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TRENDS, SOLUTIONS AND PRELIMINARY CONCEPT ON VRPTW BASED OPTIMIZATION MODEL FOR THE E-GROCERY DELIVERY

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Abstract: Online grocery shopping (e-grocery) refers to purchasing groceries using a online shopping. E-grocery has received greater attention and increasing demand during this COVID-19 pandemic, particularly in urban areas. The future of e-grocery businesses depends on how successfully e-grocers handle spikes in demand while maintaining quality, price, and delivery promises. Based on literatures, many studies have been conducted to improve e-grocery delivery system. Yet, studies on e-grocery delivery problem in Malaysia are still lacking. This has motivated our study where one of the objectives is to formulate a multi-objective VRPTW based Mixed Integer Linear Programming model for producing optimal strategies for e-grocery deliveries. This paper presents reviews of existing literatures concerning e-grocery, solution approaches to improve e-grocery delivery services and impact of these solutions, which focuses on several designs of the delivery system. This paper provides insights on e-grocery logistics operations and challenges involved. It highlights various potential solutions to e-grocery delivery problem especially those that address sustainable transportation and utilize advanced technologies such as drones and autonomous delivery robots. A preliminary concept of our e-grocery delivery operation is also presented.

Keywords: supply chain, e-grocery delivery, time slots, delivery windows, vehicle routing problem with time windows, mathematical programming model, sustainable transportation

1. Introduction

E-grocery, or online grocery shopping describes groceries which are purchased online and home delivered. Meanwhile, e-grocer refers to supermarket or grocery store offering online platform for groceries shopping with delivery service for accepted orders. Online grocery businesses emerged in 1990s and had a downturn during 2001-2006 due to low profitability resulted from high costs logistics operations and poor trust and acceptance by customers (Seitz, 2013) and rise again from 2007 onward contributed by

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change in customers behaviour and trend towards buying groceries online, enhanced ICT and improved delivery infrastructure (Melis et al., 2016). Explosive growth of e-grocery continues with availability and advancement in communication technologies (Pitts et al., 2018). E-grocery offers time and money savings, convenience and home delivery options for shoppers, and access to various e-grocery retailers (Pan et al., 2017).

COVID-19 pandemic has brought significant changes in e-grocery landscape. In the United States, market share of on e-grocery retailers increased from 3-4% to 10-15% during pandemic (Repko, 2020) while in United Kingdom, number of online grocery shopping consumers doubled (Smithers, 2020). In Indonesia, number of e-grocery customers increased by 20% in the first quarter of 2020 as compared to before pandemic (Asti et al., 2021). Another study in Indonesia by Handayani et al. (2020) highlighted factors responsible for customers' shift towards online shopping that include current pandemic related risks, checking prices, convenience, and delivery options. Survey by Günday et al. (2020) on EU-5 consumers shows 15% respondents changed to e-grocery for first time with 50% among them would choose e-grocery even after pandemic.

E-grocery in Malaysia began in mid-2000 with online grocery stores such as PasarBorong Online, SubangGrocer.com, CGdeMart.com and Citrasspice-mart.com (Md. Zaini et al, 2011). Studies on e-grocery in Malaysia have been customers' behaviour oriented. These studies include by Fauzi et al. (2017) who investigated on factors that influence consumers' intention to purchase grocery online while Tan et al. (2019) utilized Technology Acceptance Model (TAM) to investigate on customer purchase intention on e-grocery in Melaka. In addition, Fong et al. (2020) examine the influence of perceived usefulness and perceived ease of use on consumer's purchase behaviour in online grocery.

Among the most challenging issues in e-grocery services are e-grocery delivery and availability of items. Challenges on customers' side include delivery fee and time, purchasing methods, and return policies whereas on e-grocers' part are order fulfilment, last mile delivery solution, and delivery costs. Majority of the challenges faced were operational (Mkansi et al, 2018). A wide range of research focus on order delivery (transportation) and order inventory (storage). Summary of issues and challenges of e-grocery are presented in Table 1.

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Table 1: Issues and Challenges concerning E-Grocery Services

Authors	Main Focus	E-Grocery Issues & Challenges
Günday et al. (2020)	Pandemic COVID-19 Challenges for retailers and customers' satisfaction of the German e-grocery	• Delivery of groceries (delivery dates, delivery areas) • Products (availability of products in stock, freshness)
Mkansi, et al. (2021)	Investigating whether operating an e-grocery channel by leveraging existing network of stores results in superior business position and sustainability.	• Order fulfilment • Logistics last mile delivery solution • Products handling requirements • Same day, faster, on-time delivery • Transportation costs • Delivery windows / time slots • Proper delivery vehicles
Van Droogenbroeck & Van Hove (2021)	Testing a theory for determining the e-grocery's sustainability.	• Determining optimal delivery and optimal routes • Delivery cost, options, and time window • Return policies and operating on scales
Grashuis et al. (2020)	Study on e-grocery preferences under various scenarios of the COVID-19	• delivery time windows and charges • minimum order requirements • purchasing methods (in-store pick-up, out-store pick-up or home delivery)

Our study explores various e-grocery logistics options to develop the best execute e-grocery delivery system from logistical standpoint that delivers green transportations, optimal routes for e-grocery deliveries and assure profitability to e-grocers while producing practical solutions which lead to economical grocery delivery fees for customers. This paper presents our investigation on past studies to provide insights on e-grocery logistics and delivery operations. Approaches and solutions to e-grocery delivery problem are discussed including those on sustainable transportation and utilizing advanced technologies such as drones and autonomous delivery robots (ADVs). We propose a preliminary concept of e-grocery delivery based on vehicle routing problem. The remaining of the paper is organized as follows: 2. Methods of E-Grocery Delivery, 3. Preliminary Concept of VRPTW based Optimization Model, and 4. Conclusion.

2. Methods of the E-Grocery Delivery

As mentioned in Table 1, order fulfilment is one of the challenges in e-grocery. Von Viebahn et al, (2020) introduced a taxonomy-based concept to classify and structure e-grocery fulfillment and support retailers in choosing and refining profitable e-grocery

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fulfillment. The results serve as useful basis for e-grocery business and innovative e-grocery order fulfillment methods. Meanwhile, Mangiaracina et al, (2019) concentrated on innovative solutions for last-mile delivery efficiency. The study indicates there are several main factors that affect cost of deliveries. First, failure to deliver, second, the density of customers in delivery regions and third, the process's level of automation. As described in Lodni et al. (2021), grocery deliveries can be classified into four categories. First category is related to home delivery for ordered groceries where groceries are gathered at the point-of-sale (POS), i.e., grocery store or supermarket. For second category, it is still home delivery and delivery day but groceries were compiled at distribution centre (DC). The third one involves groceries compiled at POS, not delivered to home, but rather customers retrieve groceries from certain pick-up points. Meanwhile, fourth category refers to groceries gathered at DC and customers pick up groceries from pick-up points.

The study by Liu et al, (2021) focuses on design of sustainable urban e-grocery distribution network. The study proposes a multi-objective optimization model to capture cost components' characteristics and environmental effect with the aim of establishing location of facilities that optimizes quantity of parcels delivered to two tiers and determine optimal routes at each tier, and also minimizes cost associated to carbon emissions. The study develops a hybrid multi-objective meta-heuristic algorithm called hybrid immune algorithm (HIA). Results indicate HIA can solve the multi-objective two-echelon location routing problem and the model and algorithm can be applied using real-life data.

Yowtak et al, (2020) proposed multiple grocery delivery service models involving unmanned aerial vehicles (UAVs), internal combustion engine vehicles (ICEVs) and battery electric vehicles (BEVs) for grocery delivery. Based on results, while UAVs contribute less environmental effects as compared to ICEVs, high-payload UAVs are not yet an economically-feasible alternative to long-range BEVs in grocery delivery based on capital and fuel costs. Meanwhile, Crişan and Nechita (2019) solve e-grocery delivery by proposing a new greedy heuristic capable of reducing overall transportation time of the combined truck and drone delivery system, and new cost function that includes drone's flight time, and compares it to existing techniques. Comparison results indicate total time savings for proposed algorithm is significant as study involves real world scenarios that contributes toward future solution. Furthermore, findings of study by Koiwanit (2018)

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indicates drone delivery is one of the most environmental-friendly transportation choices for online shopping system.

This paper highlights the ideas of e-grocery delivery system, presenting comparison of deliveries design and the impact of e-grocery deliveries in general. Reviews of past literature involve three basic stages: i) Stage I: Literature Research Data Collection, where journals' articles on e-grocery delivery and web-based information are collected; ii) Stage II: Literature Analysis, where materials gathered are analyzed; and iii) Stage III: Literature Findings, where certain preliminary concept is put forward as ideas for research activities for our study. The literature review focuses on three categories which are the e-grocery deliveries design, comparison of e-grocery deliveries designs and impact and potential of innovation of e-grocery delivery.

i. E-grocery Delivery Designs

E-grocery involves online ordered groceries delivered to customers using vehicles (lorry, van, car and motorcycle) for delivery service that could be owned by e-grocers or vendor companies. Some e-grocers decide to collaborate with vendor companies in e-groceries deliveries to solve problems of overlapping delivery times and vehicle shortages during periods of high demand and surplus capacity. Nowadays, most e-grocers embark on finding new ways to enhance delivery services by reducing delivery costs and human energy, and promoting green transportation. This attracts the interest of researchers and there are many studies carried out on this topic. For example, Liu et al, (2020) studied on three types of distribution's transport namely, drones, autonomous ground vehicles with lockers and droids or bike couriers, to be selected based on type of area of delivery, for sustainable urban e-grocery distribution. Figure 1 displays multi-modal transport in e-grocery distribution while Figure 2 shows the two-echelon e-grocery delivery network proposed by Liu et al, (2020). Study by Veibahn et al. (2020) concerns with taxonomy structure of e-grocery fulfillment concept as future of e-grocery shopping, investigate on several alternative transports that are eco-friendly and cost-savings. Figure 3 shows the respective taxonomy results on e-grocery fulfillment characteristics of Veibahn et al. (2020).

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minimize GHG and particulates emissions.

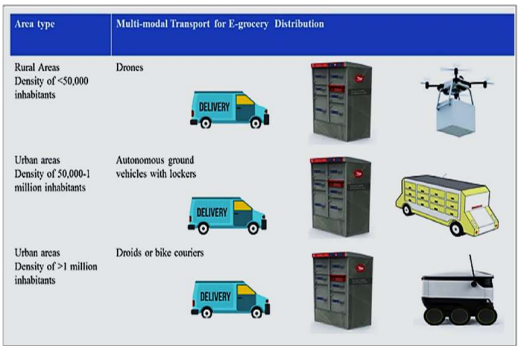

Figure 1: Multi-modal transport in e-grocery delivery network
Source: Liu et al (2020)

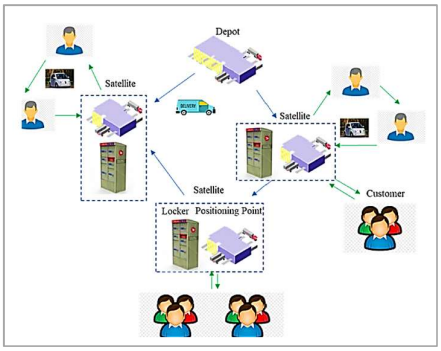

Figure 2: Two-echelon e-grocery delivery network
Source: Liu et al, (2020)

Dimension	Characteristics					
Delivery area	Local	Regional	National	International		
Fulfillment model	Regional DC	Dedicated DC	Store fulfillment	Urban CC	Drop shipping	Hybrid model
Reception type	Delivery box	Pick-up: Integrated	Pick-up: Separate	Dedicated reception box	Shared reception box	Attended reception
Operational model	Uniform	Collaborative				
Demand matching	Accurate forecasting	Supply flexibility	Inventory stockpiling			
Stock point	Retailer	Wholesaler	Manufacturer			
Delivery lead time	Same-day	Next-day	More than two days			
Delivery charges	No additional delivery fees	Additional fees for delivery				
Reattempted delivery	No reattempted delivery	Reattempted delivery without extra charges	Reattempted delivery with extra charges			
Delivery provider	Third-party	Own fleet	Crowd			
Delivery timing	None	Narrow time windows	Wide time windows			
Return procedure	No return but money back	Check return at reception	CEP return	Accept and refund in retail outlets		
Fleet	Gasoline vehicles	Electric vehicles	Others			
Product selection	Integrated selection	Separated selection				
Order threshold	No order threshold	Specific order threshold				
Picking automation	Manual	Semi-automated	Fully automated			
Picking integration	Separated	Integrated	Capacity optimized			
Picking method	Split-case picking	Piece-picking				
Routing procedure	Dynamic	Static				
Routing software	Commercial	Home-grown	Customized			

Figure 3: Taxonomy on e-grocery fulfillment concepts.
Source: Viebahn et al. (2020)

ii. Comparison of E-Grocery Deliveries Design

There are differences between each design of e-grocery delivery, which make results of each type different. Park et al. (2018) compare the environmental impacts between UAVs (i.e., drones) with motorcycles for delivery in urban and rural areas. Figure 5 and Figure 6 illustrate these comparisons. TOTAL software was used to calculate global warming potential (GWP) and amount of particulates generated

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for 1 km of delivery by drone, motorcycle and electric motorcycle. Study found that converting existing motorcycle delivery to drone delivery method is projected to

Meanwhile, Jiang and Ren (2020) present a comparative analysis of drones and riders' deliveries based on prospect theory by evaluating four factors (distance, degree of rider delay, pickup time and consumer attitudes towards drone delivery) and comparing outputs to determine the best delivery method. Benefits of drone deliveries are more obvious for longer delivery distances (more than 7 km) as compared to rider deliveries. Results of this study suggest that drones would be the best alternative to be considered for e-grocery deliveries.

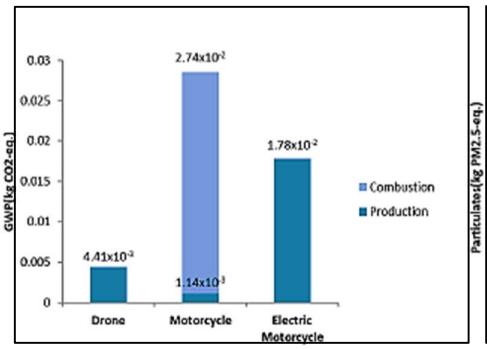

Figure 4: Global warming potential (GWP) produced per 1 km delivery by drone, motorcycle and electric motorcycle

Source: Park et al (2018)

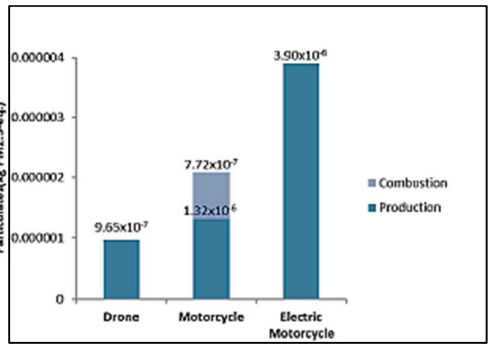

Figure 6: Particulates matter (PM2.5) produced per 1 km delivery by drone, motorcycle and electric motorcycle

Source: Park et al (2018)

iii. The impact and potential of innovation of e-grocery delivery

Many researchers have proposed approaches to solve e-grocery delivery problems. Some studies focused on single objective and while others proposed the multi-objective optimization approaches. Models, algorithms and results of past studies offer useful solution methods for e-grocers and other researchers embarking on related studies. E-grocery demand is continuously increasing and customers' expectations are high. Enhancement in e-grocery delivery services must be carried out to make it more efficient. Based on review of past studies, innovation on e-grocery delivery have started. Aurambout et al. (2019) state that rapid advancements in autonomous UAVs or drones and respective laws may enable their widespread use in last-mile goods delivery. Drone technology is expected to become a mass-market service, reducing the need for face-to-face interaction, which may be useful to control the spread of COVID-19. With no traffic

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to contend with, drones can reduce an otherwise long supply chain into half of the time used. Drones can also reduce global warming effect.

3. Preliminary Concept of VRPTW based Optimization Model

There are many studies concerning e-grocery delivery worldwide including in developing countries. However, studies for e-grocery delivery in Malaysia are limited while using alternative vehicles for delivery is considered new. Thus, our study focuses on the development of mathematical model and algorithm to solve the e-grocery delivery problem in urban areas by means of heterogeneous fleet of vehicles (e-grocers' vehicles and p-hailing services) with alternative vehicles (drones and ADVs) considered. A multi-objective Mixed Integer Linear Programming (MILP) model with four objective functions that address the costs components and environmental aspects for sustainability is proposed. Metaheuristic algorithm will be developed to solve the model. The e-grocery delivery problem applies the concept of two-echelon vehicle routing problem with time windows (2E-VRPTW). The first echelon concerns with delivering e-groceries order from a depot (either POS or DC) to satellite stations using e-grocer's own vehicles (lorry or van). Meanwhile, second echelon deals with grocery delivery from satellite station to customer using car, motorcycle, drone, or ADVs/robot depending on type of areas (single or multi-storey houses, apartments, high density, heavy traffic, etc.).

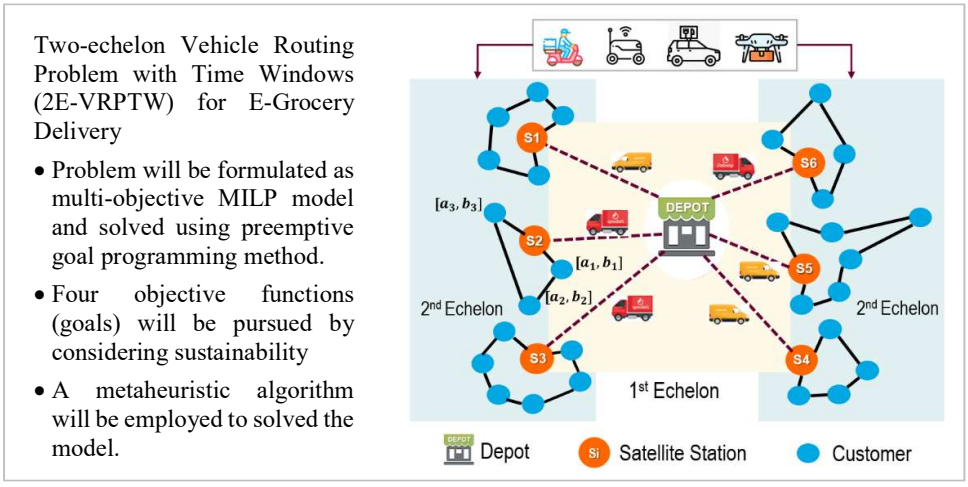

Figure 7: Our proposed preliminary concept of a two-echelon VRPTW based e-grocery delivery system

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Figure 7 display the preliminary concept of our 2E-VRPTW based e-grocery delivery model for a delivery time window or time slot (delivery hours). For each day, normally an e-grocer has between five to ten time slots for grocery deliveries. Since VRPTW is applied, for each delivery time slot, the depot has its scheduling horizon while each customer has its own service time windows.

4. Conclusion

E-grocery demand in urban areas has been rising especially during the COVID-19 pandemic situation. This is a huge opportunity for e-grocery business to flourish provided they can handle the spike in demand while ensuring quality of services, fair price and prompt delivery. However, fast and cost-efficient groceries deliveries are challenging even without considering environmental concerns and sustainability. Innovative solution must be continuously developed to improve e-grocery delivery towards costs savings, and reducing transportation cost, fuel consumption, and CO_2 /GHG emission and other pollution. This paper has presented reviews of related studies discussing challenges in e-grocery delivery, and its different designs and innovations based on technology-driven opportunity. In this paper, we also put forward a preliminary concept of our two- echelon VRPTW approach in solving the e-grocery delivery problem by means of heterogeneous fleet of vehicles and alternative vehicles to overcome related issues and challenges for more efficient e-grocery delivery. Future work includes establishing the road network for the respective e-grocery delivery problem and investigating on feasibility of method when incorporating drones or ADVs.

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