

An integrated system for synchronized urban logistics

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Abstract

We propose a conceptual integrated system that brings all stakeholders of urban logistics on a single platform, where information, material and cash flows are synchronized to attain sustainable logistics operations. Case of precinct retail logistics is used to validate this concept.

Keywords: Last mile logistics, retail flow management, integrated modeling framework

Introduction

Service industry, especially retail sector, is facing challenges of higher level of fragmentation in the last mile of logistics. For any reason this might be true, the real challenge is to synchronize the logistics operations from its origin, i.e. supplier, till destination- retail shop. The logistics synchronization in this case is a multi-stakeholder venture, which require specialized tool to tackle the problem in all its segments. The concept of Retail Precinct Management is designed and developed to syndicate efforts of various capabilities. This also serves a single platform that integrates all the stakeholders of last mile logistics. With RPM concept, the origin-destination synchronization is anticipated to achieve higher utilization of resources, minimize externalities, and thus embattled sustainability.

In this paper, we introduce the concept of Retail Precinct Management (RPM) system and various modules comprised in RPM system. Some of the modules constitute the core of RPM system, which is active throughout the last mile logistics operation. The other modules of the RPM are, although important, play a supporting role in the system. The supporting modules are passive in most of the logistics operations. The paper also displays the integration of these modules together to form a coherent system that is apt for synchronized logistics operations. A case of

considering a few modules is considered in this paper that serves as a proof of concept (POC) for RPM. This case can be extended to a generic case, including more modules together following the framework presented.

The Origin-Destination synchronization commences with orders placed by the retailers and terminates with parcels of goods being delivered to their respective locations. Figure 1 shows the system architecture of last mile logistics operation from the supplier cluster (manufacturing hub) (origin) to retailer cluster (destination). In between these two nodes of last-mile logistics, there are multiple layers of operations. Figure 2 shows the typical series of operations from supplier to retailer chain. In Figure 2, the central general topology of logistics with the timelines for above and detailed activities at the bottom. During this process of transferring goods from supplier to retailer end, various modules of RPM methodology interact with each other. Each module will have their individual inputs and also inputs from other module interacting.

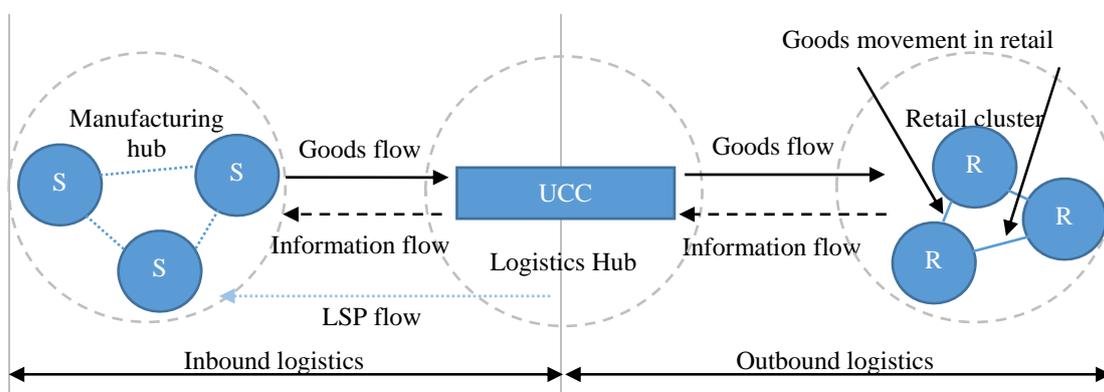


Figure 1- Architecture of last mile logistics

Step #1 – Supplier-Retailer pooling: To consolidate the demand, the suppliers and retailers are pooled based on the; delivery schedule, homogeneity of products, order splitting, quantity ordered, etc. strategies of the distributed order management. This step can be further divided into two groups; supplier pooling; and retailer pooling.

Step #2 – Consolidation and negotiation: Orders are consolidated to match the delivery schedules of the retailers as well as at the supplier end to make sure the full truck load utilization. This requires negotiation based incentive analysis for stakeholders. For example, in a consolidation situation, LSPs' incentives will be a reduced number of trips, and thus the transportation cost.

Step #3 – Vehicle routing problem (inbound) solving: Once the group of suppliers and retailers are identified according to their consolidated orders, the optimal route will be determined for the LSPs.

Step #4 – Auction mechanism for UCC dock allocation: The urban consolidation center (UCC) is a stand-alone facility located at the fringe of the center business district (CBD). The UCC facility has storage capacity constraints. To utilize the capacity efficiently, auctioning is conducted to allocate the loading and unloading dock space of the UCC to the LSPs. Each LSP will bid for the various time slots they wish to use the docks. The bid profile for the auctioning process will consist; willingness to pay, and desired time slot. Auctioning will be conducted for the inbound as well as outbound logistics of the UCC.

Step #5 – Milk-run optimization (outbound): The outbound logistics operation after the UCC is typically managed to milk-run optimization process. Other ways to manage the outbound logistics operations are VRP, underground goods mover system, or railed guided vehicles (RGVs).

Step #6 – Retail cluster goods movements: For the movements of goods in a shopping mall cluster, it is required to define the routes for intra-cluster goods movements. The goods movements can be automated or using the LSP syncing with the delivery schedule.

Step #7 – In-facility distribution: The goods stationed at the loading and unloading bays of a shopping mall need to reach to respective retail shop. The vertical goods movement also needs to be aligned with the available workforce for various activities inside a shopping mall.

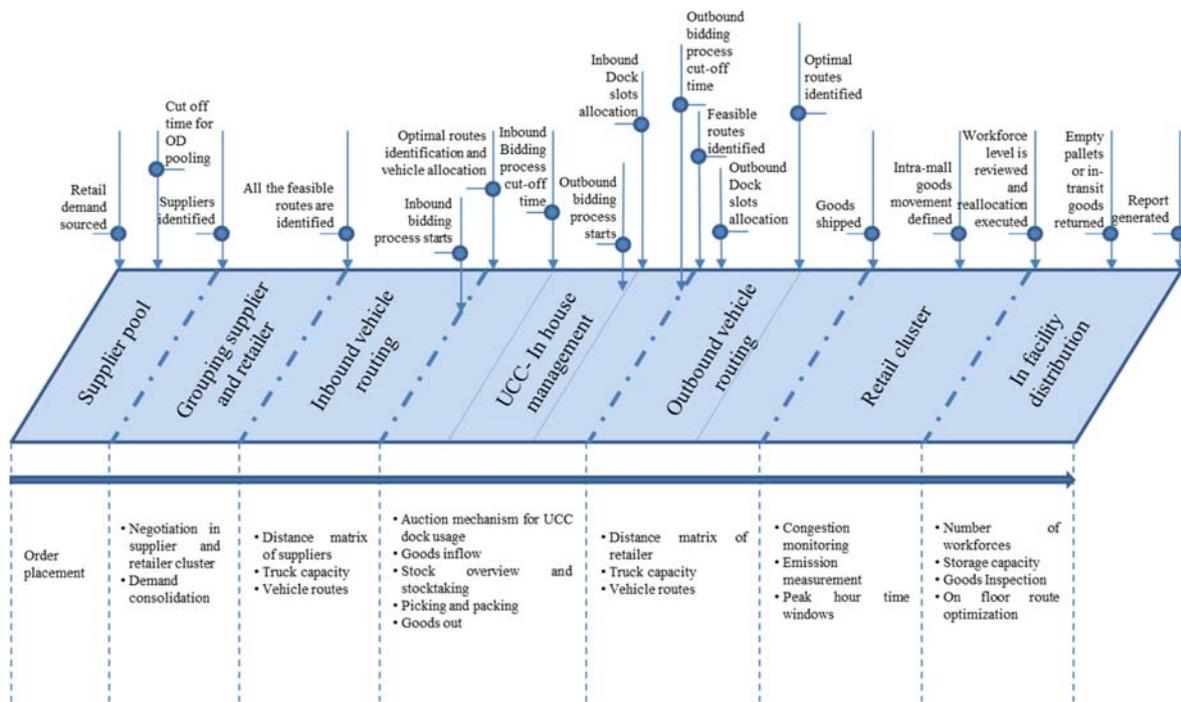


Figure 2- Chain of operations in last mile logistics with timelines

Literature review

Urban logistics play an essential role in urban management systems, which is responsible for fulfilling the needs of people on one hand, and implicitly provides the economic growth of cities on the other hand (Behrends et al., 2008; Qureshi et al., 2009). Generally, urban logistics involve all activities concerning the movement of freight and items from one location to another. Such activities might cover strategic, tactical, and operational levels, including resource design and planning, facility location and management, inventory and storage control, warehousing, fleet and labor management, loading and unloading, packaging, routing, information transaction, and customer service. Note that urban logistics comprises not only forward logistics of final goods, but also reverse logistics of recycled materials and waste (Cardoso et al., 2013; Crainic et al., 2012; Dablanc, 2007).

Due to an occurrence of new types of business, e.g. e-commerce and online-shop, and changes in consuming pattern of people, e.g. home delivery consumer, these all require very large amount of logistics activities, and it results eventually in a significant growth of urban logistics. However, various problems (in economic, environmental, and social perspectives), which are associated with such growth of urban logistics, inevitably arise. Problems of road congestion,

traffic safety, and environmental emissions are pretty much concerned by residents and administrators (Dekker et al., 2012; Klundert and Otten, 2011; Mesa-Arango and Ukkusuri, 2013), while maximizing level of services at lower costs against massive logistics demand is a particular concern of shippers and carriers (Calvete et al., 2007; Tas et al., 2013).

To cope with the aforementioned problems, the concept of city logistics has been launched (Crainic et al., 2009; Taniguchi and Thompson, 2008; Taniguchi et al., 2001; Yamada and Taniguchi, 2005). The city logistics is not a new area of concern for the city planners or developers. There are many projects, such as CIVITAS, 2012; NICHEs, 2012; and SESTUFS, 2010, that analyze and present “best practices” of city logistics. Inability to learn the lesson and right policy measures is one of the reasons for the “failures” for most of these projects (Marsden and Stead, 2011). It is also believed that the reason for not a success is lack of business case for the stakeholders of the urban logistics, e.g. shopping complexes, retailers, suppliers, logistics service providers, etc. One must not forget the most fragmented part of the supply chain or logistics is the last mile and inefficiencies involved in it. One of a few documented successes is Binnenstadsservice.nl in Holland, where the urban consolidation center (UCC) concept is adopted to support the retailers. A success factor for any initiatives could be the involvement of stakeholders (Browne et al., 2007). The major issue with the UCC is the lack of participation from the stakeholders (van Duin et al., 2010).

In this paper, it is realized that to tackle the issues of synchronized logistics, it makes sense to integrate “best practices” of urban logistics. The purpose of such integration is in use capabilities of each methodology to best suit the problem solving related to internalize positive externalities and eliminating the negative externalities. The proposed system, RPM, is a multi-module system incorporating a few modules, which defines the core of the system with a few others supporting the system to form a synchronized logistics system in the urban logistics.

Methodology

The functionality of RPM system is driven by various modules which work on integration. A few modules of RPM system can be defined as the core with other supporting modules. The chain of operations shown in Figure 2 is functioned by three of the RPM modules; Consolidation, VRP modeling, and Auction mechanism. Each of these modules operates according to their designed algorithms. Following is the description of each of these modules.

Module#1: Consolidation- In this module, the consolidation is referred at three levels; supplier level, retailer level and transit level. For the consolidation at the supplier end, the suppliers are grouped together based on the location and proximity to the randomly chosen centroid. The consolidation at the retailer end is grouping retailers that have; similar delivery schedule, product features, and location. The consolidation at transit is facilitated by a standalone physical location- also known as Urban Consolidation Center (UCC). The UCC is essentially located on the fringe of the urban area or central business district (CBD). Having a physical consolidation in the transit of last mile logistics will lead to distribute the traffic load on in-bound and out-bound logistics. The in-bound logistics may still be operated in the traditional way- using commercial vehicle that contributes more to the externalities. The outbound logistics are operated by non-conventional means- e.g. using an electric delivery vehicle that contributes minimum to the externalities. The consolidation is the first module among others after the orders are placed by the retailers. The output of the module is “list of pick up points” and will be used as an input in next module- VRP algorithm.

Module#2: VRP modeling- In VRP module, the list of pick up points is taken as a basic solution (or worst case solution) to generate the optimal routes considering the constraints on vehicle capacities and number of vehicle and distance matrix as an external input. The optimal routes are derived by using the heuristic algorithm for VRP modeling. Before solving the routing optimization problem, each LSPs need to specify their capacity in order to get the pool of LSP capacity. Given the capacity and distance matrix, the objective of the VRP algorithm is to minimize the transportation cost of the delivery (till UCC for in-bound and till retailer for out-bound). The output of the VRP algorithm is; Total Time required for Completing (TTC) a route, Vehicle truck load. The TTC is a guideline for the auction mechanism to allocate the loading/unloading docks to the LSPs. For example, if an LSP is expected to complete its in-bound route by 06:00 pm, then the probable slot to be allocated to this LSP is 06:00-06:30 pm. These outputs are keyed in to the next module, Auction Mechanism, where capacitated loading and unloading docks are allocated based on the First-Priced Seal Bid Auction mechanism.

Module#3: Auction mechanism- The auction mechanism is essentially used to allocate the limited loading and unloading docks slots at the UCC. In this auction mechanism, the auctioneer is the UCC Operator, and bidders are Logistics service providers (LSPs). The LSP will bid according to their willingness to pay (or valuation) to use the dock for preferred time window. In order to get the preference order from LSP, they are asked to bid for three different time slots at least; e.g. \$1 for T1-09:00-09:30, \$1.2 for T2- 10:00-10:30, \$0.5 for T3-15:00-15:30. As before, we solve the auction allocation, the system knows the TTC, the LSPs are suggesting the bid for winning the slots aligning the in-bound route completion time- this bid is known as suggested bid. The suggested bid is also useful to divert the traffic inflow to the UCC. Given the information keyed in for the auction mechanism; time slot available at UCC facility, bids from the LSP for respective time slots, TTC from the VRP algorithm, the docks time slots are allocated to the LSPs by following first price auction mechanism. In first price auction mechanism, the dock time slot is assigned to the LSP who bids the maximum. The output of the auction mechanism is the schedule of LSPs to visit the UCC facility with time slot assignment. Although, the first price auction is promising, multi-phase auction mechanism may work efficiently for maximizing auctioneer's profit.

Following are some of the modules, which are vital to support the RPM functionality. These modules act passively to the RPM system:

System Dynamics (SD) is the module, where 'what-if' scenarios are developed to understand the system at the macro and micro level (Panchal G.B., 2014; Panchal G.B., 2014a). This methodology is suited to those problems associated with continuous processes, where feedback significantly affects the system behavior by producing dynamic changes in the system. SD modeling is a well-developed systematic tool often used to describe system behaviors with feedback loops for accurate projections. The modeling process consists of a series of operations by means of which, and after adequate analysis and study, the model that represents the problematic reality is built. In RPM system, the SD modeling plays a role in developing predictive scenarios of monitoring variables in the system. For example, in RPM, using SD model scenarios of congestion level in the area are developed by varying key variable's value without affecting the initial setting of the problem. These key variables become the policy parameters and a combination gives a scenario for the RPM system.

Congestion monitoring is a part of 'data harmonization and analytics', where the externalities are monitored and hand on information is provided to all the stakeholders of the urban ecosystem. This part of the RPM system is vital in order to synchronize the logistics activities

throughout the last mile logistics, i.e. from supplier till the goods reach the destination. In case of congestion, the commercial vehicles are diverted to other non-congested roads of urban infrastructure. For the urban development, the congestion monitoring of RPM will help to analyze the peak and non-peak hours of the day. In countries like Singapore, London and others, the variable road pricing will be based on the identified time-windows. The derived time windows will also result in managing in-house resources efficiently, which may contribute to the in-mall distribution the bottleneck (vertical goods movement) and the bottleneck at the entrance of destination (horizontal goods flow).

Estate-wide Goods Mover System (EGMS) concept is conceived in response to the strategic shift towards better productivity via the increased use of automation and technology. At the same time to enable more land-efficient economic activities through land intensification. The central idea behind the EGMS concept involves a centralized storage facility linked to manufacturing facilities sited within the estate via a goods mover system and leveraging on technologies to enable a fast, accurate and efficient distribution system. In the RPM system, the EGMS can be implemented for a retail cluster with the combination of varied retail shops. The goods are moved seamlessly across the cluster from a centralized consolidation center (UCC) to each of the retail shop- final destination. Also, the last mile logistics operation is executed with specialized vehicle that features lower emission or use eco-friendly vehicles (e.g. electric vehicle). The successful implementation of EGMS will enhance productivity for the logistics operations while mitigating the constraints that inhibits sustainability in urban logistics.

The Integrated Goods Mover System (IGMS) concept is complimentary to the EGMS concept. EGMS involves management of goods within the estate while IGMS covers the external transportation network within the EGMS and other clusters. This is opined to ease the traffic congestions issue via increased goods consolidation and establishing a solid freight network to increase efficiency. Also with IGMS in place, the inter-cluster goods movement becomes feasible to enhance service level-availability of goods to the customers. For example, when a certain type of product is not available at one location, it can be possible to make it available using IGMS. It is believed that with IGMS the inventory level can be optimized efficiently. The IGMS requires the use of AGVs or RGVs for a seamless goods movement.

Among others, there are a few external modules which provide support to the RPM system; in-house management (UCC and loading/unloading dock management) and workforce management. The in-house management is to mainly focus on the layout of the facility with the given retail space guidelines. Normally, the practice is to dedicate retail space in a shopping mall. The in-house management also covers the decision making on dock management, where the decision making on dedicating docks to some specific retailer is taken in order to achieve maximum utilization. The similar decision making needs to be done at the consolidation facility-UCC. The dock assignment to the delivery truck, in-bound or out-bound, is facilitated in the UCC management module. In association with in-house management, the workforce management is a module where the number of workforce is decided which will satisfy the demand of loading and unloading operation till the goods are delivered to respective retail shops.

Integrated framework for the RPM system

To synchronize all the logistics activities of the supplier cluster till retailer cluster, it is required to integrate various modules of RPM system methodologies together. Figure 3 shows the integration of core modules as well as supporting modules. Each module is specialized with

capabilities in synchronizing the logistics operations in their last mile. The output of one module may serve as input for other module(s). To begin with the core of RPM system, in the consolidation module, a pool of suppliers and retailers is created aligning the delivery schedules. To participate in the consolidation, each stakeholder needs incentives, which can be tangible or intangible. Based on the type of incentives, the negotiation terms are set among the stakeholders. These negotiation terms serve as one of the inputs for this module. The output of the consolidation is; 1) supplier pool, 2) consolidated demand, 3) location of suppliers. After the orders are consolidated, the information about the number of vehicles with the respective capacity required will be available in the next module. The supplier pool in the consolidation module is the basic solution (or worst case scenario) for the next module- VRP. Next in the VRP module, taking inputs from the consolidation module, the number of vehicles with vehicle capacity as well as additional inputs, such as a distance vector between suppliers and the UCC (or matrix in case of multiple UCCs), is used to solve the vehicle routing problem (VRP) to find; 1) optimal routes, 2) maximum duration to complete routes, 3) vehicle allocation.

The UCC facility comes with capacity constrained space, which will have to be allocated to the users- LSPs. The loading/unloading docks of the UCC will be auctioned and bids are asked from the LSPs for various time slots. Along with these, it is also required to know the number of phases the auction mechanism will be running and also which mechanism to follow; first price or second price sealed (or unsealed) mechanism. The output from the auction mechanism is; 1) allocation of dock, 2) LSPs' schedule to use the loading/unloading docks of the UCC. The same auction mechanism is used to allocate the loading/unloading docks of the shopping mall. Next, the in-house (UCC) management takes input as; 1) space allocation to LSP from auction mechanism, 2) schedule of the LSPs to visit loading and unloading dock. The complete orders from inbound logistics are segregated in the UCC to define the schedule for the outbound logistics. The output of the UCC management is; 1) delivering orders or the order to fulfill from the UCC to the retail shops, 2) the schedule for the use the outbound dock for the delivery LSPs. The outbound logistics schedules are aligned with the delivery schedules at the retailer cluster.

The service level- availability of goods at the retail shops can be achieved by integrating goods flow throughout the network. The shops will then become a shared warehouse, which may not require addition cost. The goods flow in the network also useful in the view of reverse supply chain (return of goods). The inter-cluster goods movement module to handle this part of logistics needs truck load share of each retail shop and distance matrix of retail cluster. The output of routing problem in inter-cluster goods movement is; 1) optimal routes, 2) time to complete the route, 3) space allocated in the vehicle. Once the goods are segregated at the UCC, the last mile of the logistics needs to be executed by good mover system. As a part of outbound logistics (from UCC to retailer cluster), the Estate-wise Goods Mover System (EGMS) needs a number of AGVs with their capacities. The output from this module is; 1) schedule of AGVs and 2) optimal routes across the retail cluster. With the use of automation for the outbound logistics, it is anticipated that the externalities will be reduced in this leg of the logistics. However, to ascertain minimum externalities, the congestion monitoring system needs to be in place. Along with the output from the goods mover system, this module needs guidelines to maintain minimum externalities (CO₂, NO₂, etc.).

The status-quo of the congestion monitoring is fed to the system dynamics (SD) modeling. In SD modeling, with the system setting unchanged, several scenarios are developed. The SD modeling is required to make the predictive analysis about the externalities through the micro and macro level adjustments in the system. For example, the micro-level adjustments are; 1) review

the workforce allocation, 2) revise the combination of the workforce. For the macro-level adjustment, input such as incentives to promote the consolidation and improved negotiation terms will feed into the system to see their effect on the externalities through various modules of RPM system. Along with these adjustments in the system variables, the other input for the SD modeling is the range of the various variables that will serve as a guideline. The output from the SD modeling to in-house management are; 1) number of workforce needed to satisfy the demand, 2) combination of workforce required for some specialized operations in-house.

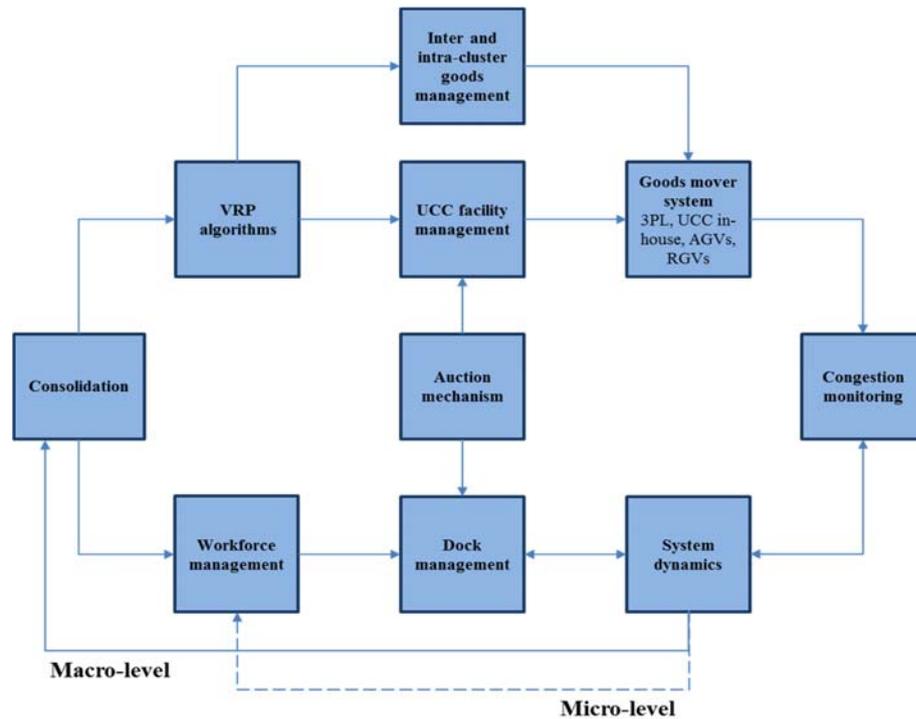


Figure 3- Integration of urban logistics modules

With the revised setting of workforce level and other input from auction mechanism, the docks are maintained with an optimum workforce level to satisfy the demand of loading/unloading operations. Here, other recommendations taken from the system dynamics are in dock configuration needed to satisfy the overall objective of minimum externalities in the precinct. The idea is to utilize the docks to their fullest capacities. The optimum workforce level is maintained to keep the seamless loading/unloading operations. The output of workforce management is to configure the workforce and their role in the last mile delivery. The available workforce is managed and in some cases reviewed to decide proportion of the workforce for each category of activity; such as transfer staff, inspection staff, reviewer staff, PO checker, etc.

Conclusion and future work

The urban logistics is believed to be the most fragmented part of the supply chain. It gets worse with the demand uncertainty and lack of visibility in the demand. Moreover, the customer/consumer behavior is also difficult to assess while managing last of the logistics. To

tackle this problem, it is required to integrate the possible solution approaches intending towards synchronized last mile logistics operations. In this paper, we have proposed one such integrated approach with the objectives; to minimize externalities, improve truck load utilization, utilize workforces efficiently, and improve capacity utilization. This integration is hypothesized to work well for most of the urban logistics related issues- spatial constraints, scarcity of land, limited resources, high and uncertain demand. Moreover, all the stakeholders are likely to internalize positive externalities. The scenario analysis of RPM system is helpful in drawing some of the predictions about the externalities and also the policies to counter those. In the future, the RPM system capability can be extended to system learning using some of the innovative approaches- big data, machine learning etc. Using these approaches, the system would provide the recommendations to manage the last mile logistics efficiently.

Acknowledgement: This work is supported by the Science and Engineering Research Council of the Agency for Science, Technology and Research Grant #1224200003.

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