGY
In order to confirm the state of awareness of unmanned warehouse drone technology, we present the results of conversations with three executives from three industries about their knowledge of current unmanned warehouse drone use and their thoughts regarding the future of unmanned warehouse drone use. While the executives appear optimistic about the support supply chain that falls largely outside of their direct control, the conversations suggest that executives are much less informed and optimistic about the future technology that impacts the physical supply chain more directly under their control. Given the importance of supply chain velocity and order accuracy—physical and informational—to supply chain integration and competitive advantage (Handfield and Linton, 2017; Hofman, 2004), as well as the quick resolution and mitigation of supply chain disruptions (Craighead, et al., 2007), more work should address the information gap among decision-makers regarding
digital technologies such as unmanned warehouse drones and 3D printing that will have an impact on the physical supply chains of the future. The results from our conversations suggest that supply chain decision-makers appreciate the potential of information technology yet remain staunchly traditional in their views of the physical aspects of supply chain technology. Questions and responses appear in the appendix.

Regional Wholesale Club

The vice president of transportation for a regional wholesale club with operations in 15 states is responsible for improving operational efficiencies by automating transportation tasks and optimizing the planning of shipments. The transportation function efficiency depends upon accurate inventory information and tracking movement of goods at distribution centers throughout the shipping process. This executive expressed an appreciation for the ability of unmanned warehouse drones to conduct inventory audits, monitor for security breaches, and trailer pool validation in the distribution center environment.

With regard to the company’s greatest warehouse operational bottlenecks, he cited four areas. First, the “put to club” case or tier breakdown consumes much more time than the full pallet cross-dock process. Second, peak volume times see congestion in the building and yard. Third, certain specialized processes require holding inventory at the distribution center rather than sending immediately to the store, which slows velocity. One example is holding candy during the warm months to be processed one day per week in temperature-controlled trailers. Fourth, sorting through non-merchandise returns such as empty pallets, dunnage, plastic, and water jugs is slow and cumbersome.

The wholesale club enjoys several advantages. One is strong internal inventory controls resulting in inventory shrinkage that is well below the industry average. Another is vendor-owned inventory for most cold goods until they reach the stores. The company has achieved very low inventory in storage at only $50 million out of $1 billion of goods moving through its supply chain (5% of total value of goods moved). Company financials reveal the benefits of this performance: inventory turns were 10.6 and receivables turnover was 81.1, more than double and quadruple, respectively, for the retail industry overall (CSI Market, 2017). Such a lean supply chain could be improved even further through unmanned warehouse drones in conjunction with RFID tracking in order to monitor the cargo yard in real time. This could improve visibility and real-time decision-making greatly over the current system of periodically walking the yard and make the company’s lean supply chain more resilient against disruptions. Improved cost accountability could be an additional benefit since allocating costs of current activities such as the yard walks proves complex; a drone would provide detailed records of its observations, associated inventories and assets, and time spent.

National 3PL

A national account manager at a national 3PL made the connection between unmanned warehouse drones and tracking trailers, yet prefers GPS tracking as a solution. The 3PL is primarily a transportation company focused on trucking that also provides warehousing, logistics, and intermodal services. The company assets include nearly 5,000 trailers and 2,000 power units with low dwell times, which explains the manager’s preference for GPS tracking. The company owns multiple facilities near the ports of Baltimore and Norfolk and leases public warehouse space. With many mobile assets and few fixed facilities, this 3PL could benefit less from unmanned warehouse drones, although unmanned warehouse drones could provide trailer tracking and security of the existing facilities and yards where the company drops its trailers.

National Supplier of Electronic Hardware Components

The third conversation was with the warehouse manager at a leading national supplier of electronic hardware components. Much of their product fits in either a large box size of 8.5 x 8 x 3.5 inches (21.5 x 20.3 x 8.9 cm) or a small box size of 6.5 x 4 x 3.5 inches (16.5 x 10.2 x 8.9 cm). Average pick time by humans is 1 minute 5 seconds, due to small product
size, multiple SKU’s, and a bar coding system that suffers occasional signal interruptions common to Wi-Fi technology and the slowdowns common to trying to scan barcodes in general. The package size and light weight of the company’s products seem ideal for future unmanned warehouse drones, especially in combination with an upgrade from barcode technology to a more reliable and sophisticated technology such as RFID. The manager demonstrated insightful understanding of unmanned warehouse drone technology with the observation that they would provide a greater pay-off if the warehouse’s ceilings were higher.

Interviews Summary
Overall, these conversations suggest that supply chain managers may not understand the potential for operational improvements offered by the current generation of unmanned warehouse drones. A limited understanding of the current benefits and potential of unmanned warehouse drones underscores an even more limited understanding of the future of unmanned warehouse drone technology.

IMPLICATIONS AND FUTURE DIRECTIONS
Warehouse drones represent a fundamental shift in supply chain management in several ways. Operationally, warehouse drones improve warehouse functionality by better utilizing available space, reducing production downtime, reducing labor turnover and downtime, improving health and safety, increasing warehouse flexibility, and increasing productivity output. These benefits argue in favor of adoption of warehouse drone technology especially as costs continue to diminish as the industry matures.

Substantial research has assessed technology adoption and the rate of technological diffusion, and this research suggests combining extant models to provide more comprehensive guidance for decision-makers to assess cost and timing of technology adoption in order to determine investments in warehouse drone technology. Limited research assesses the specific impacts of robots on economic and productivity outcomes (Muro and Andes, 2015), especially in the supply chain context, making further research in this area vital.

This paper offers several important questions that should be addressed in future research:

1) Future research should confirm early findings that robots have contributed to productivity gains on the scale of the steam engine’s effect on late 19th century productivity, the archetypical general purpose technology (Graetz and Michaels, 2015).

2) Assuming these findings regarding general robotics productivity gains find confirmation in subsequent research, they suggest that work needs to be done to explore the perceptions of executives regarding the advantages and disadvantages specific to the context of warehouse drones.

3) Relatedly, future research should measure the financial impact and cost trade-offs of drone technology in the warehouse setting. Financially, drones shift from human labor that constitutes variable costs to fixed investments in capital. Higher fixed costs create an impetus to maximize productivity so as to spread the cost of capital over more units—making warehouse drones apt for the high volume, high-throughput e-commerce distribution center environment.

4) With talent shortages predicted of at least 6 openings to each available laborer (Ruamsook and Craighead, 2014), many distribution center and warehouse managers confronting the supply chain talent shortage may see the opportunity for relief by replacing human workers with drone automation. In this scenario, automation may have two effects, firstly alleviating the challenge of filling technically qualified positions, and secondly freeing up resources so that companies can better afford to train workers for the work that automation cannot perform. Assuming that countries
where more automation prevails actually generate more jobs or at least lose less jobs (Graetz and Michaels, 2015), automation seems unlikely to solve the talent shortage, yet may become the price of entry into an industry competing for efficiencies and workers. More research needs to address the important role of warehouse drones in particular and automation in general in relation to the issue of employment and human resource management.

5) Future research should be conducted and oriented toward understanding the circumstances under which drones and automation could replace or complement human labor. This requires more complete enumeration of the functional roles and physical capabilities of drones. The current state of drone applications focuses on surveillance, inventory management, and picking, with picking reliant on humans to pick up-and-place the inventory while the warehouse drones and robots perform shuttle duties. As noted previously, experts project that in the near future robots will be able to pick most forms of products and seem likely to be able to master the challenging task of identifying and retrieving a single item from a jumbled box (Baskin, 2017). Warehouse automation technology can currently handle approximately 75% of products. Some warehouse tasks continue to pose additional challenges, especially assembly tasks, delicate small items such as produce, and packaging in plastic or partially obscured products, such as garment-on-hangar (Ackerman, 2016). A comprehensive typology of applications would facilitate the advancement of both drone technology and managerial decision-making regarding adopting new automation technology.

6) Strategic managerial and organizational factors related to the rate of adoption of warehouse drone technology, and the timeline for implementing new technologies in supply chain settings should be defined. An indicator of the potential for improvements appears in the Capgemini (2016) report which found that almost half of managers (48%) communicate with supply chain partners primarily through “traditional” technologies like phone, fax and emails rather than internet or cloud-based technologies—the same survey-based work revealed that two-thirds of the same executives expected adoption of major new technologies to integrate their supply chains in the next five years. Managers will need clearer guidance for this new technology and others to follow. Adoption and application of warehouse drones present many additional opportunities for future research.

CONCLUSION

Current unmanned warehouse drone technology offers the potential for significant efficiency gains both for inventory handling and inventory transparency. Unmanned warehouse drones offer strong potential with inventory audits and real-time supply chain visibility. Warehouse drone technology supports supply chain competitive advantage vis-à-vis supply chain integration and shortened cycle times to support improved customer service levels and supply chain responsiveness. Based upon recent developments in the Amazon warehouse robot competition, the application of unmanned warehouse drones to reduce the greatest warehouse cost—picking—appears to be on the verge of rapid adoption. The Amazon warehouse competition may have generated innovation of robot pickers to commercial application in four years, and it seems reasonable to expect a similar timespan for the technology to incorporate unmanned warehouse drones. As early adopters companies that invest in unmanned warehouse drones will garner operational benefits sooner and be better positioned for the next generation of unmanned warehouse drones.
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Dr. Farris started the industry-focused logistics and supply chain management program at UNT in 1997. The program is presently ranked 5th globally for research productivity, 6th nationally by Gartner for undergraduate programs, and 3rd nationally based on teaching supply chain technology. E-Mail: TheodoreTed.Farris@unt.edu

(Footnotes)
1 US Bureau of Labor Statistics,
https://www.bls.gov/iag/tgs/iag493.htm#workforce
CONTAINER SHIPPING IN THE GREAT LAKES: CURRENT SITUATION AND FUTURE POTENTIAL

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ABSTRACT

Containerization has had an outsized impact on the growth of global trade over the past 60 years. The Great Lakes-St. Lawrence Seaway is an important bi-national waterway. Since the advent of containerization in the 1950’s there has been much excitement about the prospects of scheduled container shipping in the Great Lakes. There is a perception that direct container service will add value to the economy of the Great Lakes-St. Lawrence Basin (GLSLB). However, due to unique shipping constraints in the Great Lakes-St. Lawrence Seaway, significant container service has not materialized. This research seeks to explain the current state of container shipping in the Great Lakes, as well as provide an analysis of the feasibility of future container shipping in the Great Lakes. It is very important for policymakers to understand both the opportunities for container shipping, and the barriers and issues with such services. A lack of understanding of these points can lead to missed opportunities and/or the potential for significant expenditures of time and money on unrealistic projects.

INTRODUCTION

Container shipping has become synonymous with the rise of global supply chains. The movement of shipping containers on the world’s oceans is growing, and the economies of many parts of the world are tied to the efficiencies associated with a single box moving from a producer in one country to a consumer in another country. The rapid growth of global trade has lowered the cost of goods in many parts of the world. Subsequently, it has placed unprecedented demands on container ports and the surface systems that serve these ports.

The Great Lakes and St. Lawrence Seaway has a rich history of being an economic driver for Eastern Canada and the U.S. Midwest. As the Great Lakes Region has attempted to strengthen its role in global commerce, the potential for increased waterborne movement of containers into the Great Lakes has long been of interest to port agencies and their municipalities. There is a perception that the direct movement of containers by ship into a Great Lakes community will be beneficial to the local economy and allow it to more effectively participate in global trade.

However, it is very important for policymakers to have an understanding of both the opportunities for container shipping, and the barriers and issues with such services. A lack of understanding of these points can lead to missed opportunities and/or the potential for significant expenditures of time and money on unrealistic projects. Over the last 40 years or so many ports and local government entities have expended large sums of money and resources on consulting studies, service subsidies and other efforts to attract container services to the
Lakes. This paper seeks to clarify the opportunities and obstacles for such services so as to provide for more informed decisions by policymakers and political leadership.

This research examines the current state of container shipping in the Great Lakes, and its potential for growth. First, a background on containerization, commerce on the Great Lakes, and container shipping on the Great Lakes is presented. This section is followed by a review of Great Lakes container shipping traffic levels and an analysis of this traffic. Then, an analysis of various issues that are likely to impede scheduled container services is reviewed. The next section then suggests what services might be viable. The paper then offers some conclusions on the state of container shipping and the potential for direct scheduled international container services.

BACKGROUND

Containerization
In 1956, American businessman Malcom Mclean loaded the first standardized containership in the Port of Newark, NJ bound for Houston, TX. The event was met with criticism at the time but would later come to mark the beginning of a revolution in global trade (Donovan, 2004). The advent of the containership has been credited as a catalyst for the growth in global trade that the world has seen in the last 60 years. In an empirical analysis of containerized shipping data from 1970-1992, Bernhofen, El-Sahli, and Kneller found that containerization had a statistically significant impact on the growth in trade amongst industrialized nations (2015). While containerization has allowed for more cargo to fit onto ships, much of the gain in efficiency has been from shorter loading and unloading times. A study done by McKinsey found that before containerization, a dock worker could load 1.7 tons of cargo per hour onto ships. Five years after containerization, this number rose to 30 tons per hour, a tremendous increase in productivity. (McKinsey, 1972). While not all ports have been able to reap the benefits of containerization, it has helped to expand global commerce through a reduction in prices and increases in efficiency (Notteboom, Rodrigue, 2008).

Throughout the 21st century, containerization and container ports have continued to grow throughout the world. Table 1 shows the volume of traffic moving through the fifteen largest ports in North America. Also shown is Halifax, which is #24 on the list. The largest container port in the world is Shanghai, which set a world record moving more than 40 million TEUs1 in 2017. In addition, Singapore and Shenzen each handle more than 25 million TEU’s annually.

Commerce on the Great Lakes
The Great Lakes have a storied history of transportation stretching back hundreds of years. From the fur trade to the lumber trade, to the iron and copper booms of the 19th century, the St. Lawrence and the Great Lakes have played an important part in the development of the region. (Taylor, Roach, 2007). Stretching from Montreal, QC in the east, to Duluth, MN in the west, the waterway spans 2,342 miles (Figure 1) (Dimitrascu, Higginson, 2007). Historically, the Great Lakes have primarily transported bulk commodities such as iron ore, grain, coal, and aggregates. These trends have held true to the present day with the primary commodities transported during the 2016-2017 shipping season being grain, iron ore, coal, and dry bulk (SLSMC/DC, 2017). These commodities are carried by a combination of Laker vessels, and ocean going ships. The inter-lakes shipping industry is highly reliant upon the domestic steel industry (Dimitrascu, Higginson, 2007). The decline in the domestic steel industry is a contributing factor for the overall decline in inter-lake traffic since the mid-twentieth century. Laker traffic in the Montreal-Lake Ontario portion of the Great Lakes system peaked in 1977 with 38.3 million metric tons, with oceangoing traffic peaking in 1978 at 23.1 million metric tons (Taylor, Roach, 2007, SLSMC/DC, 1992). This compares to 17.6 million metric tons of Laker traffic, and 11.2 million metric tons of ocean traffic in 2017. Despite an overall decline in traffic, the Great Lakes-St. Lawrence Seaway still has a major bi-
### TABLE 1
**NORTH AMERICAN CONTAINER TRAFFIC**

<table>
<thead>
<tr>
<th></th>
<th>Port</th>
<th>2016 TEU’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Los Angeles</td>
<td>8,856,783</td>
</tr>
<tr>
<td>2</td>
<td>Long Beach</td>
<td>6,775,170</td>
</tr>
<tr>
<td>3</td>
<td>New York/New Jersey</td>
<td>6,251,953</td>
</tr>
<tr>
<td>4</td>
<td>Savannah</td>
<td>3,644,521</td>
</tr>
<tr>
<td>5</td>
<td>Seattle/Tacoma Alliance</td>
<td>3,615,752</td>
</tr>
<tr>
<td>6</td>
<td>Vancouver</td>
<td>2,929,585</td>
</tr>
<tr>
<td>7</td>
<td>Hampton Roads</td>
<td>2,655,707</td>
</tr>
<tr>
<td>8</td>
<td>Manzanillo</td>
<td>2,580,660</td>
</tr>
<tr>
<td>9</td>
<td>Oakland</td>
<td>2,369,641</td>
</tr>
<tr>
<td>10</td>
<td>Houston</td>
<td>2,182,720</td>
</tr>
<tr>
<td>11</td>
<td>Charleston</td>
<td>1,996,276</td>
</tr>
<tr>
<td>12</td>
<td>Montreal</td>
<td>1,447,566</td>
</tr>
<tr>
<td>13</td>
<td>Honolulu (FY)</td>
<td>1,211,997</td>
</tr>
<tr>
<td>14</td>
<td>San Juan (FY) fy 2015-16</td>
<td>1,200,000</td>
</tr>
<tr>
<td>15</td>
<td>Lazaro Cardenas</td>
<td>1,115,452</td>
</tr>
<tr>
<td>24</td>
<td>Halifax</td>
<td>480,722</td>
</tr>
</tbody>
</table>

Source: American Association of Port Authorities.

### FIGURE 1
**THE GREAT LAKES ST. LAWRENCE SEAWAY SYSTEM**
national economic impact. The waterway serves a significant portion of both the United States and Canada, with the GLSLB containing 27% of the population of the United States, and 62% of the population of Canada (Stewart, 2012). A 2011 study found that the waterway generates $35 billion dollars in business revenues (Martin, 2011).

**Container Services in the St. Lawrence Seaway and Great Lakes Region**

The St. Lawrence Seaway enjoys the geographical advantage of having the shortest trans-Atlantic route to Western Europe (Hull, 2015). Given that during the 1960s, 70% of international maritime trade was conducted on the Northern Atlantic trade route, the St. Lawrence Seaway was positioned to benefit from the advent of containerization (Guy, Alix, 2007). Manchester Liners was the first company to establish a Europe to Montreal container route in 1968. They were then followed by companies such as CAST, CanMar, and CP Ships. (Alix, Comtois, Slick, 1999). Early on, companies experimented with container shipping out of Quebec City. However, due to the size of the port and market, these operations soon moved to Montreal (Alix, Comtois, Slick, 1999). Before long, Montreal had established itself as the container shipping center of the St. Lawrence Seaway.

As Montreal established itself as a major container shipping center other communities began to explore how they could extend containerization into the Great Lakes region via feeder services to Montreal or with scheduled direct container services with European ports. This posed certain challenges, including a shipping season of 9 months, as well as constraints on ship size due to the lock and dam system used on the St. Lawrence Seaway System (Hull, 2015). Nevertheless, companies such as Manchester Liners established feeder service to and from other Great Lakes cities and Montreal (Hull, 2015). As late as 1979, Manchester Liners was running a container feeder service from Montreal to Cleveland, Detroit, Chicago, Milwaukee, and Toledo (Globe and Mail, 1979). However, as Mayer (1978) noted, this service went bankrupt only a couple of years later. These ships faced stiff competition from trucks and railroads that also transported containers from the Midwest to Montreal and other east coast ports. It was the intermodal connections that made Montreal a great container port, and at the same time limited container shipping by water west of Montreal (Guy, Alix, 2007). However, the combination of comparatively low container traffic, limitations on ship size, and intermodal competition kept larger Lakes waterborne container operations from developing in the latter half of the 20th century (Mayer, 1978).

Despite this, ports around the Great Lakes have been interested in scheduled container services, which potentially could offset the loss of traffic from domestic cargo. Over the years, news of potential container service has made headlines in cities including Milwaukee (Connole, 1987), Duluth (Belz, 2014), Chicago (New York Times, 1979), and Muskegon (Watson, 2017). Reports on Great Lakes port studies of direct international scheduled container services go back many years. For instance, in 1989, James Kellow, Director of the Detroit/Wayne County Port Authority at the time, said that “we believe we need regularly scheduled liner services,” and that the “economics are there” (Markiewicz, 1989). In the mid 80’s, a study by DeWin, a joint Detroit/Windsor port promotional agency, outlined the potential for a Northern Europe to Detroit/Windsor scheduled direct container service using 500-600 TEU vessels (DeWin, 1989). Like many other such efforts nothing developed. A similar 1989 report commissioned for DeWin suggested a liner service that would generate large profits.

More recently, in 2010, the Port of Toledo went as far as to install two container cranes to try and attract feeder service (Lavigne, 2013). Currently, the Port of Cleveland has invested time and resources ($3.1 million in subsidies for 2500 containers over the season) in a scheduled container service using the decks of bulk carriers, however this service has recently seen significant drops in its very limited volumes (Miller, 2018). As of January, 2018 the Cleveland Port was working at negotiating an extension of its contract with the carrier. In addition, in the 2015-2018 period, the Port of
Muskegon has been working to develop cross-lakes and linked international container services (Stephen Kloosterman, Watson, 2017), although the stated goal of services starting in 2017 has not materialized.

**GREAT LAKES CONTAINER TRAFFIC TRENDS AND SERVICES**

In order to understand trends in Great Lakes container traffic over the years the authors obtained traffic data from two principal sources—the US Army Corps of Engineers (USACE) Navigation Data Center and the Great Lakes-St. Lawrence Seaway’s Annual Traffic Reports. The USACE data provides information on the number of TEU’s at major ports in the U.S. These ports, in 2016, handled over 36 million TEU’s with the Port of Los Angeles being the busiest with almost 6 million TEU’s handled. (See Table 1 for other large ports). By contrast, all of the U.S. Great Lakes ports are lumped together and typically are at or near the bottom of the TEU Table. For instance, in 2016, all U.S. Great Lakes ports combined handled only 1,328 TEU’s—about 5 TEU’s per day on average for the typical 280 day sailing season. This compares to 15-20,000 TEU’s per day for Los Angeles and 4,000 TEU’s per day for the Port of Montreal.

All waterborne containers entering or exiting the Great Lakes must pass through the St. Lawrence Seaway. The St. Lawrence Seaway publishes an annual report that shows the tonnage carried in containers passing through both the Montreal-Lake Ontario (MLO) Section of the Seaway and the Welland Canal Section of the Seaway. The MLO Section has much higher container tonnage due to the location of container ports located near the Montreal terminal area. As noted previously, Montreal is a major container center ranked as 12th busiest in North America. The MLO Section of the SLS handled 58,605 metric container tons in 2017 whereas the Welland Section handled 12,557 metric tons. Much of the above traffic originates and terminates in the Montreal-Lake Ontario Section of the Seaway which means that it never makes it to the Upper Lakes.

The graph in Figure 2 shows long term container trends for the Welland Canal Section of the Seaway. This provides evidence of the earlier attempts to develop container traffic in the Great Lakes. In the 1978-80 period, there were 15,000-22,000 TEU’s each year passing through the Welland Canal Section into the upper Great Lakes. These levels generally declined to year 1999 when only 40 TEU’s were counted. The 21st Century continued with extremely low levels of traffic with most years less than 500 TEU’s and many years less than 100 TEU’s. This changed in 2014 due to initiatives by the Port of Cleveland to develop regular sailing schedules for containers and other traffic to and from the Cleveland area.

The Cleveland port efforts mentioned earlier provide an interesting study on traffic prospects for direct scheduled container services in the Lakes. Based on the SLS Annual Traffic Tonnage reports for Cleveland, the authors calculated that the port handled 825 TEU’s in 2014, 2,934 in 2015, 1,615 in 2016 and 1,256 in 2017. These values may differ somewhat from local sources because they assumed each TEU contained ten tons of cargo. Overall, the Cleveland traffic declined 57.2% between 2015 and 2017 despite substantial subsidies to get the business started. Additional perspective on the volumes involved can be gained by looking at the number of trains it would take to move this traffic between Cleveland and the Atlantic Coast. For comparison purposes, about two 600 TEU trains (one each direction) could carry the 2017 combined full year traffic of 1,256 TEU.

The Cleveland traffic was in large part due to the establishment of a monthly chartered ship between Cleveland, Ohio and Antwerp, Belgium (Lavigne, 2013). The service, operated by Spliethoff, is marketed as a niche shipping solution that can save up to 4 days in transit time to Europe vs East Coast ports (SeeNews North America, 2013). While it is billed as the only container service in the Great Lakes, it does not exclusively carry containers. Spliethoff utilizes multi-purpose ships that can carry bulk cargo as well as containers. The same ship that operates on the Cleveland to Antwerp route
delivered 20 containers of bulk equipment to the port of Detroit in 2015 (Bonney, 2015).

ISSUES LIMITING IMPACTING FUTURE GREAT LAKES CONTAINER SERVICES

Absent major changes in the geopolitical and economic climate, a number of issues stand in the way of increased container shipping into and out of the Great Lakes. While no one obstacle is necessarily insurmountable, taken together these factors make it very difficult for scheduled container services to operate. These issues have been well known to academics and policymakers for many years. For instance, Dr. John L. Hazard of Michigan State University, a noted authority on Great Lakes shipping, and a mid’60’s Assistant secretary of Transportation for Policy, summarized a number of issues in various mid 70’s-80’s presentations and reports (Hazard, 1987; Hazard, 1988). He mentioned Seaway problems for container shipping related to augmented overland competition (rail and truck), lock and canal size limitations, the limited nine month shipping season, and a move towards shippers favoring speed and reliability of service with smaller shipment sizes and inventories. These issues are also well known to more recent analysts of Great Lakes shipping. For instance, James K. Higginson and Tudorita Dumitrescu (2007), in their article on Great Lakes shipping, note many of the issues mentioned above, and which we review below.

Following are some of the key issues:

**Small Seaway Size Ships Could Not Compete in the Trans-Atlantic Market**

A major issue deals with ship size and the Seaway size limitations. Containerships continue to increase in size and efficiency. OOCL recently completed the OOCL Hong Kong, which can carry over 21,000 TEU’s. This ship is over 1300 feet long, has a beam of 193 feet and draft of 45 feet. There are many other ships being built, or recently built, in the 18,000-21,000 TEU range. By comparison, the larger ships coming into the Port of Montreal are in the 4,400 TEU range. A containership moving west of Montreal would need to be much smaller because of the dimensional constraints of the Seaway. A container ship passing through the Seaway into the Great Lakes would likely be in the 1000-1500 TEU range. The international shipping community would classify this size ship as a feeder ship.
It would be difficult or impossible for these small vessels to effectively compete in Trans-Atlantic trade against the large ships that will serve the Port of Halifax or the Port of New York/New Jersey, or the medium size ships serving the Port of Montreal. A small vessel requires a crew similar to a larger vessel yet the larger vessel can carry 3-10 times the number of TEU’s. There has been discussion over the years regarding expansion and deepening of the St. Lawrence Seaway locks and channels. However, that does not currently appear to be on the horizon, and current efforts are being directed towards funding to maintain Seaway infrastructure in its present configuration.

**Viable Trading Routes into the Great Lakes are Limited**

Another issue is that any container waterborne movement into the Great Lakes would have to capture traffic from the ports of Halifax, Montreal, and New York/New Jersey. A container route into the lakes could be most effective in capturing traffic between these ports and European or Mediterranean ports since it could provide a direct movement into the North American heartland. In fact, Halifax often markets its port as being at least a day closer sailing distance to Europe then the Port of New York/New Jersey. However, the adverse distance associated with traffic from other parts of the world (i.e., ships from southern points have to travel far north around New Brunswick and the Gaspe Peninsula to gain access to the St. Lawrence River) appears to make this an unlikely move.

**More Ships Are Required to Service Great Lakes Ports**

Due to the high fixed costs of today’s containerships, owners prefer an operating plan that gets as many trips as possible from a given vessel in a given service. A service from Northern Europe (e.g., Hamburg, Antwerp etc.) to Montreal takes about 7-8 days—depending on the number of stops. Cycle time including port time is about 21-days—that is, a given ship will be able to depart Montreal for Northern Europe every 3-weeks. Weekly service would thus require three ships. If a ship went beyond Montreal to Detroit or Chicago additional time would be required given the longer distances and sailing times — about one additional week to Detroit and two additional weeks for Chicago service.

- Three ships can provide a weekly service between Montreal and N. Europe
- Four ships would be required to provide a weekly service to/from Detroit
- Five ships would be required to provide a weekly service to/from Chicago

These ships would have to be much smaller than the ships serving only Montreal and all five ships would have less capacity than just two larger ships leaving Montreal. Twice weekly service would require respectively 8 and 10 ships.

**Service Levels Would Be Less Than Currently at Montreal**

Montreal currently is able to generate sufficient traffic to offer very high levels of service to Northern Europe with ships departing at least 3-5 times each week. Close to daily departure opportunities make this very attractive for companies involved in closely timed low inventory supply chain operations. Weekly or bi-weekly service would be much less desirable and would increase inventory and other carrying costs. Further, it is difficult to see how such a service could be competitive with Montreal, Halifax, or the Port of New York/New Jersey given the well-developed rail and truck networks designed to service these ports.

**Alternative Modes of Transportation Provide Good Levels of Service**

Railroads and trucking companies have developed extensive intermodal service networks serving Montreal, Halifax, and New York. Both CN and CP provide multiple daily train services from Detroit and Chicago to dockside in Montreal. A container loaded in these cities can be transported and loaded on a ship in Montreal in 2-3 days and then be on the way to Europe. This level of service and the frequent sailings from Montreal offer shippers from the Midwest the ability to regularly ship and receive containers. There are similar intermodal rail services from Chicago to the East Coast where again sailings
are very frequent. The most time sensitive freight could be trucked from Chicago to one of these ports in less than a day if necessary and be on its way to Europe. Weekly or twice weekly sailings from Great Lakes ports would incur both longer transit times and longer wait times for a ship.

Nine Month Season Makes Competition Difficult
A very difficult problem is the three months in the winter when the Seaway is closed. Shippers will have to make alternative arrangements for this time period and the other modes will be reluctant to offer attractive rates for this type of seasonal service. The railroads and truckers will not maintain an inventory of locomotives, railcars, and trucks that cannot be utilized fully throughout the year. As such, they will try to convince the shippers that they would be better off by contracting year-round with them to take the traffic to Montreal or another port. Any new service proposed for the Great Lakes will likely find significant resistance from the railroads and truckers to prevent them from switching a portion of their traffic to ocean vessels coming to a Great Lakes port. This could include initiatives to raise rates on traffic on other routes.

The Harbor Maintenance Tax Would Add Costs for U.S. Bound Containers
The U.S. imposes a .125% Harbor Maintenance Tax (HMT) on the value of goods imported into the U.S. by water. This Harbor Maintenance Tax is used to provide dredging and other maintenance activities at U.S. ports, channels, and harbors. This tax is also used to pay for the operation of the St. Lawrence Seaway Development Corporation—the entity responsible for the operation of the two U.S. locks on the Seaway. This tax would apply to the value of any containerized goods imported into a U.S. Great Lakes port. For example, the owner of a container containing $100,000 of merchandise would have to pay U.S. Customs $125 for that container. This tax only applies to goods entering the U.S. by water—it does not apply to goods landed in Montreal and trucked or railed into the U.S. It would however apply to any goods landed at an east coast U.S. port. The HMT gives the ports of Montreal or Halifax and the surface modes that serve them a cost advantage over east coast U.S. ports or container ships coming into the lakes to service U.S. ports. Containers tend to have higher value products compared to the other traffic and the HMT would affect them more than other types of cargo.

POTENTIAL CONTAINER SERVICES
Given the above barriers, aside from niche shipping services, conventional container services do not appear to be viable in the Great Lakes because of size constraints and the difficulty in competing in the trans-Atlantic market with much larger ships. However, it may be possible to trans-load containers from a larger vessel to a smaller Seaway size vessel at Halifax or Montreal. This type of “short sea shipping” is common in Europe and may have some application in North America. However, rail and truck services are much more efficient in North America and whether feeder type services could compete is not clear. Another issue relates to whether trans-loading costs at the transfer port could be kept low enough to make the concept viable. None-the-less, this is where there may be some possibility of services that can compete. But many of the above issues also create problems for cross-lake feeder services. For instance, the nine month season is a very large impediment to a viable commercial operation.

CONCLUSION
With the exception of niche shipping services serving specific markets, the authors do not believe there is significant potential for conventional container ship service into the Great Lakes. The smaller vessels that could fit through the Seaway could not compete in the trans-Atlantic trade with the much larger ships serving Montreal, Halifax, and New York. Further, the extra time involved in serving ports such as Detroit and Chicago and the infrequent service from these ports would not be attractive to shippers. They are accustomed to almost daily service between major eastern ports and Northern Europe as well as efficient rail and trucking services to and from these ports. The three-month winter closure of the Seaway would be a major problem for shippers.
and the high rates they would pay the railroads or truckers during this period would further negate any economic advantage. The Harbor Maintenance Tax is a further economic obstacle for containers landing at U.S. ports especially as compared to containers landing at Montreal and moving by rail or truck to the Great Lakes Region.

There will always be containers moving on the Great Lakes as incidental or project related cargo. There may in fact be an opportunity to increase this business particularly in certain specialty or low volume areas where containerization makes sense. There may also be the potential for certain types of short sea feeder services for containers moving up-bound from Halifax or Montreal into Lake Ontario or possibly Lake Erie. A Canadian port would have an advantage since it would be exempt from the HMT. These feeder services, if economically viable, would likely be low volume compared to existing volumes currently moving by rail and truck.

However, regularly scheduled transatlantic container services face many challenges that make them very unlikely given the cost structure and service dimensions offered. Even with subsidies, these services are unlikely to succeed. While there have been many studies and efforts over the last 50 years to initiate scheduled container services none have been proven viable. While the current Cleveland service continues, traffic levels have declined from earlier years even with subsidized operations. Given this record, it is critical that policymakers have an objective analysis of the current traffic levels, competition, obstacles, and potential for such services. Otherwise there is a risk of significant expenditures of time and effort on proposals that are not viable.

REFERENCES


BIOGRAPHIES

John Floyd is an Undergraduate Research Assistant within the Department of Marketing and Supply Chain Management in the Mike Ilitch School of Business at Wayne State University. He will be graduating in August 2018 with a B.S. in Global Supply Chain Management Honors. His research interests include various transportation and logistics topics. He can be reached at fx2236@wayne.edu.

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(Footnotes)

1 TEU means a “Twenty-foot Equivalent Unit” and is the common way of measuring cargo activity at a given port even though some containers may be longer than twenty feet. For example, a 40 foot container would be counted as two TEU’s. A 20 foot container (TEU) has a maximum gross weight of 52,910 pounds per international standards. This results in a tare maximum weight of 48,000 pounds. Most containers weigh considerably less.

2 The SLS Traffic Reports report metric tons in containers. The authors converted this to short tons, and assumed ten tons per container. This process allows comparisons with USACE and other U.S. sources that use short tons.

3 The Seaway can accommodate ships with a maximum dimension of 225.5 meters long (740 feet), 23.8 meters in breadth (78 feet) and 9.1 meters draft (30 feet).
Guidelines for Journal of Transportation Management
Submission/Publication

GENERAL

1. Editor Contact Information – Dr. John C. Taylor, Associate Professor of Supply Chain Management, Department of Marketing and Supply Chain Management, School of Business, Wayne State University, Detroit, MI 48202. Office Phone: 313 577-4525. Cell Phone: 517 719-075. Fax: 313 577-5486. Email: taylorjohn@wayne.edu

2. Articles should be submitted electronically to Dr. Taylor at taylorjohn@wayne.edu.

3. Articles should be submitted using Microsoft Word for Windows in either doc or docx formats. Articles prepared on Mac systems should be saved in Word for Windows compatible format. Accepted articles, in final form, are also submitted via email.

4. Article length should be in the range of 6000-7000 words including references. Tables and figures are in addition to the word count. However articles including all text, references, appendixes, tables and figures (but excluding front matter) should not exceed 30 double spaced pages in the format described below. Shorter articles are also acceptable. It will be difficult to publish articles much longer than 7000 words.

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1. First Page - Title of the paper, name and position of the author(s), author(s) complete address(es) and telephone number(s), e-mail address(es), and any acknowledgment of assistance. Times New Roman with 12 point font.

2. Second Page - A brief biographical sketch of each author including name, degree(s) held, title or position, organization or institution, previous publications and research interests. Include each author’s email address at end. Maximum of 90 words per author. Times New Roman with 12 point font.

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\[ y = c + ax + bx \]
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A FRAMEWORK FOR EVALUATING SUPPLY CHAIN PERFORMANCE

Terrance L. Pohlen, University of North Texas

ABSTRACT

Managers require measures spanning multiple enterprises to increase supply chain competitiveness and to increase the value delivered to the end-customer. Despite the need for supply chain metrics, there is little evidence that any firms are successfully measuring and evaluating inter-firm performance. Existing measures continue to capture intrafirm performance and focus on traditional measures. The lack of a framework to simultaneously measure and translate inter-firm performance into value creation has largely contributed to this situation. This article presents a framework that overcomes these shortcomings by measuring performance across multiple firms and translating supply chain performance into shareholder value.

INTRODUCTION

The ability to measure supply chain performance remains an elusive goal for managers in most companies. Few have implemented supply chain management or have visibility of performance across multiple companies (Supply Chain Solutions, 1998; Keeler et al., 1999; Simatupang and Sridharan, 2002). Supply chain management itself lacks a widely accepted definition (Akkermans, 1999), and many managers substitute the term for logistics or supplier management (Lambert and Pohlen, 2001). As a result, performance measurement tends to be functionally or internally focused and does not capture supply chain performance (Gilmour, 1999; Supply Chain Management, 2001). At best, existing measures only capture how immediate upstream suppliers and downstream customers drive performance within a single firm.
Developing and Costing Performance Measures

ABC is a technique for assigning the direct and indirect resources of a firm to the activities consuming the resources and subsequently tracing the cost of performing these activities to the products, customers, or supply chains consuming the activities (La Londe and Pohlen, 1996). An activity-based approach increases costing accuracy by using multiple drivers to assign costs whereas traditional cost accounting frequently relies on a very limited number of allocation bases.

\[ y = a^2 - 2ax + x^2 \]

REFERENCES


Revised August 30, 2011
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