Federated locker system in last mile problem with Big Data

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As the number and percentage of people who live in urban areas grow, the supply chains that serves them increases in geographical span and complexity, putting current urban infrastructures and established supply chains under stress, leading to increasing attention being placed on the importance of managing the freight transportation system and the integration and reliance on real-time congestion information. Over the past few years, the demand for parcel delivery services has drastically increased due to the growth of E-commerce. According to the "Global B2C E-commerce Report 2015", E-commerce sales have been experienced a consistently high growth rate of from 2010-2015. The growth of E-commerce has been an unstoppable force that has created increasing complexity in many supply chains. Other than the volume of demand, the expectations of customers are maturing, forcing many Third-Party Logistics (3PLs) to improve their delivery capabilities to stay relevant in the market. In response, delivery companies have been expanding their last mile capabilities to attract partnerships with online E-commerce stores. One such delivery option is the use of self-collection parcel lockers. Self-collection lockers has been a trend that is increasing popular in many countries. Many literatures have studied and analysed its benefits as compared to traditional home deliveries by claiming that this service could reduce transport cost through consolidation and removes the constraint of time.

However, selecting the locations for these lockers is crucial as it determines the volume of demand the facility can serve. Being a facility problem, the allocation of self-collection lockers has its own set of unique considerations. Firstly, the area of demand that each locker can cover is limited to the distance that a customer is willing to travel. In Singapore, POPStation lockers by Singpost are placed 2500m away from each other (Singapore Post Limited, 2015). This takes the assumption that the maximum a customer will walk within the radius of the locker is 1250m. Secondly, another characteristic to include would be the presence of competition from existing facilities. Unlike most public facilities in literatures, lockers face intense competition which can affect their utilization. Lastly, the storage capacity of self-collection lockers must be accounted for. Consumers will look for alternate facilities when a locker facility is full.

In Singapore, well established companies such as Singapore Post Limited have set up global networks of lockers around Asia. (Singapore Post Limited, 2015). However, despite being a leader in this market, POPStations in various locations have been permanently shut down in the past two years. This renders an analysis on the current environment on locker's in Singapore. The objective of the paper is to present a mathematical approach to determine the optimal locations for p-number of locker. The definition of optimal is the locations which maximises the total consumer's demand captured by that company. The model will take the perspective of a 3PL entering the market in Singapore.

In This paper, we will consider the Maximal Covering Location Problem (MCLP) to solve this particular problem. The problem will be constructed as a Capacitated p-Maximal Coverage Location Problem (p-MCLP) in a competitive environment. There are few literatures that employ a mathematical model to solve a Capacitated p-MCLP with competition. Most mathematical models address the issue of capacity and competition separately and heuristics is employed to address both conditions. Heuristics such as Gravity model has been a popular solution as it can simulate the customers behaviour of searching for the nearest available locker that is not at full capacity. This paper, will be using reallocation constraints in the model to achieve such a customer behaviour rather than heuristics. Using Singapore as an example, this paper will aim to construct a mathematical model to determine the competitive optimal allocation of lockers.

Another contribution of this paper is the use of public big data. Currently no literature on facility problems covers the area of self-collection lockers based on public data. This model is solved based on real public data, such as residence population, train station volume and realistic route distance by Google. For example, we consider real distance rather than Euclidean distance in the literature. A total of 37807 real distances were obtained between shopping centres and residential clusters and 16680 between the shopping centres and train stations. The same code was used for the competitor POPStations which was a total of 37264 distances between the POPStations and residential clusters and 16440 between the POPStation and MRT stations. This data driven approach will encourage future extension to such an application.

In this paper, 3 models (un-capacitated, capacitated, capacitated with competition) are proposed and results from them are further analysed. In addition, various sensitivity analysis are conducted to explore the effect of different parameters in the model. We also conduct the analysis between heuristics Huff's gravity model and mathematical models. Furthermore, to make this work valid and results presentable, we conduct another dimension vehicle routing problem together with the network location problem in order to achieve the integrated system optimality. The test data is from company's real customer record, the comparison is presented between current cost and those with locker systems by using Google real traveling distance. The results show the benefits of the locker system to the whole society. Furthermore, we study the possibility to share all different source lockers to optimize the capability of the "Federate locker systems" to avoid over-setup problem and to achieve maximal utilization of all source lockers.

While this study is specific to the application of self-collection locker networks, the model can be applied to other applications that have similar characteristics.