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Analysis of the Omnichannel Delivery Network with Application to Last Mile Delivery

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***Abstract*—**Business-to-Customer (B2C) delivery options have improved to meet increased demand in recent years. The change in end users has forced logistics networks to focus on customer service and sentiment that would have previously been the priority of the company or organization of origin. This has led to increased pressure on logistics companies to extend traditional B2B networks into a B2C solution while accommodating additional costs, roadblocks, and customer sentiment; the result has been the creation of the omnichannel delivery network encompassing a number of traditional and modern methods of package delivery. In this paper the many solutions within the omnichannel delivery network are defined and discussed. It can be seen through this analysis that the omnichannel delivery network can be applied to reduce the complexity of package delivery and provide customers with more options. Applied correctly the result is a reduction in cost to the logistics company over time, even with an initial increase in cost to obtain the technology.

***Keywords*—**Network planning, Last Mile Delivery, LMD, omnichannel delivery network, omnichannel logistics.

I. Introduction

CURRENTLY delivery networks can be broken down into two main methods for the movement of goods, known as business-to-business (B2B) and business-to-customer (B2C), each with different logistics requirements. Traditional B2B networks require the movement of large amounts of goods from one location, such as a warehouse, to a limited number of destinations, such as stores and malls. Delivery of these items require larger trucks with limited stops at centralized locations, which limits the complexities in the logistics process and improves cost-effectiveness [1]. An example of a B2B delivery would be a clothing manufacturer shipping goods to a local store and a store within a larger mall. Both deliveries are to a business and require large shipments of the goods from a centralized location.

Recently, B2C delivery options have become more common with same-day and instant delivery projected to encompass 20-25% of the market by 2025 [2]. Driven by ecommerce, B2C delivery options are on the rise and force logistics networks to focus on individual customers rather than companies or businesses. Adding to the complexities, businesses often view logistics companies as extensions of their public image as 74% of customers admit mistakes in package delivery can diminish their opinion of a company [3]. All of this leads to increasing pressure on logistics companies to extend traditional B2B networks into a B2C solution while accommodating additional costs, roadblocks, and customer sentiment. Examples of this can be seen every day as logistics companies increase services from weekdays to daily, provide same-day delivery options within hours, and allow delivery time window choice at no additional cost to the general public.

A major logistics problem for package delivery is known as the Last Mile Delivery (LMD) problem. In various forms this problem has existed since the 1800s, but the general form of this problem is known as the travelling salesman problem (TSP) and was defined in the 1930s. For the TSP one salesman has to visit a certain predetermined number of clients in various locations (network creation) with the goal of minimizing some cost function, often the travel time and/or distance required (route optimization). This results in what is known as an NP-hard problem, meaning optimal results require great computational complexity which increases super-polynomially as the defined network becomes larger [4]. LMD is a variation of the known TSP with additional requirements for network design (which is not covered in the TSP), technology constraints, delivery options, and cost functions depending on the focus of the network and customers receiving the packages. This problem is further defined and explored in the following section.

Between managing end-customer sentiment, business customer expectations, and the complexities of the LMD problem, logistics companies have to be capable of providing numerous delivery options in high-pressure environments to meet expectations. This has resulted in the creation of what has become known as the omnichannel delivery network covering the entire range of delivery options and preferences. Delivery applications, time window preferences, location preferences, security, methods, etc. all have to become available to customers at all levels and be encompassed within the same network [5]. Logistics companies must be capable of integrating these options into their existing network to increase customer sentiment while reducing cost functions in order to succeed with the expectations of today's world.

II. Breakdown of Known Problems

LMD is believed to makeup approximately 53% of total financial shipping cost in today's delivery process [6]. The movement of packages and goods from a centralized warehouse to a final destination is a complex and interesting problem, especially for B2C shipments. Accomplishing this requires a number of steps, which may not be intuitive to the general public. Initially there must exist a network for the purposes of

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package delivery, which can include businesses, homes, centralized drop-off locations, and other various options within the omnichannel delivery network covered in the next section. Then, packages must be received, sorted, and loaded to appropriate vehicles within the warehouse or distribution center. Mechanisms for this process are made more complicated by the fact that vehicles are not loaded at random nor to capacity, rather they are loaded based on stops within their route. Finally, the route, including stops, (or the TSP) is determined based on geographical region, cost minimization, and capacity of the given vehicle; which can lead to a cyclic process between these phases [7]. Further steps can be added to this process through the determination of hubs and stops necessary, which is common in real-world scenarios. For example, in B2C shipments not every home will get a package delivered on a daily basis, so they will not require the same stops making the network dynamic and eternally changing.

All of these intricacies can lead to a convoluted, elaborate system prior to the introduction of additional costs and customer sentiment considerations. The additional mileage required within a logistics fleet to accommodate the increasing number of B2C shipments results in increased financial costs. Agents of this cost include the need to increase the number of vehicles within the fleet to accommodate additional stops and ensure backup vehicles are available, more consistent part replacement due to wear-and-tear, increased breakdown and accident occurrence due to increase in vehicles on the road, and an increase in necessary employees to accommodate these issues [8]. This is prior to considering non-financial costs, such as pollution and congestion on the roads. LMD is currently the most highly polluting segment of the supply chain, without the consideration of the increase in traffic jams and emissions from effected vehicles due to the increase in road congestion [9]. With the supply chain system currently responsible for around 25% of greenhouse gas emissions (the leading cause of climate change), the importance of this as a cost factor should not be ignored. With the forecast that emissions from transportation will increase by 30% in the coming years when compared to previous levels in 1990, emissions are particularly important when considering cost within the supply chain [10].

Additional restrictions that must be accommodated are then added by authorities, both government and local, and customer/ business requirements for individual deliveries. In attempts to decrease on-road congestion, space occupation, and pollution from vehicles many authorities will put restrictions on where and when logistics vehicles are allowed on the road. This can mean logistics companies pay a fee to use certain roads or services (such as parking) or it can mean a ban, ranging from certain time periods within the day to entirely off-limits [11]. Also, not all roads can be accessed by logistics vehicles, a situation that is common in older cities and suburban towns built to accommodate carriages and small cars rather than trucks and larger vehicles.

Finally, the customers and businesses have requirements that can increase the needs on the LMD system. From the customer perspective these needs can range from last minute changes to delivery address and time window to consistent visibility to package status. All potential consumer needs must be accommodated to maintain positive customer sentiment levels, sentiment levels that are a priority for businesses when considering hiring any logistics company [3]. Businesses then have additional requirements of the logistics company, such as electronic verification of package delivery through a signature on a device [12]. Another example of this can be seen in Amazon one-day and instant delivery options, which require a logistics network to collect a package from a warehouse and deliver to a customer home (B2C) within a few hours.

Each of these requirements and restraints on the growing logistics network can result in additional costs and complications with package delivery for both B2B and B2C options. As a result, a number of innovations have been created and implemented within the networks to assist in accommodating these needs while reducing the complexity of the LMD problem where possible. These innovations are encompassed by the omnichannel delivery network, which involves the use of existing logistics networks and current technology.

III. Omnichannel Delivery Network

The omnichannel delivery network encompasses a number of traditional and modern methods of package delivery, usually with a focus on B2C deliveries. Although an omnichannel network for goods will often include technology and methods for ordering the goods, determining shipment type, and other ecommerce applications, these options are outside the current scope of the delivery logistics network. Methods and technology within the omnichannel network for logistics, how they provide solutions, and their associated problems are discussed below.

A. Package Visibility Applications

Today a majority of customers that logistics companies deliver to have access to the Internet through a Smart Phone or similar device. As a result, many companies, including UPS and Amazon, have created applications that can be downloaded by businesses and customers to assist in package visibility and delivery specialization. Through these applications packages can be tracked to show real-time location and expected delivery time window at destination providing full visibility to the network for customers. Some applications even allow customers to see the GPS location of the LMD driver with their package within a certain range of the final delivery point [13]. Additionally, delivery location, time window, and signature requirements can be adjusted to better fit the needs of the customer through a single button on the application. Within the application it is even possible to inform the driver where on the property a customer would prefer the package to be left, such as on the porch or in the garage using the garage key (also provided by the customer through the application) [14].

For businesses and individuals making shipments, these applications are equally useful providing the visibility to package delivery described above and additional benefits. Changes to package requirements and inquiries can be submitted through applications, as well as requested pick-up of

packages. Manifests (documentation containing package tracking numbers and associated delivery points) can be scanned and uploaded for easy submission to the logistics company and payment methods can be applied directly. Both customers and businesses shipping or receiving shipments can provide feedback and submit complaints directly through these applications as well [15]. Unfortunately, while these applications increase package visibility, and likely customer sentiment towards the logistics company as a result, they do not improve LMD problems or reduce cost. It is actually possible that these applications increase cost of LMD as they allow for last minute adjustments to planned package pick-up, requirements, and delivery [15]. However, serving the needs of customer sentiment is important for the future business of the logistics company and must be accommodated.

B. Traditional Home Delivery

A majority of individuals are most familiar with traditional home delivery, which is an available service for every logistics company from government-run USPS to Amazon. To accomplish this method a driver is sent out from a warehouse or hub in a vehicle filled with packages to drive door-to-door and deliver these items. As mentioned in the above section customers can change these delivery locations or provide further instructions on where to leave packages. However, either way the driver must go from one location to the other delivering a small quantity of packages to individual customers at their preferred location [16].

Many costs and problems exist with this method of delivery and are described later in the section on LMD general problems. In addition to the above-described issues, this method of delivery is not as secure as some other methods. Thieves, known as "porch pirates", can steal packages directly from drop-off locations and mailboxes if they are not in a locked area [17]. Requiring a customer signature reduces this risk, but adds to the drivers' responsibilities, increases time spent at each stop, and causes repeated deliveries when a customer is not home to sign. If a customer is not at home to sign for the package a predetermined number of times, the customer will be required to go to another location to pick-up the package causing an inconvenience to them as well [16]. Therefore, a signature is not a feasible solution for all package deliveries.

C. Controlled Access Systems

An example of a controlled access system was mentioned above with the description of a customer providing a garage key code for a delivery driver. Another example would be a package room in an apartment building where only delivery drivers and tenants have the key to access the room. These systems provide the driver with a key or code that controls access to the location where the packages will be delivered until a customer can pick them up. They can be placed in apartment buildings, complexes, and outside (or inside) houses to increase the security of dropping off a package without a signature or required hand-off [18]. While these methods do increase the security of traditional home delivery, they do not resolve the other known issues of LMD. Since these systems can be placed anywhere and be of any size the number of stops and time required at each stop is not decreased, so the cost function remains relatively unchanged for the logistics company. However, they do increase customer satisfaction and trust, which will then likely increase overall customer sentiment.

D. Reception Boxes

Similar to controlled access systems, these reception boxes can be placed anywhere and require a key or code to access. However, these boxes are fixed to a wall outside of a customer's home or residence and can only be accessed by that customer. As a result, customers can choose to receive a text message or other notification when a package is delivered in their reception box and these boxes can even be temperature controlled to protect potential food or medicine that was delivered [7]. Unfortunately, these boxes are subject to similar positive solutions, with increased security since only one customer can access each box, and negative associated problems as controlled access systems.

E. Delivery Boxes

Delivery boxes are once again a similar technology, except instead of belonging to customers these boxes belong to the delivery or logistics company. Pre-filled with packages and goods they are attached to a customer residence through a kind of locking mechanism provided on-site and meeting the specific needs of that box. Once a customer has emptied the box it can be picked up by the logistics company for reuse at a later time [7]. While these boxes increase security, similar to reception boxes, since only one customer has access to the packages, they provide additional complications as well. It is necessary for customers to have the on-site locking mechanism available, which may reduce customer satisfaction if they are responsible for the mechanism and maintenance. Also, the boxes will need to be picked up by the logistics company, potentially adding stops and routes to a system that already has cost and congestion issues described above. These boxes resolve the security issue, but do not change the cost function for logistics companies in a positive way (cost is actually increased) nor increase customer sentiment.

F. Collection Points

Another method of package delivery that is common at this time is the use of a collection point within a reasonable distance of the customer's chosen location. These collection points are often found in stores or shops, such as Staples, the UPS Store, or even the local post office. Customers can then arrange a pick-up time with the collection point to get their package or request a delivery to another location if that service is offered [18]. These points allow for increased package security, as they hold the package until the customer appears to receive it, and a decrease in the number of stops, as delivery drivers can drop-off a large quantity of packages at the point that would have otherwise been delivered to a number of different locations within the region. As a result of the benefits of these collection points the cost function for the logistics company is decreased and security for the customer is improved. However, should a customer choose to request a delivery from the collection point

to a residence the cost of the delivery is simply transferred to another company, reducing the overall benefit. The delivery would then again be subject to the security concerns described above. Also, customers may have to go out of their way to pick-up packages at these points and the hours they can pick-up could be limited, reducing overall customer satisfaction in some cases. While this solution decreases the cost function and provide security for customers, it may not be applicable to all individuals and the positives can be negated in certain situations.

G.Bike Messengers

In response to LMD problems related to climate change, congestion, and restriction by authorities many logistics companies have incorporated the use of bike messengers to delivery packages. These bikes often have a shuttle or attachment on the back where packages are loaded and carried throughout the route. Riders are not subject to the congestion costs and restrictions as traditional vehicles, removing the need to potentially pay fees and limited road access either from legal restrictions or road size. Additionally, there is the benefit that no greenhouse gas is emitted during the delivery process [19]. Unfortunately, this solution does not resolve all of the known LMD problems. There is still the issue of package security once a delivery is made at the destination, so additional technology described above will need to be applied. Also, bike messengers can carry significantly less packages than logistics vehicles, which limits the number of packages that can be delivered through this method. This means logistics companies will have to hire more bike messengers than they would have had to hire vehicle drivers to cover the same region for networks that provide this option.

H.Crowdsourcing and the Gig Economy

Recently an alternative to having employees of a logistics company deliver packages at all has been created known as crowdsourcing and the gig economy. In this model individuals not working directly for the logistics company will pick-up packages at a centralized location. They will then go out and deliver these packages to various customers and receive direct payment from the logistics company for their work on a delivery count basis. Many Americans are already using this system through services, such as Uber and Grubhub, and logistics companies already apply this tactic during peak shipment times, such as the holiday season [19]. Similar to collection points, this once again reduces the cost function for the logistics company while transferring the cost to another entity and does not resolve the security issue described. Security concerns are actually increased since the individual delivering the package has limited affiliation to the logistics company, which raises questions related to quality of service and trust for customers [19]. Depending on how the individual choses to deliver the package, and compensation policy of the logistics company, tolls and fees may or may not be avoided. Once again, crowdsourcing could result in a decrease in cost for the logistics company itself, but only by transferring cost and with the penalty of potentially decreased customer sentiment.

Additionally, there is a moral issue with the gig economy that has been raised recently, especially with the current COVID-19 pandemic. Since these workers are not directly affiliated with the logistics company, they do not receive benefits, such as healthcare, workers compensation, or other protections should an employee get injured or need assistance. Pay is not guaranteed and is provided by work completed, rather than by hour, putting many individuals at a disadvantage. In addition to moral dilemmas, these problems with the gig economy can lead to serious questions about what defines an “employee”, how those employees should be treated by a company, and potential legal penalties for companies that do not treat gig workers according to law in the future [20].

I. Smart Lockers

Smart Lockers or locker banks are a more recent technology similar to a collection point, but with added security and automation capabilities. These lockers will be placed at a central point, such as the main lobby of an apartment complex, center of a gated community, local post office or store, etc., where the logistics company will delivery packages for customers that choose the location. Each package is scanned and placed within one of the lockers individually, at which point the customer will receive a code through a text message or notification which can be used to access that locker. No physical key is required, one cannot even be used for many of these systems, guaranteeing the individual who picked up the package is the customer who received the code [18].

These lockers have many benefits for logistics companies and customers. Reduction in cost is achieved by providing a centralized drop-off location and since locations are often easily accessible for the logistics companies the difficulties associated with local and government restrictions are usually avoided. Also, since a majority of the time they are located at a focal point of the community, customers have easy access to their packages, which are secure, and can pick-up at a convenient time for them since these locations are often available 24/7. Some lockers can even be modular, meaning parts of the locker system can be added or removed as necessary to accommodate available space [21]. Cameras and additional measures can even be added to increase security and safety. However, these lockers do still leave a number of open issues for logistics companies. One example is that not all individuals within a community will want to use these lockers, leading to the need to continue traditional home delivery or receive a decrease in customer satisfaction. Another problem is the location of these smart lockers. As mentioned above they are usually at a focal point of the community, but that is not always the case. Lockers too far from a customer will mean the customer has to go out of their way to receive their package, once again simply transferring the cost from the logistics company to the customer. In fact, when polled on smart lockers customers admitted locating them close to home was more important than any other factor when considering utilization [18]. Therefore, the placement of smart lockers can drastically alter the change in cost function and customer sentiment for the logistics company and must be weighed and calculated accurately for optimal benefits.

J. Autonomous Roaming Smart Lockers

Roaming smart lockers, or locker banks, provide the same technology and capabilities as the smart lockers described above, except they move from location to location throughout a community or region. Often smaller than stationary smart lockers, to improve their ability to be moved, they travel on a schedule and allow for package access through the same methods as described above. These lockers move through an automated process with the goal of decreasing the distance customers must travel to pick-up their packages without increasing drop-off locations [19].

The same positive and negative results can be seen with roaming smart lockers as with stationary smart lockers. One major difference is the reduction in travel distance for customers, since the lockers will autonomously do some of the travelling for them on a given path, without an increase in drop-off locations for the delivery company. This can lead to increased customer satisfaction since the lockers are made more easily accessible. Additionally, there is the reduction in wasted space resulting in better overall space utilization and reduced costs to maintain the associated space. However, there is the added difficulty of timing the locker locations based on customer needs, since a customer that is not within the area at a given time may miss the closest locker location resulting in annoyance and decreased sentiment [19].

K. Drones

Many future technologies are currently being tested for potential application to LMD solutions and one of the main technologies is drones. In many simulations, and in some cases real-world situations, drones have been capable of making package deliveries to outdoor locations. They have been deployed from a central warehouse or from a logistics vehicle to reduce the amount of time drones are required to spend in the air and save battery [22]. Currently, packages are placed outside of a residence or at another outdoor GPS location by drones with success in suburban and rural areas. It is believed that drones will find the best applicability in rural areas for the future of LMD [19].

Drone technologies can provide extreme cost reduction for logistics companies, without a loss in customer sentiment or trust. However, many are still in the process of testing and cannot be deployed at scale with current technology. Issues such as lack of existing infrastructure, battery life, legal restrictions, inability to access indoor locations, and package size and weight restrictions pose a threat to package security and drone applicability to all deliveries. Also, drones have the potential to cause damage if the package is dropped or accidently delivered to the wrong location if the guidance technology is incorrect or the drone is pushed off course. Finally, drones can be affected by natural elements, such as wind and rain, making them difficult to use in many areas of the world [23].

L. Robots and Droids

Similar technology to drones can be applied to the use of robots and droids for package delivery. Usually these are deployed from a logistics vehicle and drop-off packages at surrounding locations, once again delivering outside only at this time. Some tests have shown robots capable of climbing steps and dropping off packages at the front door of a residence. Other droids can hold a package within a compartment and wait for the customer to provide a code to grant access. Either way these robots and droids provide a method of autonomous delivery within a region, most often a suburban area with clear pedestrian access [22]. However, similar to drones, robots and droids have roadblocks for use in today's society. While they are cheaper than drones, often the battery life is even less, their maximum speeds are slow, and testing requirements are higher. These standards are the result of the robots and droids interacting more with people than a drone, since they use known pedestrian paths and if the artificial intelligence fails people could be hurt. Also, not all robots and droids are equipped to handle different roads, steps, etc. and if they fall over, they can be stuck in that position until found by an individual [22]. Despite these difficulties, perfecting these automated steps for delivery of a package plays a role in allowing the use of autonomous vehicles for logistics companies.

M.Autonomous Vehicles

Finally, autonomous (or self-driving) vehicles are likely to play a role in LMD in the near future, in some cases they are actually already being tested and applied today. Many individuals are familiar with this technology through recent innovations in the field from companies such as Uber and Tesla. Benefits of applying this technology would likely be a reduction in accidents and more available time for drivers to organize packages within the vehicle and prepare for the next delivery. At this time the goal of this technology would be to remove some pressure from the driver, allowing for longer drive times where necessary and removing constraints such as human error when driving [22]. In the more distant future, it may even be possible to send out autonomous cars with robots and droids on-board for delivery purposes rather than drivers, but that is not a current application.

Unfortunately, autonomous vehicles are not ready to be deployed at-scale in today's society for a number of reasons. As with robots and droids there are higher regulations for this technology since a mistake in the artificial intelligence could put humans at risk of being injured. Detailed and consistently updated maps are required to assist with navigational systems and decisions that a human might make while driving and liability questions must be answered from a legal perspective before these vehicles can be put on the road in large numbers. Finally, they are costly due to the required technology and require additional maintenance and checks that non-autonomous vehicles do not [22].

IV. Conclusion

In the future LMD solutions will be limited only by the available technology and creativity of innovators. It is even estimated that 80% of future LMDs will be made through the use of autonomous technology. We can see through drones and robotics the potential these technologies bring to a more

connected, eternally evolving world. However, it is necessary to consider a number of factors when creating new technology for LMD. One major factor is the required skill-set for application of this technology [19]. In the example of the drones that use a logistics vehicle as a base a driver would have to be taught to load the drones with packages, ensure the environment is safe for drone delivery, and potentially provide troubleshooting on-site. This skill-set is very different from the current job requirements of a logistics driver.

Additionally, it is necessary to consider individuals with disabilities prior to deployment of any new technology. LMD solutions that exclude a portion of the population by not accommodating handicap accessibility can result in a decrease in customer satisfaction by accidently ostracizing a portion of society. Therefore, it is important to consider all factors, including location and how the technology itself works, prior to deployment [24]. However, it can be seen that through an omnichannel network the LMD problem can be made less complex and provide customers with more options. Even by transferring some of the cost to customers it can result in an overall reduction, with one study showing that once a certain threshold of locations is broken carbon emissions are reduced by dropping off at a centralization location and having customers retrieve their packages [9]. Applied correctly this will result in the reduction of cost to the logistics company over time, even with an initial increase in cost to obtain the technology. Cost can be based on finances, climate change, etc. or even be defined as an increase in customer satisfaction and positive sentiment.

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