A Mobile Application for Collecting Task Time Data for Value Stream Mapping of the Final 50 Feet of Urban Goods Delivery Processes

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Delivery options have become very diverse with online shoppers demanding faster delivery options (e.g, 2-day delivery, same day delivery options) and more personalized services. For this reason, transportation planners, retailers, and delivery companies are seeking ways to better understand how best to deliver goods and services in urban areas while minimizing disruption to traffic, parking, and building operations. This includes understanding vertical and horizontal goods movements within urban areas. The goal of this project is to capture the delivery processes within urban buildings in order to minimize these disruptions. This is achieved using a systems approach to understanding the flow of activities and workers as they deliver goods within urban buildings. A mobile application was designed to collect the start and stop times for each task within the delivery process for 31 carriers as they deliver goods within a 62-story office building. The process flow map helped identify bottlenecks and areas for improvements in the final segment of the delivery operations. It also highlighted consistent tasks conducted by all carriers as well as differences with given carrier type. This information is useful to help decision-makers plan appropriately for the design of future cities that encompass a variety of delivery processes.

INTRODUCTION

With ongoing population growth in urban areas and increased popularity of online shopping, demands for goods are rapidly increasing in metropolitan cities. This increase has dramatically affected the delivery times and created new efficiencies that are challenging current transportation infrastructure particularly in larger cities around the world. Inefficiencies in delivery operations began causing negative cascading effects on the city roads, adding tensions and costs to residents, retailers, freight carriers, and city officials. In an effort to understand the delivery operations, many researchers have focused on the studies related to parking and routing problems (horizontal goods movement). However, the fundamental aspects of the urban goods movement consist of the delivery tasks performed by delivery workers such as pick-up and delivery activities within the building (vertical goods movement). The delivery process time spent outside of the vehicle can be much longer than the driving time, accounting for up to 87 % of the entire urban freight delivery process (Allen, et al., 2000, Alvarez & Calle, 2011).

Delivery workers are required to perform various activities such as parking, loading and unloading goods, pick-up and delivery operations, taking freight elevators (Morris, 2009). With a lack of data to examine the overall performance of delivery operations in urban buildings, there has been a scarcity in documentation and analysis of the off-vehicular delivery activities. This final segment of deliveries can be very complex and costly, as much as 28% of a product's total transportation cost (Goodman, 2005) and it is often considered as the most inefficient part of the supply chain (Dablanc, 2007, Kin, 2017).

Although researchers have been addressing the importance of incorporating urban goods movement in urban policies (Dablanc, 2007, Quak, 2008, Lindholm, 2013), it has been challenging to obtain quantitative data of delivery operations inside of the urban buildings due to limitations in technology and data collection methods. This paper introduces systems engineering methods such as value stream mapping (VSM) to examine the delivery process flows in an office building in downtown Seattle.

VSM is an effective tool for identifying system efficiencies and has been used in industries related to manufacturing and health care services (Serrano, et al., 2009, Ries, et al., 2013, Wu, et al., 2012). In the clinical setting, Ries et al. (2013) applied VSM approach to capturing the process flow of children with severe traumatic brain injury (TBI) using a mobile application with a 96% inter-rater reliability. The study indicated that mobile application appears intuitive and reliable to use, even in stressful environments such as Emergency Departments (Ries et al., 2013). Using a mobile device as a data collection tool is also widely accepted in asset management and construction management (Dabi et al., 2016).

Fawcett and Cooper (1998) emphasized the importance of logistics performance measurement with the statement, "if you can't measure it, you can't manage it". Dicksen et al. (2009) suggested that setting up a value stream map (VSM) can provide in-depth insights on the existing process in operations and allow researchers to identify areas for improvements. With a better understanding of delivery operations inside of the building, decision-makers such as transportation planners, building managers, and carriers can enhance the overall quality of service and work performance through the improved operation policies.

Allen et al. (2000) made similar research efforts to identify delivery activities by representing 12 delivery steps performed by a goods vehicle driver when making a delivery. However, the previously introduced delivery steps were very simplified, missing a lot of complexities in urban delivery operations inside a building. Time restricted deliveries such as two hours, one day or two days deliveries are gaining popularity in the industry and they are expected to add more complexity in urban delivery operations.

Because VSM divides the delivery process into micro levels, we can identify non-value added tasks and activities that contribute to long delivery times and failed delivery attempts, two main issues in urban deliveries. Non-value added time is defined as the time associated with any reduction in the quality of delivery service and can include the additional length of stay and higher costs with no commensurate benefit to the customer (Ries et al, 2013). In a delivery setting, non-value added time could involve carriers, receivers, security professionals when goods are being delivered. One example of non-value added time would be the time when a delivery worker talks with a security guard on non-work-related topics for a considerable time. As the entire delivery operations inside the building are fragmented in various activities, extensive monitoring would be required.

One way to overcome this challenge is to develop a mobile application that is highly portable to easily measure the delivery process times. Using mobile devices has become a very popular data collection method for government transportation agencies in both asset and construction management fields to increase efficiency, data richness, and communication (Dabi, 2016). Mobile devices such as cell phones and tablet pcs are lightweight and capable of communicating with a web-based database using Wi-Fi or Cellular data. While using a mobile device for data collection, the data collectors can still interact with carriers and other building staff simultaneously if needed. With easy portability and diversified functionalities of mobile devices, we were able to capture and measure data for the complex delivery operations that occur in the vertical movement. Mobile devices are easily available for government agencies and similar processes and software can be replicated and used for assessing unique urban delivery systems in numerous urban cities.

METHODS

In this study, data was collected from an office building in the Central Business District (CBD) in downtown Seattle using a customized mobile application built to measure the vertical movement of delivery workers. The data measurement processes were focused on the final segment of the delivery process, which is also referred to as the final 50 feet (Urban Freight Lab at the University of Washington, City of Seattle, 2017). A team of four data collectors was assigned to measure the movements and processes of delivery activities from 9 AM to 4 PM for five concurrent business days (Monday – Friday) between January 31 and Feb 4, 2017.

The data collectors gathered time data on delivery activities by following individual delivery workers who entered the building. The data collectors were standing inside the loading bay or street curbs around the building and started collecting data from a commercial delivery vehicle was parked till the vehicle leaves the building after deliveries.

Value Stream Mapping Application

This data collection application was specifically developed to capture timestamps of each task that individual delivery workers are performing during their delivery processes. The application included 5 major task categories that were broken down into colors. The major tasks that occurred within each category were then broken down into task buttons with different color codes to make it simple to follow:

- Pink: Activities involved with vehicle operation (e.g. parking, driving away, open/close cargo compartment
- Gray: Repeated activities throughout the delivery process (e.g. walking, talking, calling, organizing goods)
- Green: Loading /unloading goods
- Yellow: Activities involved waiting and taking elevator, escalator, stairs
- Navy: Activities involved delivering goods (e.g. Looking for receivers, receiver signs for goods, drop off goods, scanning goods)

To collect time-stamps the start of a task, the data collector simply presses on the task button. The application records the immediate time of tapping and calculates the duration of each task. The displayed buttons have the name of pre-identified tasks. In addition, data collectors can generate new task buttons by typing the names on the input area located at the bottom of the application if the performed action was not previously defined. The application allows very accurate collection of various tasks and durations. The data collector also captured and recorded the frequencies of failed delivery attempts in the 'notes' section by typing the texts and numbers.

To ensure accurate data collection, the application automatically saves information that the data collector enters on the application to the web-based database in real-time. In case of low-network connection or no Wi-Fi, the information can also be stored offline on the mobile device that can then be uploaded to the web-based database when an internet connection is restored. This information can be transferred to the database at a later time by pressing 'Export' button when there is a stable network. The list of collected data includes:

- Name of building
- Name of the data collector
- Name of delivery company
- Types of delivery truck
- Types of goods being delivered
- Number of delivery workers
- Timestamp
- Pictures
- Frequencies of failed deliveries and additional notes

The user interface of the data collection application is shown in Fig 2. The application was developed by using Swift programming language in iOS, an operating system used for mobile devices manufactured by Apple Inc. Different types of buildings can have slightly different delivery tasks because the delivery processes can be unique to each building depends on a specific building structures and configurations. Therefore, we ensured that predefined task buttons can be easily modifiable and customizable in changing the task names and numbers of buttons for different building types.

Figure 1. The user interface of the mobile application

Data collection process has three basic aspects: 1. timeliness of collecting, processing, and recording data, 2. accuracy and precision of the data collected, and 3. integration of data for efficiently supporting decision-making (Fintsch 2004). By using the mobile application, all three aspects could be improved from the conventional data collection methods. First, time-saving for collecting, processing and recording data could be significant. SQL database can be synchronized into a table format on a report or be shared in MS Excel format which can be used in other analyzing tools such as R or Matlab for further analysis.

Second, accuracy and precision of the data decreased human error that occurs through the manual logging of information with pen and paper. Also, the mobile application allows a data collector to take photos which can be used for quality control of the collected data. Photos can be shared in the presentations and documentation to assist effective communication between data collectors and audiences and readers.

The collected data was later used to create a VSM, which visualizes the detailed components of the delivery process. The VSM of delivery processes in the office building can increase the visibility of logistics process and provide a better understanding of the delivery operations in urban cities. Such information can be shared to gain information on delivery times and activities for similar office buildings in other urban areas. As many customers make purchasing choices based on the quality of services, both carriers and retailers become aware of the importance of improving the

quality of delivery services for the customers. Our VSM approach can, therefore, provide vital performance metrics to make crucial decisions in various companies' policies. (Lapide). The ultimate goal of this approach was to ensure the applicability of VSM in the delivery operations in urban cities using our uniquely designed mobile application.

RESULTS

Standardization

Prior to the start day of data collection, data collectors conducted a pilot test at the selected office building. During this pilot test, they learned how to use the application and became familiar with the application and the unique delivery operations. Also, they learned the characteristics of the building structures such as parking facilities and locations of freight elevators. Based on the pilot test results, the task buttons were created and ordered the process steps.

Reliability

To ensure the reliability of using the mobile application for the generation of VSM, we compared the results from the four data collectors for using the mobile application. The data collectors measured the same length of times for various delivery activities with the application by watching a pre-recorded video of delivery operations. intraclass correlation (ICC) was used to assess the reliability of data collected by the application. 98% intraclass correlation was observed for using the mobile application, indicating the mobile application method showed very low variations in collecting the same time data between the data collectors. This indicates that the mobile application can be understood clearly to different data collectors and improve the method of collecting accurate time data. Questionnaires regarding the intuitions of the mobile applications and general feedbacks from this test assisted shaping the final mobile application. Data collectors showed a preference for using the mobile application as compared to the pen and paper method. The main reasons included the elimination of the need for manual data entries on paper and simplicity of pressing the button to capture all the information automatically.

Value Stream Mapping

The gathered delivery time data on the database could be analyzed and displayed in a VSM, providing valuable insights on urban freight operations. The VSM can play a vital role in the decision-making process for various organizations including government officials, retailers, and carriers. The example of our VSM is shown in Fig 3. Common time-consuming activities include parking in limited loading docks or street curbs, using freight elevators, signing for deliveries by receivers, waiting for access to the buildings. Delays in simple wayfinding could affect the overall flow of a delivery process while they can easily be avoided with better communications between the building managers and the delivery workers. The VSM provides insights on where the

dwell times are occurring and how each building infrastructure are used during the final 50 feet of goods delivery. With a better understanding of the current practices in urban freight system, dwell times and failed deliveries could be minimized.
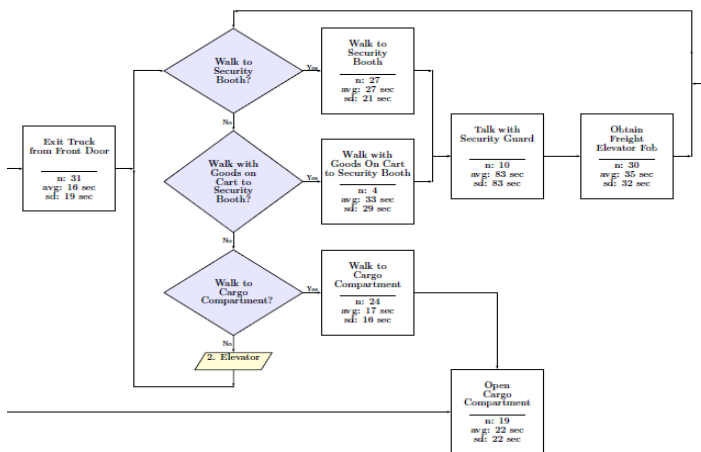

Figure 2. A part of the process flow map for deliveries in an office building

DISCUSSION

The main objective of this study was to develop an appropriate tool for collecting quantitative performance time measures for the final segment of delivery operations. Delivery activities inside of the buildings share similar standardized processes such as loading and unloading goods, pick-up and delivery operations, and taking freight elevators. By creating VSM with time measurements, time spent for each delivery activity could be better understood and also compared among urban buildings. Some delivery activities could be also unique to different buildings based on various delivery policies within the buildings or building conditions. In a way to observe and measure the detailed delivery activities of an office building in downtown Seattle, a mobile application was uniquely designed for data collectors to shadow individual delivery workers within the building. By using this easy-to-use mobile application, data collectors successfully captured times for each delivery task and recorded data in real-time data was used to creating a VSM which provides the overall process flow of urban deliveries.

Quantifying delivery operations by using our systematic VSM approach can provide insights on the current delivery processes in the cities, which can be better accounted for the future urban policies. In carriers' point of view, VSM can provide strategies that they can learn from other delivery companies when the same actions are performed in more effective ways.

Some limitations were associated with the data collection process, as the delivery workers were aware that they were being watched by the data collectors although data collectors minimize any interactions with the delivery workers. In some cases, they rejected data collectors to follow them, resulting in potential selection bias. One approach to resolve this issue would be to use video recorders where the delivery workers may not recognize the fact that they are being monitored.

Another possible approach is to position each data collector to monitor specific activities in different locations such as next to the elevator at the lobby, or at the mailroom, or specific floors until the delivery workers arrive at each location, rather than following one delivery worker throughout the whole delivery process.

FUTURE RESEARCH

The next step of this study is to develop the VSM tool for other types of building types with their unique pre-defined delivery tasks. Categories of the selected buildings include hotel, office, historical, retail, and residential buildings. Sequential flow maps for each building can be created to describe the goods delivery process in highly concentrated urban areas. This will allow us to compare delivery activities in different building types and learn from the differences and implement a best practice solution. With the accurate time for delivery tasks, we can also build simulation models and generate regression models for each building type. We can also conduct a pilot test to improve delivery systems by implementing innovative solutions such as delivery locker systems or consolidation centers in the future. Now that we developed a way to quantify the delivery performances in times measure, we will be able to compare the performance before and after the new delivery operations.

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