Development of a Dashboard to Improve Fleet Maintenance for a Food Bank

La'Tricha Parks, Steven Jiang and Lauren Davis
Department of Industrial and Systems Engineering
North Carolina A&T State University
Greensboro, NC 27411, USA
lparks1@aggies.ncat.edu, xjiang@ncat.edu, lbdavis@ncat.edu

Abstract

Fleet maintenance is the process fleet manager utilizes to manage fleet and asset information from acquisition to disposal. It helps the companies reduce costs, improve efficiency and safety. Second Harvest of Metrolina Food Bank (SHMETROLINA) distributed over 70 million pounds of food and household items to approximately 800 partner agencies in 2019. With the critical need for transportation for distribution, a vehicle experiencing downtime will disrupt scheduled routes to partner agencies and increase repair costs for SHMETROLINA. This research developed an interactive dashboard using R shiny to help non-profit food bank fleet managers make informed decisions for effective fleet maintenance operations and support the food bank operations to meet hunger needs. The dashboard consists of the visualizations of the maintenance cost, mileage, and operational cost for individual and fleet vehicles from the data collected by the food bank.

Keywords
Dashboard, Fleet Maintenance, Food Bank

1. Introduction

Food insecurity is defined as an individual or household's inability or limited access to safe and nutritious food they need for an active, healthy life (Campbell, 1991; Coleman-Jensen, Gregory & Singh, 2014). According to USDA Economic Research Service, 10.5 percent of U.S. households were food insecure in 2020, where 6.6 percent (8.6 million households) had very low food insecurity (USDA, 2021). Feeding the Carolinas is a non-profit program working to solve and prevent food insecurity in North Carolina and South Carolina. The program currently has 10 Feeding America Food Banks across North Carolina and South Carolina. These 10 Food Banks distribute perishable goods to several different counties throughout North Carolina and South Carolina. As part of Feeding the Carolinas, Second Harvest of Metrolina (SHMETROLINA) is located in Charlotte, North Carolina. SHMETROLINA has a regional distribution warehouse and three branches that supply grocery items to over 800 partner agencies in North Carolina and South Carolina. Over 70 million pounds of food and household items were distributed to 24 counties in 2019-2020, as seen in Figure 1. 42 million pounds were fresh produce, meat, and dairy. SHMETROLINA serves a population of over 553,000 people, including almost 182,000 children and 48,000 seniors. The food bank distributes food from the central warehouse in Charlotte and through their smaller branches in Hickory, NC, Anderson, SC, and Spartanburg, SC.

SHMETROLINA is a non-profit organization where 80 percent of the food is donated, 7 percent is received from other food banks, and approximately 13 percent of the food comes from government commodities. These foods need to be delivered to partner agencies through a fleet of vehicles. SHMETROLINA has 36 vehicles, of which seven are out of service, that distribute to over 800 partner agencies. With a critical need for transportation for distribution, a vehicle experiencing downtime disrupts scheduled routes to partner agencies. Unfortunately, currently, SHEMETROLINA does not have a practical approach to increase its fleet's life span, and the donations do not contribute to the maintenance of the vehicles. Specifically, SHMETROLINA is facing the following challenges: • Difficulty to predict the time for repair maintenance; Lack of funds for maintenance; Unstructured information in decision-making in fleet maintenance.

The objectives of this research are to collect maintenance data from SHETROLINA and develop an interactive dashboard by integrating data analytics with visualization tools to extract useful information that can help food bank managers make decisions for effective fleet maintenance operations and support the food bank operations to meet hunger needs.

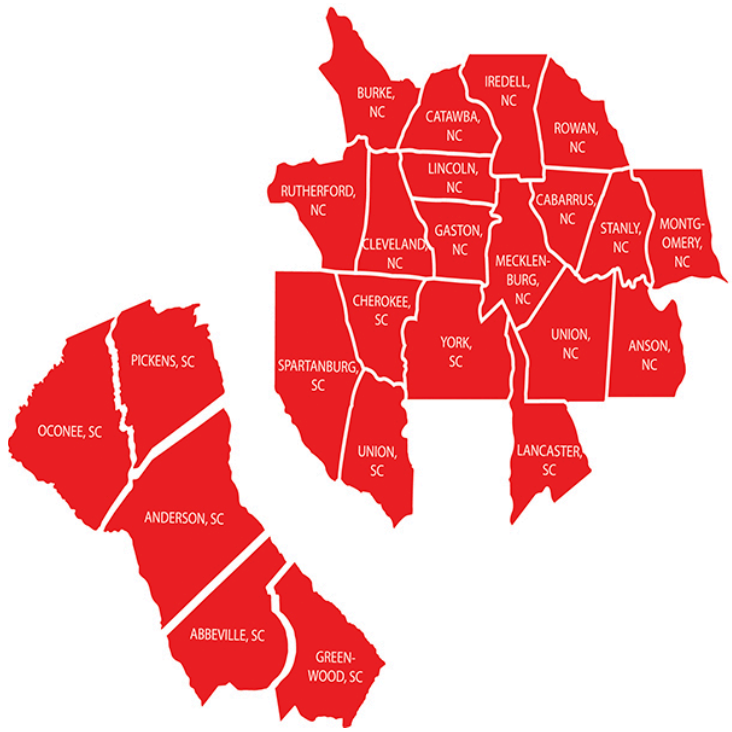

Figure 1. A map of the 24 counties SHMETROLINA serves in North Carolina and South Carolina.

2. Literature Review

Vehicle fleet management (VFM) aims to optimize the performance measures through decision making (Topaloglu, 2007). The primary function of fleet management is to use digital means to track and manage the activities and conditions of vehicles (Bright, 2020). The fleet structure is determined by the fleet size, vehicle brand, and age. Managing fleet structure helps identify specific vehicles for elimination and opportunities to "right-sizing" the fleet. Right-sizing the fleet is dependent on the route to load ratio to ensure safe and efficient distribution of goods. The optimal fleet size depends on the relative cost of increasing fleet size compared to the waiting cost associated with undersized fleets (Turnquist, 1986). The responsibility to maintain fleets is divided between multiple stakeholders, such as drivers, mechanics, and managers. The purpose of such is to control the entire lifecycle of vehicles alongside reducing associated risk, improving efficiency, increasing productivity, and ensuring compliance with legislation.

Nowadays, companies, corporations, and organizations use vehicle fleets to deliver products and services (Wang, 2019). While the type of vehicle is less important for companies, their essential characteristic is that a large number of vehicles are utilized to transport their customer's needs (Spuntrup, 2018). To ensure a safe and efficient fleet, essential factors to maintain fleet management such as scheduling, telematics, financing, or operational cost must be maintained to be cost-efficient. Unfortunately, many businesses choose to neglect vehicle maintenance because it is not their core business function (Wang, 2019). Neglected vehicle maintenance could cause more maintenance repairs, which leads to shorter life spans and higher costs for the fleet. The failure of proper maintenance checks could also lead to vehicle failure, accidents, death, and failed state inspection, causing environmental impact.

In general, there are two types of maintenance: Preventive Maintenance (PM) and Corrective Maintenance (CM). They ensure that the equipment availability target is achieved with reasonable maintenance cost or maximum profit (Husniah, 2017). PM is performed before the occurrence of a failure and intends to decrease the probability of unforeseen breakdowns (Rashidnejad, 2018). CM is performed after the event of failure. PM operations are performed in a specific and decided period, while the CM operations need time for a problem to occur rather than PM to be performed (Lopez-Santana, 2016). To avoid unnecessary maintenance, which increases the cost and may also increase the risk of further wear, an effective PM schedule should depend on quality, reliability, and a lifecycle cost analysis (Li, 2012).

Non-profit organizations are private, voluntary organizations operating for a public or social benefit, making them significant to society. There are no limitations to the diversity of non-profits in the United States (Anheier, 2014). Their operations could consist of healthcare, education, and food security. With funds from the government and donors, the service is free or cheaper than for-profit organizations, making the service critical for some families to survive. The contribution to community development and the environment has increased research for non-profit organizations over the years. To ensure efficient distribution, non-profit organizations' managers must manage maintenance to operate their fleet, also known as vehicle fleet management. Unfortunately, the lack of research on fleet management in non-profit organizations makes it difficult to operate efficiently.

Food banks are non-profit organizations providing food security needs related to the global socio-economic crisis (Coque, 2017). Food banks play an essential role in providing solutions for food deprivation. They can improve food security outcomes when perishable food groups are available, operational resources are adequate, and stakeholder's needs are identified and addressed (Bazerghi, 2016). However, the dependency of available donated supplies determines which part of their stakeholder's needs can be satisfied.

Compared to traditional for-profit organizations, where the supply chain is firmly based on customer's needs, food banks heavily depend on donations from families, donors, industries, institutions, and other food banks to operate the flow of the supply chain. Related to retailers in a traditional supply chain, distribution centers and consumption centers are recipients. Distribution centers distribute batches of free food while consumption centers, also known as soup kitchens or shelters, provide prepared meals on-site for food-insecure families (Berner, 2004).

Approximately 800 million people in the world are food insecure, and the need for distribution will have an increase of 70% by 2050 (Coque, 2017). As part of operational resources, distribution plays a vital role in the supply chain. The key to distribution is how the goods are efficiently transported from one location to another. However, transportation is one of the highest overhead costs for non-profit organizations. It involves a fleet of different vehicle types, such as refrigerated trucks (refer trucks) for perishable foods, traitor trailers for large loads of dry foods and goods, and personal vehicles for smaller donations or meetings. There are also various means of operations through a complicated network structure (Dejax, 1987).

Non-profit and humanitarian organizations depend highly on transportation in order to operate their services and meet stakeholder's needs. Unfortunately, the funds to maintain a respectable fleet size, operate, and keep an effective fleet are challenging due to the organization's dependency on government agencies and donors for the source of aid. Key factors, such as preventive maintenance, driver training, routing, and schedule, could increase the lifecycle of the fleet while being cost-efficient.
In summary, the literature review shows that there is little research for food bank fleet management and there is a strong need to study fleet maintenance for a food bank and provide data driven decision making to fleet managers of a food bank.

3. Methods

In this research, we used R shiny to clean, visualize and analyze trends to assist SHMETROLINA fleet management's decision-making. An interactive dashboard was developed to help the food bank closely look at essential data and relationships between data sets.

3.1 Data Collection

Data obtained from SHMETROLINA consist of fleet information from July 2019 through October 2020 for 36 vehicles. Six fields describe the details of each vehicle: truck or van information, truck cost, preventative maintenance, tag renewal dates, insurance cost, and mileage for each month. SHMETROLINA monthly fleet expenses was obtained and included total fleet miles, total fuel cost, fleet fuel per mile, total fleet fuel gallons, total fleet repair cost, and rental expenses. In addition, specific information for each vehicle, such as the truck type, driver's name, year, mileage, and truck number was obtained. We also acquired the preventative maintenance schedule from SHMETROLINA for the fiscal year 2019 that consists of only 21 refrigerated trucks, the truck's number, the truck driver's name, and PM due dates. PM schedule also shows that most vehicles are maintained from September to November with a six-month cycle.

3.2 Challenges Encountered with Data Collection

Data collection was a very challenging task. Due to COVID-19, communication with SHMETROLINA was very limited due to the high demand of food insecurity. The data received is only for the fiscal year 2019, where repair data is from July 2019 – October 2020 while mileage data is from October 2019 – October 2020. Besides limited data, the quality of the data (i.e., missing data and inaccurate data) and lack of route plans are also a challenge. A few missing and inaccurate data entries affected the results.

3.3 Data Preprocessing

Raw data collected must be cleaned and manipulated before conducting analysis. This step is called data preprocessing. Data preprocessing is a technique used to clean and transform raw data into an understandable format. The messy data was formatted where all missing fields were processed, and required fields were filtered. The preprocessed data allowed the data to be more understandable to conduct analysis. There are several opportunities for errors in data collection. Manual data entry can cause many errors, such as inaccurate data or missing data. SHMETROLINA has disposed of and received vehicles throughout the fiscal year, which also caused inaccurate data when looking at results. All data preprocessing occurred in R studios.

All raw datasets were imported into R using the "*readr"* library. The dataset was checked for missing values within the miles traveled monthly, odometer readings, and monthly repair cost. Patterns showed fields with missing values were resulted in the vehicle either being sold, new, not repaired, or driven for that month. New vehicles showed patterns of missing fields before the purchase, while sold vehicles showed the same pattern after being disposed. Missing values for mileage and repair were then replaced with zeros, while odometer readings were replaced with column-wise values. The data was then separated into data frames to focus on specific key fields, such as mileage traveled, repair cost, and operational cost.

3.4 Development of an Interactive Dashboard

In this research, we chose R shiny to develop an interactive dashboard to assist SHMETROLINA in managing its fleet. To better analyze the data, the dashboard is separated by two tabs for individual vehicles (labelled as Truck) and the overall fleet (labelled as Fleet). In the individual vehicle tab, line charts were developed to show the repair cost and mileage traveled for individual trucks and vehicles. Line charts were also used to show the odometer readings and replacement cycle to determine the age of the truck compared to others.

The “Fleet” tab, consists of quality control, line, pie, and bar charts for the fleet’s mileage traveled, repair cost. The visualizations are split into two sub tabs, performance and trends. Performance tab, analyze the usage of the vehicle by the drivers and manufacturer of the fleet. The tab also visualizes the fleet’s cost by the repair and operational costs using pie and bar charts. The trend tab consist of the two standard quality control charts, X-bar, and S, to analyze patterns of process variation from special causes or common causes related to the repair cost and mileage traveled. X-bar and S charts are used to observe the control of the fleet related to the mean and variation estimated from subgroups. Subgroups are constructed from the measurement of the data at any given time. Upper and lower control limits are then produced for each subgroup. When a point is outside the established control limits, the process is due to a special cause or out of control.

Operational costs used to run day-to-day expenses also appear in the section. When trucks or vehicles within the fleet are experiencing downtime or need maintenance on the basic transportation needs, fleet managers must make expense decisions to keep the fleet operating, resulting in excessive spending that could be avoided if vehicles experienced less downtime. However, most operational costs are necessary (i.e., fuel cost), but some could be avoided.

The interactive dashboard for this research allows the food bank managers to view and interact with the data from the overall fleet to individual trucks and vehicles. Fleet managers can compare the usage and repair cost of multiple trucks to decide better mission plans, maintenance scheduling, and disposal of vehicles. Visualization charts shown in the dashboard will help fleet managers interact and analyze the yearly and monthly breakdown of the fleet cost, driver’s performance, and usage of trucks based on the manufacture.

4. Results and Discussion

4.1 The Interactive Dashboard

The dashboard is separated by two tabs for individual vehicles (labelled as Truck) and the overall fleet (labelled as Fleet) as seen in Figure 2.

In the "Truck" tab, information about the repair cost and mileage traveled for individual trucks and vehicles as well as the odometer readings and replacement cycle is provided. Repair cost and mileage data from SHMETROLINA shown in Figure 2 is collected for the fiscal year 2019. Managers may select one or multiple trucks or vans from the truck selection drop-down box to see data visualizations of each vehicle by the manufacture and status of the truck. Such as the average usage of selected trucks using quality control charts and the correlation for mileage versus repair cost. Visualizing the usage of vehicles may show trends that could help SHMETROLINA improve its preventive maintenance schedule and route plans.

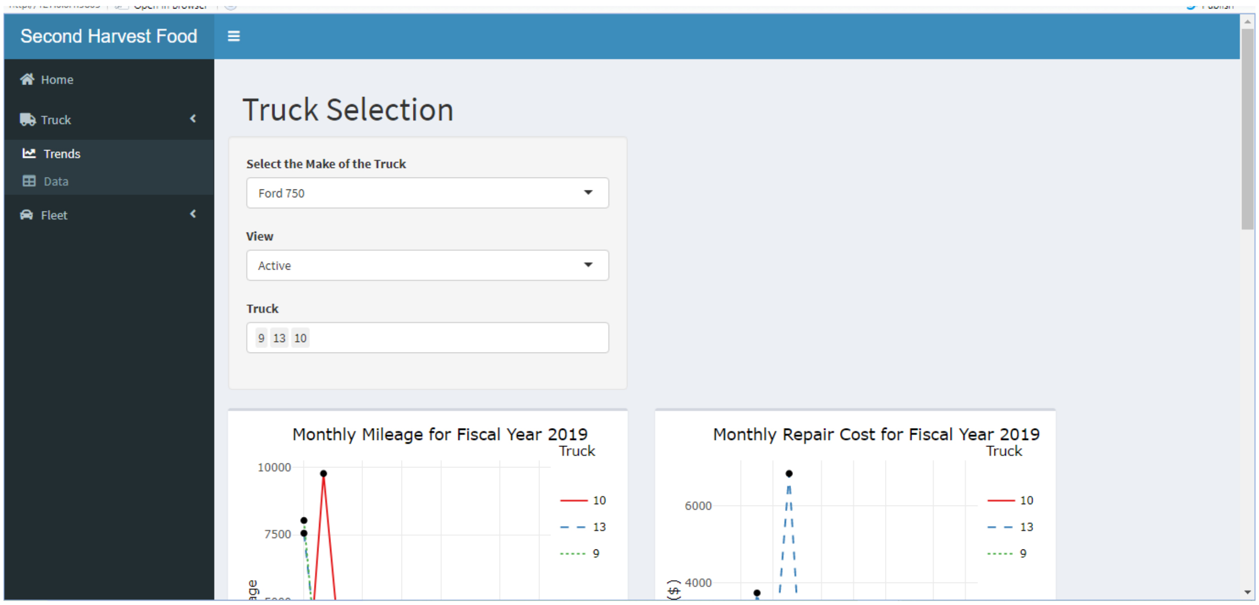

Figure 2. Dashboard showing individual trucks and vans for miles traveled and repair cost for FY19.

The "Fleet" tab, as seen in Figure 3, consists of quality control, line, pie, and bar charts for the fleet's mileage traveled, repair cost. The visualizations are split into two sub tabs, performance and trends. Performance tab, analyze the usage of the vehicle by the drivers and manufacturer of the fleet. The tab also visualizes the fleet's cost by the repair and operational costs using pie and bar charts. The trend tab consist of the two standard quality control charts, X-bar, and S, to analyze patterns of process variation from special causes or common causes related to the repair cost and mileage traveled. X-bar and S charts are used to observe the control of the fleet related to the mean and variation estimated from subgroups. Subgroups are constructed from the measurement of the data at any given time. Upper and lower control limits are then produced for each subgroup. When a point is outside the established control limits, the process is due to a special cause or out of control.

The fleet has 36 vehicles, where several were sold or donated within the fiscal year. To better analyze the usage of the current fleet, only current active and new refer trucks were visualized to construct a new maintenance approach. Therefore, X bar and S control charts for the fleet appear in this section.

Operational costs used to run day-to-day expenses also appear in the section. When trucks or vehicles within the fleet are experiencing downtime or need maintenance on the basic transportation needs, fleet managers must make expense decisions to keep the fleet operating, resulting in excessive spending that could be avoided if vehicles experienced less downtime. However, most operational costs are necessary (i.e., fuel cost), but some could be avoided.

4.2 Discuss of the Dashboard

Currently, fleet managers determine the replacement of the fleet by the odometer reading of each truck. The higher the odometer reading, the older or sooner the truck will be replaced. Based on that decision, the fleet's average age was visualized by each manufacture of the fleet, shown in Figure 4. Ford and Prius are the personal vehicles and vans used for smaller transport, while the others are refrigerated trucks (refer trucks) used for more extensive distribution.

To better understand the usage of the fleet, one of the newest refers manufacturers, Freightliners were analyzed. Freightliners are the most common and newest compared to the rest of the refer trucks, shown in Figures 5 and 6. Freightliners traveled the most over the Fiscal Year, as shown in Figure 5, with the frequent repair cost. The assumption of the overuse of newer vehicles by non-profit organizations causing vehicle downtime gave awareness to the data visualizations of Freightliners.

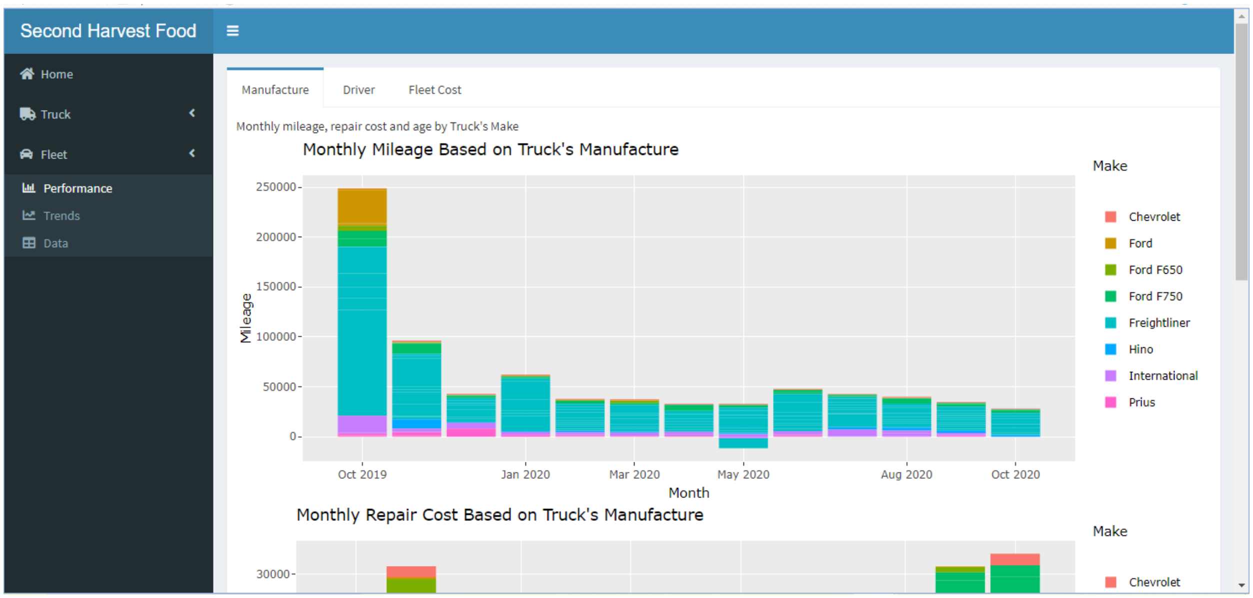

Figure 3: Fleet tab for the overall fleet repair cost, mileage traveled, and operational cost (i.e. fuel and rental cost).

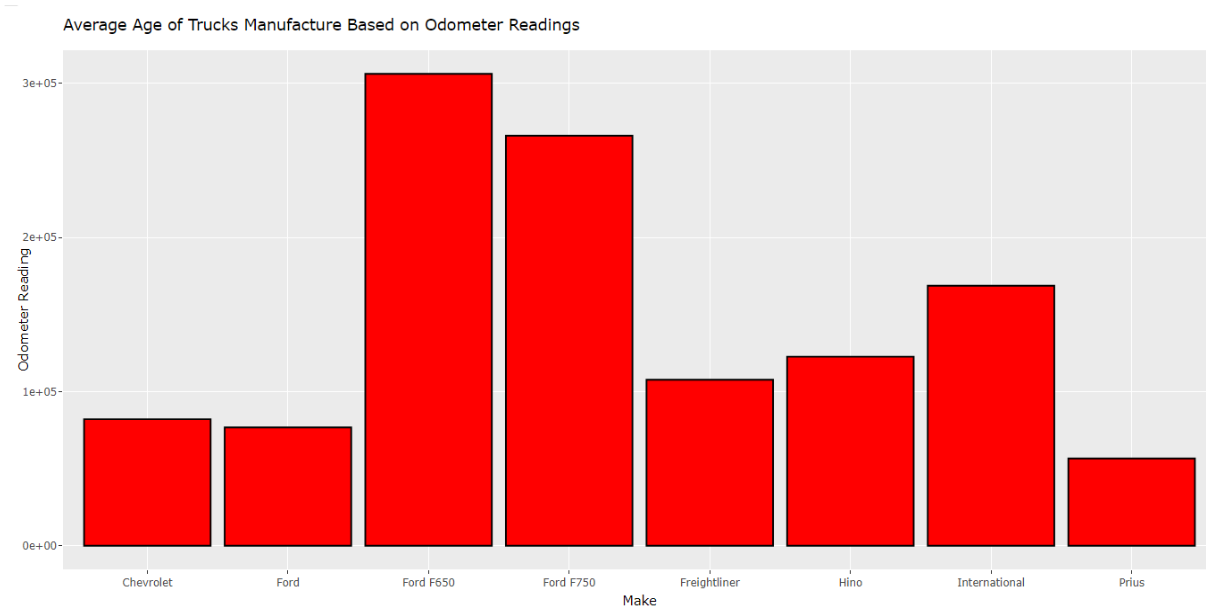

Figure 4: Average age of truck's manufacture based on odometer readings

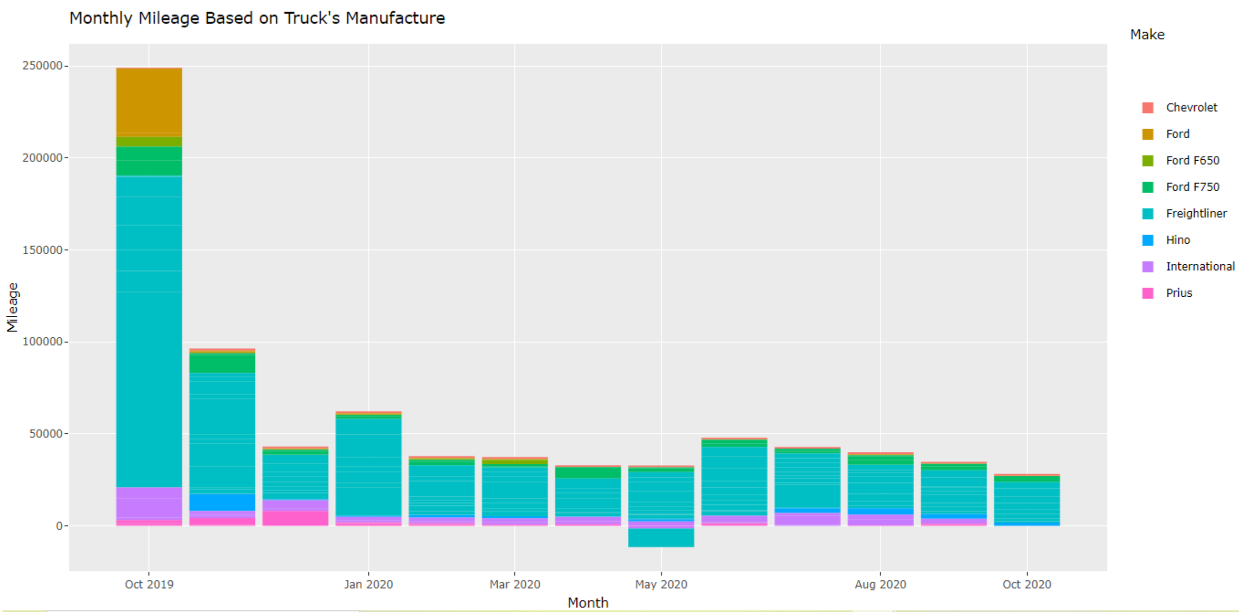

Figure 5: Monthly mileage based on truck's manufacture

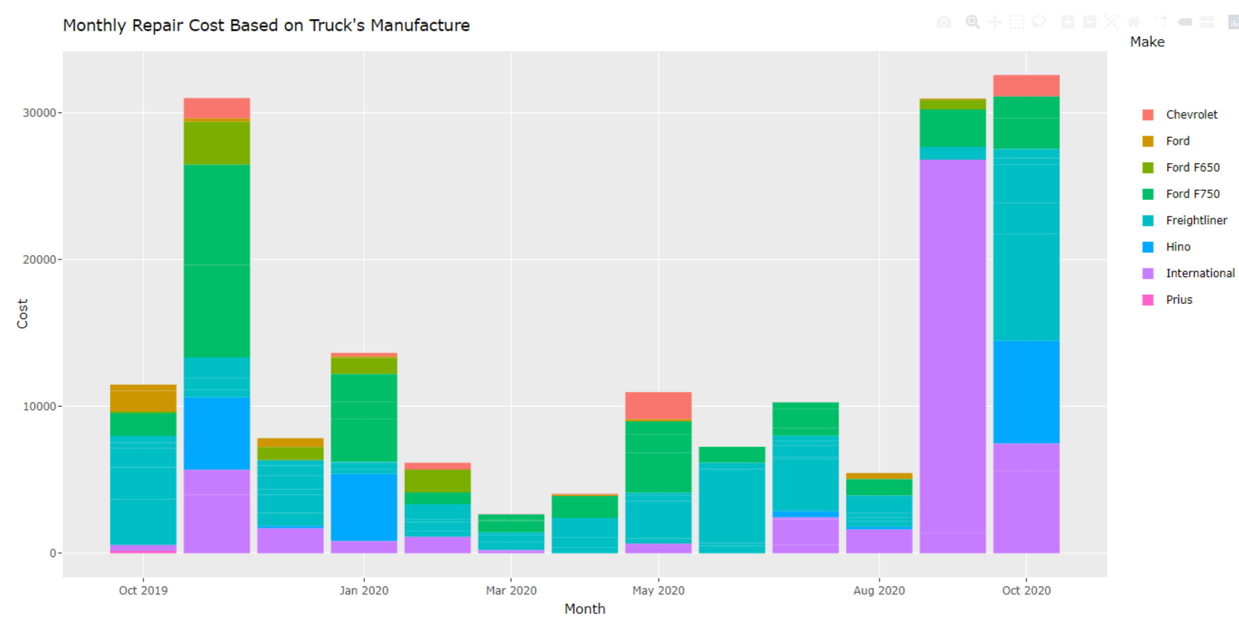

Figure 6: Monthly repair cost based on truck's manufacture

To take a closer look, individual Freightliner trucks were visualized. Specifically, line charts were developed to show the repair cost, and mileage traveled for the individual trucks. In addition, comparing the usage of new, close to new, and older refer trucks may show trends that could help SHMETROLINA improve its preventive maintenance schedule and routing plan. As previously stated, the data for mileage and repair costs was collected from October 2019 until October 2020. Therefore, the comparison of new, close to new, and older refer trucks, based on odometer readings from Figure 7, was analyzed using the following trucks: Truck 9 is considered an older 24' refer truck, dash green; Truck 10 is a close to new 24' refer truck, solid red; Truck 13 is a newer 24' refer truck, dash blue.

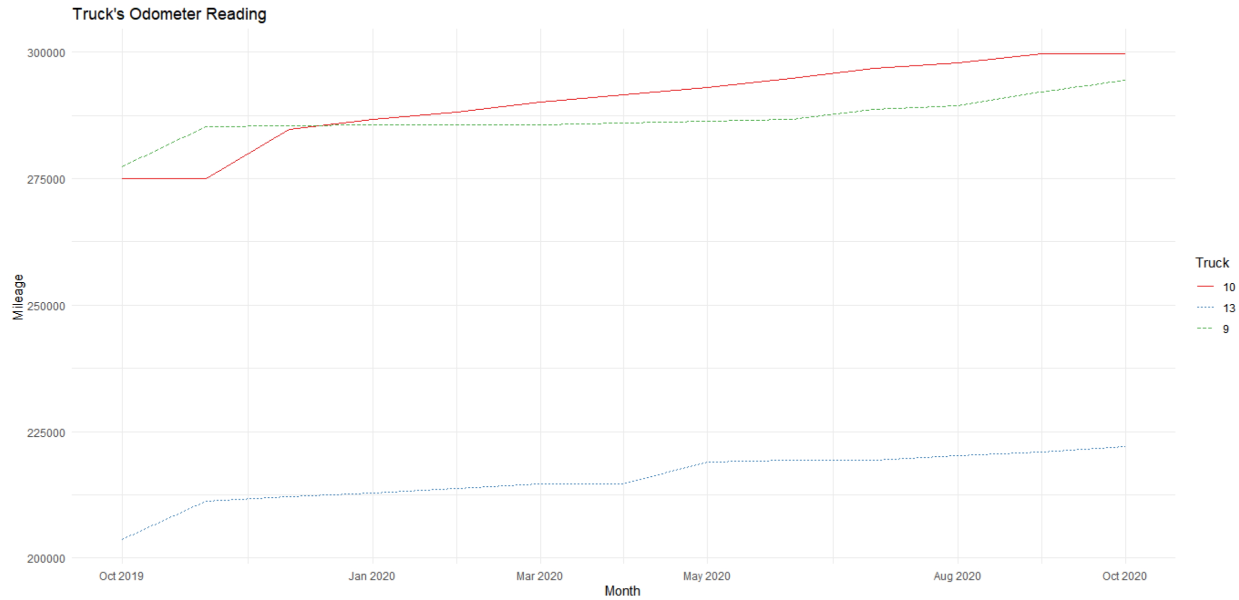

Figure 7: Odometer reading for age of selected trucks

Mileage traveled shown in Figure 8 by truck 9, and 13 shows an excessive number of 8,000 miles traveled in October 2019, followed by downtime or very few miles traveled with repetitive repair costs for the fiscal year, Figure 9. Compared to the older trucks, truck 10 shows zero miles traveled for October 2019, with approximately 10,000 miles traveled for the month of November. The newer truck traveled more over the fiscal year, accumulated the least amount of repair cost, and experienced little to no downtime.

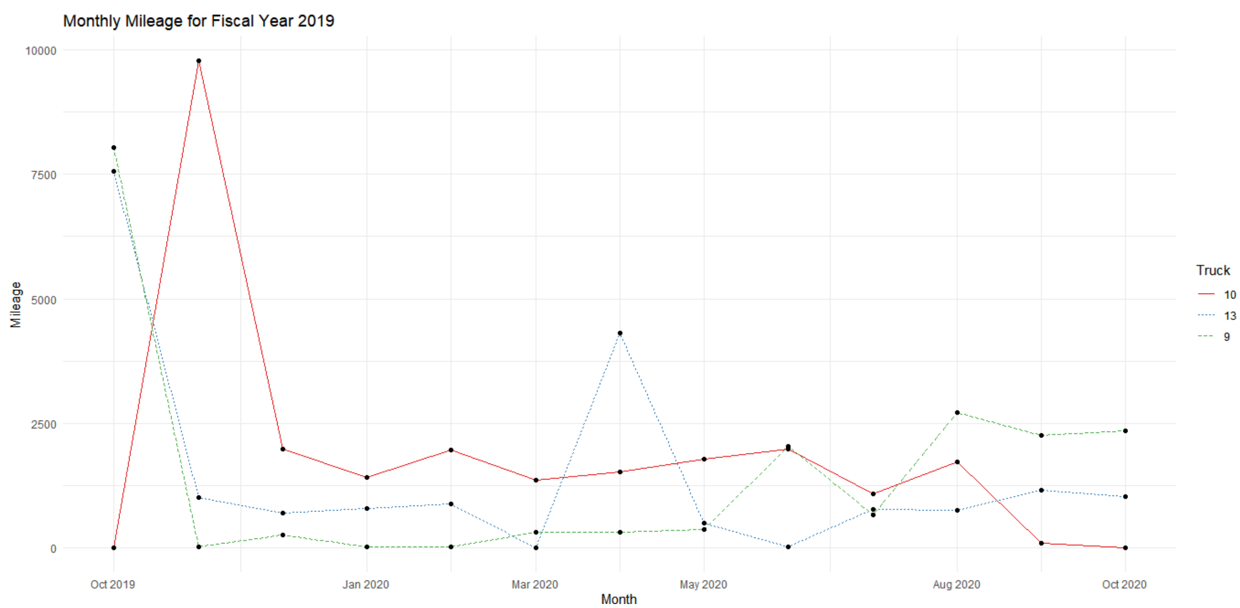

Figure 8: Comparison line chart for monthly mileage for fiscal year 2019

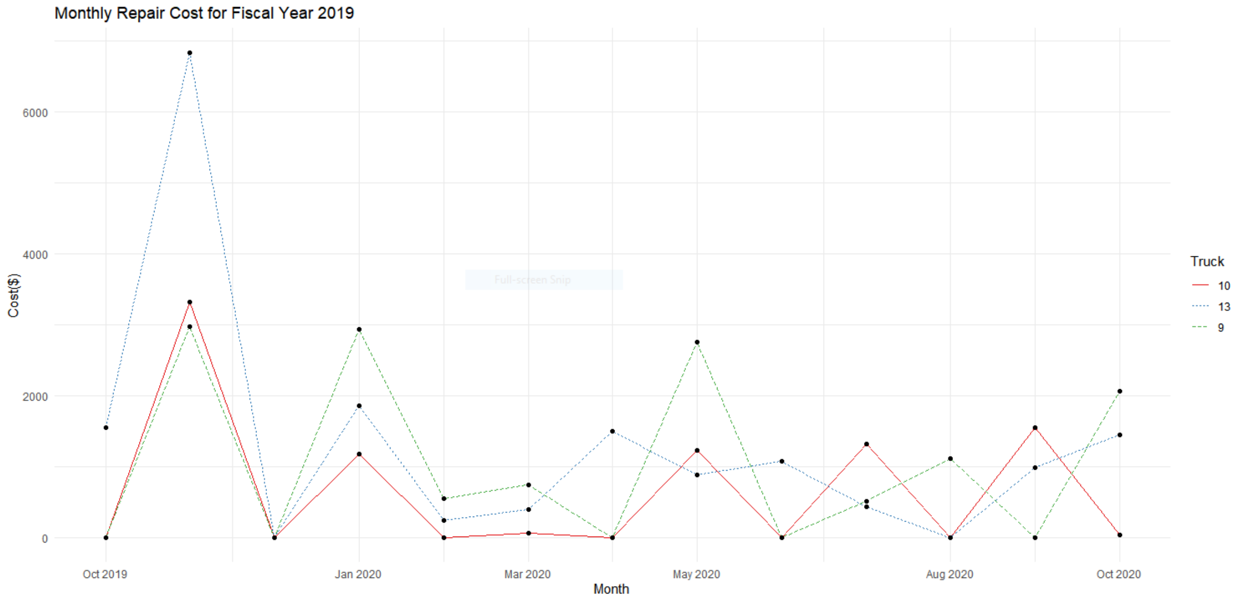

Figure 9: Comparison line chart for monthly repair cost for fiscal year 2019

Vehicle downtimes are shown to be experienced after long traveling distances. If maintenance scheduling were performed after a reasonable amount of mileage of maybe 5,000 compared to every six months, the vehicle might experience less downtime. Figure 10 is a thermometer plot created for each selected vehicle to show the percentage of the monthly mileage traveled divided by 5,000 miles. Truck 10 current PM schedule is for November 2019 and May 2020 but accumulated 5,000 miles by January 2020 and another 5,000 by May 2020. Similar, truck 13 maintenance schedule is for November 2019 and May 2020 but accumulated 5,000 by April 2020. Unlike the other trucks, truck 9 current PM schedule is for September 2019 and March 2020 but has a 161% of mileage traveled for October 2019. Immediately after the overuse of 61%, the truck experienced downtime for most of the Fiscal Year. If trucks were maintenance every 5,000 miles, the repair cost might be reduced.

Figure 10: Selected truck's mileage traveled thermometer plot.

Recommendations analyzed from the interactive dashboards for SHMETROLINA would be to distribute truck's mission types between truck's age or manufacturer. The trucks should be evenly distributed for mission types based on age and size. Older trucks should distribute shorter distances, while newer trucks can distribute to farther locations. Using the thermometer plot to get the status of the truck's preventive maintenance schedule, to help reduce vehicle downtimes. The change in PM schedule will also help lower fleet cost by avoiding unexpected repair costs and rental costs to operate the fleet. Route planning and analyzing drivers would decrease fuel usage, fuel cost, and frequent tire replacements. Telematics software would benefit the foodbank by collect accurate information for routes and drivers handle.

6. Conclusion

This research developed an interactive dashboard to assist food bank fleet managers to make data driven decisions. The interactive dashboard allows the fleet managers to detect the trend, identify potential problematic areas and take preventive actions. This research provides a way to integrate analytics with visualization to assist fleet management for a nonprofit organization. Finding of this research will benefit non-profit organizations that depend on distribution to reduce vehicle downtime, maintenance cost, or reduce errors related to fleet management decision-making. We have shown through visualization results that proper decision-making techniques can improve the overuse of vehicles and inefficient PM scheduling. However, the data collected in this study was limited to one fiscal year, and a more detailed analysis using at least five years of data (when available) could improve the effectiveness of the dashboard.

7. Acknowledgement

This research is partially funded by NSF **N**RT: Improving strategies for hunger relief and food security using computational data science (Award #: DGE 1735258**)**. We would like to thank Mike Luke and Michael Sepe from Second Harvest of Metrolina for their assistance in the study.

References

Anheier, H., (2014). Non-profit Organizations. *Theory, Management, Policy 2nd ed*. 57

Bazerghi, C, McKay, F., Dunn, M., (2016). The Role of Food Banks in Addressing Food Insecurity: A Systematic Review. *J Community Health 41*, 732-740.

Berner, M., & O'Brien, K., (2004). The Shifting Pattern of Food Security Support: Food Stamp and Food Bank Usage in North Carolina. *Nonprofit and Voluntary Sector Quarterly*, 655-672.

Bright, B. (2020). What is the purpose of fleet management. *Norse Corp*.

Campbell, C. C. (1991). Food Insecurity: A Nutritional Outcome or a Predictor Variable? The Journal of Nutrition, 121(3), 408-415.

Coleman-Jensen, A., Gregory, C., Singh, A. (2014). Household food security in the United States in 2013. USDA-ERS Economic Research Report (173).Dejax, et. al, (1987). A review of empty flows and fleet management models on freight transportation. *Transportation Science*, 227-248.

Coque, J. (2017). Adapting nonprofit resources to new social demands: The food banks in spain. *Sustainability*, 643.

Husniah, H., Pasaribu, U., Supriatna, A., Iskandar, B, (2017). Optimal Number of Fleet Maintenance Contract with Policy Limit Cost. *2017 4th International Conference on Control, Decision and Information Technologies*.

Li, J., Mourelatos, Z., and Singh, A. (2012). Optinal Preventive Maintenance Schedule based on Lifecycle Cost and Time-Dependent Reliability.

Lopez-Santana, E. (2016). On the combined maintenance and routing optimization problem . *Reliability Engineering and System Safety*, 99-214.

Rashidnejad, M., Ebrahjmnejad, S., Safari, J. (2018). A bi-objective model of preventive maintenance planning in distributed systems considering vehicle routing problem. *Science Direct*, 360-381.

Spuntrup, F. (2018). Asset fleet management in the process industry - a conceptual model. *IFAC, Volume 51*, 281-286.

Topaloglu, H. and Powell, W. (2007). Sensitivity analysis of a dynamic fleet management model using approximate dynamic programming. *Operations Research* , 319-331.

Turnquist, M. and Jordan, W. (1986). Fleet sizing under production cycles and uncertain travel times. *Transportation Science*, 227- 236.

Wang,Y., Limmer, S., Olhofer, M., Emmerich,M., Back, T., (2019). Vehicle Fleet Maintenance Scheduling Optimization by Multi-objective Evolutionary Algorithms. *2019 IEEE Congress on Evolutionary Computation (CEC)*, 2019, pp. 442-449, doi: 10.1109/CEC.2019.8790142.

Biography

La'Tricha Parks received her BS in Engineering Mathematics from Saint Augustines University and her MS in Industrial and Systems Engineering from North Carolina A&T State University. She is a National Science Foundation National Research Traineeship fellow.

Steve Jiang is an Associate Professor in the Department of Industrial and Systems Engineering at North Carolina A&T State University. His research interests include visual analytics and human systems integration as applied to manufacturing, service and healthcare industries. He is an active member of IIE, HFES and ASEE.

Lauren Davis is a Professor in the Department of Industrial and Systems Engineering at North Carolina A&T State University. Her research interests are in the management of for-profit and not-for profit/humanitarian supply chains with specific focus on performance in environments constrained or uncertain supply, uncertain demand, and disruptions in operations caused by extreme events. She is an active member of IIE and INFORMS.