# PREMIUM E-GROCERY: EXPLORING VALUE IN LOGISTICS INTEGRATED SERVICE SOLUTIONS[1]

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***Abstract*** *— E-grocery is gradually becoming viable or a necessity for many families. Yet, most e-supermarkets are seen as providers of low value "staple" and bulky goods mainly. While each store has a large number of SKU available, these products are mainly necessity goods with low marginal value for hedonistic consumption. A need to acquire diverse products (e.g., organic), premium priced products (e.g., wine) for special occasions (e.g., anniversary, birthday), or products just for health related reasons (e.g., allergies, diabetes) are yet to be served via one-stop e-tailers. In this paper, we design a mathematical model that takes into account consumers' geo-demographics and multi-product sourcing capacity for creating critical mass and profit. Our mathematical model is a variant of Capacitated Vehicle Routing Problem with Time Windows (CVRPTW), which we extend by adding intermediate locations for trucks to meet and exchange goods. We illustrate our model for the city of Istanbul using GIS maps, and discuss its various extensions as well as managerial implications.*

*Keywords — Dynamic consumer-led demand, e-grocery, logistics, premium goods*

## INTRODUCTION

Little is known about the development of e-grocery delivery in the context of emerging market geodemographic conditions. And yet, there has been a marked acceleration both in scope and scale in the use of e-grocery [11]. Recent studies in Turkey show that along with e-grocery, e-shopping in general doubles every year and e-retailing has increased to 200 million dollars in 2006 from 9 million dollars in 2000 [1] [6]. Equally significant, the scope of the type of products and services sold online by the major retailers transcend various markets including, grocery, white goods, and many other services. As the scale and scope of e-grocery technologies develop and change, it is easy to overlook the fact that new technologies can stretch visions, resources and capabilities to a point where stakeholders need to re-think, in situ, what further advantages the local condition have to offer. As explained in [14], firms may compete for jurisdictional control by constructing barriers to entry and forging monopolistic and oligopolistic advantage in a particular technology or geographical market. Despite the growing presence of e-grocery delivery facilities, there has been limited examination of the ways for last mile logistic actors to add value, gain influence and shape the delivery chain.

In this paper we present an overview of the corollary of changes underpinning the e-grocery delivery chain in an emerging market metropolis' context. The specific objectives are to: (i) investigate the role of advanced logistics in enabling further value added through extra services and more efficient use of the geographical context; and (ii) develop an outline for our mathematical model which is a variant of Capacitated Vehicle Routing Problem with Time Windows (CVRPTW) extended by adding consolidation locations. The paper is therefore still embryonic, with much work to be done on measurement, and empirical methods.

## BACKGROUND

The increasing popularity of e-shopping has led to a growing number of delivery vehicles in residential areas and the realization by users that many more services and goods are now available for delivery [15]. As home delivery increases so does (a) the number of failed deliveries and (b) the cost of using multiple independent providers [5] [9]. Recently, collection and delivery points (CDPs) have emerged as a solution [1] [7] [8]. CDPs can be unattended in the form of locker points/shared reception boxes or attended in service locations such as shop in shops, petrol stations, post offices, community centers, tobacconists, bus and underground stations and schools [12] [13]. This method, while heralded for its cost saving (mileage, environmental, time, capacity utilization) and possibility of link shopping, is still not making use of the local geography and it requires a

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specific trip by customers to collect their belongings [16]. Seeking to further develop flexibility in e-grocery delivery, while adding further services, our model exploits this reality in Istanbul's new emerging landscape.

The socio-geographical distribution of consumers in Istanbul reflects patterns found in most emerging metropolises. Therefore, our model should find applications in many countries where e-retailers tend to invest. Beyond the fact that prime catchment individuals (e.g. time poor-cash rich) in Istanbul tend to live in concentrated areas, in dwellings that have the potential to give a competitive advantage to e-retailers, and e-grocers in particular. The majority of dwellings in Istanbul are formed with three different types of accommodation: 1) individual homes or apartments without any security or common/shared services, located in the old city center; tending to be older buildings in small streets with little parking opportunities, 2) small complexes of 25-30 dwellings with security, and 3) large complexes with 200+ dwellings. Type 1 represents a classic case for the CDP concept, while types 2 and 3 show potential for our model. For types 2 and 3, other opportunities include: a) most of the inhabitants being recently relocated and often lacking retail experience in the immediate neighborhood where the retailing structure is often poor; b) IT infrastructure being provided to some dwellings with instant access to e-retailers, c) drop-off and storage areas being present as part of the security services, and d) the possibility for socio-demographic and life style segmentation.

In addition, to match the requirements of modern lifestyle, our proposed framework includes the extra difficulty of delivering premium or variety goods (e.g. organic fresh vegetables, fish, and special occasion products) that are not typically available from the e-retailer's catalog and must be pulled from elsewhere in the supply network. The logistics aspect of our approach addresses exactly this: design and execution of a network system where goods are acquired from (possibly different) vendors at multiple locations in the supply network and delivered to each customer. This dimension of last-mile delivery is in fact lacking in many previous studies in the literature where standard versions and extensions of the vehicle routing problem (VRP) are studied (see [3] [4] for surveys on VRP and [2] [10] for more recent related studies). Our work extends these studies by bringing into the overall picture premium source locations, consolidation points for transfering goods between vehicles, and the possibility of multiple store sourcing for any given order, and it attempts to explore any potential value that may be realized as a result.

## MODEL

The general setting in our model is that two sets of vehicles operate, one originating at the store from which standard e-delivery products are assembled and shipped, and the other originating at a depot location, visiting premium source locations for customers who have premium products in their e-basket. We further assume that consolidation points are activated whenever premium products are ordered, and each customer is associated with a single consolidation point from which all premium products are picked up before final delivery.

The following notation is used in our model:

| | |
|---|---|
| $I, I^p$ | : set of all customers and set of customers that require premium products, $i \in I$, $I^p \subseteq I$ |
| $L$ | : set of all consolidation points, $l \in L$ |
| $S^o, S^d$ | : set of route origin and destination locations (store + premium source depot) |
| $S$ | : set of all route origin/destination locations, $S = S^o \cup S^d$ |
| $T$ | : set of all premium source locations |
| $K$ | : set of all vehicles |
| $K^s, K^d$ | : disjoint sets of vehicles originating at a store or a depot, respectively, $K^s \subseteq K$ , $K^d \subseteq K$ |
| $c_{ij}^k$ | : per km transportation cost for vehicle $k$ along arc $(i,j)$ |
| $t_{ij}^k$ | : time it takes to traverse arc $(i,j)$ for vehicle $k$ |
| $f_k$ | : fixed cost per run of using vehicle $k$ |
| $h_l$ | : fixed cost per run of using consolidation point $l$ |
| $o_k, d_k$ | : origin and destination location indices from/to which vehicle $k$ operates, $o_k \in S^o, d_k \in S^d$ |
| $J_k$ | : set of locations reachable by vehicle $k$, $J_k = I \cup L$ for $k \in K^s$, $J_k = L \cup T$ for $k \in K^d$ |
| $q_i, q_i'$ | : capacity use of customer $i$'s entire product list and premium-only product list |
| $C_k$ | : capacity of vehicle $k$ |

$n_i$ : number of distinct premium products ordered by customer $i \in I^p$

with the following decision variables:

$x_{ij}^k$ : 1, if vehicle *k* traverses arc (*i*,*j*), $i, j \in I \cup L \cup S \cup T$, 0 otherwise

$y_{il}^k$ : 1, if products of customer *i* to be picked up at consolidation location *l* by vehicle *k*, 0 otherwise

$z_{it}^k$ : 1, if source *t* to be used for servicing some or all products of customer *i* by vehicle *k*, 0 otherwise

$s_i^k$ : arrival time at location $i \in I \cup L \cup S \cup T$ by vehicle $k \in K$

$Q_k$ : 1 if vehicle *k* is used, $k \in K$, 0 otherwise

$R_l$ : 1 if consolidation point *l* is used, $l \in L$, 0 otherwise

The model is then formulated as follows:

$$\min \sum_{(i,j)} \sum_{k} c_{ij}^k x_{ij}^k + \sum_{k} f_k Q_k + \sum_{l} h_l R_l \tag{1}$$

subject to

$$\sum_{j \in J_k} x_{o_k j}^k \le Q_k, \forall k \in K \tag{2}$$

$$\sum_{j \in J_k \cup \{d_k\}} x_{o_k j}^k = 1, \forall k \in K \tag{3}$$

$$\sum_{j \in J_k \cup \{o_k\}} x_{j d_k}^k = 1, \forall k \in K \tag{4}$$

$$\sum_{i} x_{ih}^k = \sum_{j} x_{hj}^k, \forall k \in K, \forall h \in I \cup L \cup T \tag{5}$$

$$\sum_{k \in K^s} \sum_{j \in J_k \cup \{d_k\}} x_{ij}^k = 1, \forall i \in I \tag{6}$$

$$s_i^k + t_{ij} - M(1 - x_{ij}^k) \le s_j^k, \forall i, j \in I \cup L \cup S \cup T, \forall k \in K \tag{7}$$

$$y_{il}^k = 1 \Rightarrow s_l^k \le s_i^k, \forall i \in I^p, \forall l \in L, \forall k \in K^s \tag{8}$$

$$\sum_{k \in K^s} \sum_{l} y_{il}^k = 1, \forall i \in I^p \tag{9}$$

$$\sum_{j \in J_k \cup S^d} x_{lj}^k + \sum_{r \in J_k \cup S^o} x_{rl}^k \ge y_{il}^k, \forall i \in I^p, l \in L, k \in K^s \tag{10}$$

$$\sum_{k \in K} \sum_{j} x_{jl}^k \le R_l, \forall l \in L \tag{11}$$

$$\sum_{k \in K^d} \sum_{t \in T} z_{it}^k = n_i, \forall i \in I^p \tag{12}$$

$$y_{il}^k = 1 \text{ and } z_{it}^{k'} = 1 \Rightarrow s_l^{k'} \le s_l^k, \forall i \in I^p, \forall l \in L, \forall k \in K^s, \forall k' \in K^d \tag{13}$$

$$\sum_{j \in J_k \cup \{d_k\}} x_{tj}^k \ge z_{it}^k, \forall i \in I^p, \forall t \in T, \forall k \in K^d \tag{14}$$

$$\sum_{i \in I} q_i \sum_{j \in J_k \cup \{d_k\}} x_{ij}^k \le C_k, \forall k \in K^s \tag{15}$$

$$\sum_{i \in I^p} q_i' \sum_{t \in T} z_{it}^k \le C_k, \forall k \in K^d \tag{16}$$

$$a_i \le s_i^k \le b_i, \forall i \in I, \forall k \in K^s \tag{17}$$

$$x_{ij}^k \in \{0,1\}, \forall \text{arc}\,(i,j), \forall k \in K \tag{18}$$

$$y_{il}^k, z_{it}^k, Q_k, R_l \in \{0,1\}, \forall i \in I, \forall l \in L, \forall t \in T, \forall k \in K \tag{19}$$

$$s_i^k \ge 0, \forall i \in I, \forall k \in K^s \tag{20}$$

In this formulation, the objective function (1) combines three cost terms: variable cost of transportation, fixed cost of each vehicle, and fixed cost of each consolidation point. Total profit to be made serving the customers in set $I$ is a constant, therefore it is excluded from the objective function. Furthermore, constraints (2) make sure a vehicle $k$ does not traverse an arc if the vehicle is not used, constraints (3)-(5) are vehicle flow balance constraints at each node of the network, constraints (6) ensure that a customer is always visited by one vehicle, constraints (7) properly calculates arrival times of vehicles at each location ($M$ is a large number), constraints (8) are if-type constraints (which have not been linearized for the sake of readability) that make sure premium products for customer $i$ are picked up at consolidation point $l$ by vehicle $k$ before they are delivered to customer $i$, constraints (9) make sure each premium-good-requiring customer is associated with a single consolidation point, constraints (10) make sure a vehicle serving customer $i$ enters consolidation point $l$ if the premium products ordered by customer $i$ are to be picked there, constraints (11) make sure only used consolidation points are visited, constraints (12) ensures correct number of premium source locations are visited for each customer, constraints (13) make sure premium goods are dropped at consolidation points before they can be picked by vehicles en route to customers, constraints (14) ensure that a vehicle enters a premium source location if a customer is associated with that location, constraints (15)-(16) make sure vehicle capacities are not violated, and finally constraints (17) ensure the customer time windows are honored.

To solve this model, we have chosen to use a Tabu Search based heuristic VRP algorithm, which is available as part of the commercial ArcGIS 9.3 geographic information system platform and its Network Analyst extension. We use this algorithm in the next section where we solve two instances of the CVRPTW.

## AN ILLUSTRATIVE EXAMPLE

To illustrate the main concept we explore in this paper, we present an example for the city of Istanbul. We pose two scenarios: one where an e-delivery company delivers grocery products to several locations in Istanbul, and another where an extended fleet is utilized to collect high-premium goods from multiple source locations, which are then transferred to the store-originating vehicles with the final destination as customer locations. We show the potential profit increase, despite the increase in logistics costs.

The study area covers part of the asian side of Istanbul, where many elements of our model are present. We consider two different premium products, namely fish and flower. In Figure 1, these are marked with the fish and green leaf symbols respectively. Also in Figure 1 are the customer locations (star symbol), e-delivery store location (yellow square), extended fleet depot location (orange square), and consolidation points (plus symbol).

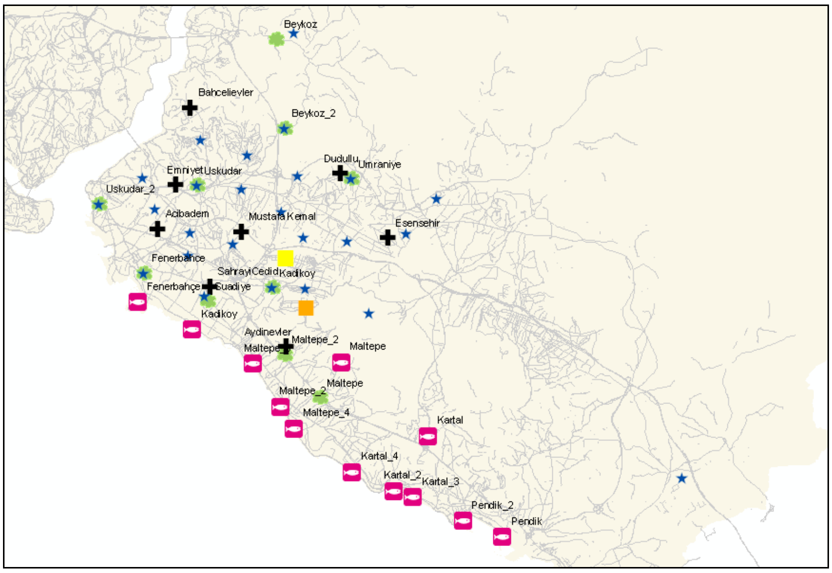


FIGURE 1
Problem setting in Istanbul

In this first scenario, we attempt to solve the e-delivery routing problem by serving the customers in a traditional way, i.e. via a fixed number of trucks leaving the store with all products loaded and visiting customers sequentially to make deliveries. We assume a 3-hour delivery time frame allowing 9 customers per vehicle on average, with the store operating 2 vehicles. This means considering a subset of 18 customers from the original set shown in Figure 1. We assume an average basket size of $100, 10% of which is the bottomline profit. Note that these are customers for which only store products are available for purchase and the delivery vans drive straight to customer delivery locations after loading up at the store.

In the second scenario, when additional premium products are available for purchase, not only further customers will place new orders, but some existing customers will extend their current orders with the added choices. The additional profit generated will (hopefully) offset the increased logistics cost. In our example, a total of 25 customers request e-delivery (up by 39%), with an average basket size of $120. Out of this $120, 10% profit is achieved with the first $100, and 50% profit is achieved with the remaining $20.

We present in Figures 2a and 2b, the routing solutions obtained by a) running the tradional VRP model, and b) solving the model presented in the previous section. We assume that 3 vans operate from a single depot to visit high-premium source locations and on to consolidation points, in addition to the 2 store-originating vans. In both cases, we assume a variable transportation cost of $1 per km. and a fixed monthly vehicle cost of $1080 as well as a monthly $450 for each consolidation point (which translates into $12 and $5 per run, respectively, assuming 3 runs a day, 30 days a month).

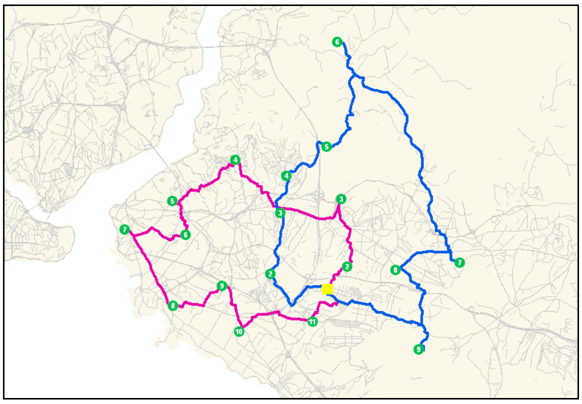

FIGURE 2A
Standard e-delivery with 2 vehicles

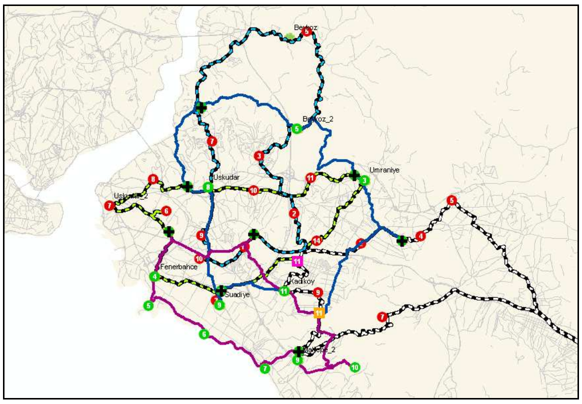

FIGURE 2B
"Premium e-delivery" with 3 vehicles

Our calculations, as shown in Table 1, indicate the potential profit that may be realized for the online delivery company by offering the addional premium products for e-delivery. In this example, the company incurs additional logistics cost of $167.07 dollars, but this is sufficiently offset by the additional profit of $320.

While our analysis shows the potential profit that may be realized from the extended service, various parameters clearly impact the amount of such profit, if any, or the breakeven point. Two of these are the basket size and the % profit margin (for standard as well as premium products). Keeping the basket size and profit margin constant for standard goods, we present a 2-dimensional sensitivity analysis of the remaining two parameters, the standard+premium basket size and the premium profit margin, in Table 2.

TABLE 1
Comparison of standard and extended e-delivery models

| | **Store Products Only** | **Store + Premium Products** |
|---|---|---|
| Number of customers served | 18 | 25 |
| Number of vehicles used | 2 | 5 |
| Cost of vehicle per km | $1 | $1 |
| Fixed cost of vehicle per run | $12 | $12 |
| Total km's driven | 56.61 | 147.68 |
| Number of consolidation points used | - | 8 |
| Cost of consolidation point per run | - | $5 |
| Total Cost | $80.61 (=12×2+56.61×1) | $247.68 (=12×5+1×147.68+5×8) |
| Profit from standard products | 180 | 250 |
| Profit from premium products | - | 250 |
| Total profit | 180 | 500 |
| Net profit | $99.39 | $252.32 |

TABLE 2

Net profit difference as a function of standard+premium basket size and premium profit margin

| Profit Margin / Basket Size | 110 | 120 | 130 | 140 | 150 | 175 | 200 |
|---|---|---|---|---|---|---|---|
| 10% | (72.07) | (47.07) | (22.07) | 2.93 | 27.93 | 90.43 | 152.93 |
| 25% | (34.57) | 27.93 | 90.43 | 152.93 | 215.43 | 371.68 | 527.93 |
| 50% | 27.93 | 152.93 | 277.93 | 402.93 | 527.93 | 840.43 | 1152.93 |
| 75% | 90.43 | 277.93 | 465.43 | 652.93 | 840.43 | 1309.18 | 1777.93 |

## CONCLUSION

Our analysis indicate that there are forgiven profit opportunities for e-grocers. As shown in our illustrative scenarios, involvement of premium goods offers possibilities in improving both the number of customers served and the basket size. E-fulfillment is clearly a complex process which needs to integrate not only logistics, retailers and consumers' logics but also reflect closely the dynamic social environment in which it is evolving. E-grocery fulfillment will need, in the future, to be seen as a tool where further added value can be derived in order to achieve sustainable growth and competitive differentiation. Identifying key logistic components, socio-demographic soft factors and understanding how these components inter-relate and react for delivering further value are prerequisites of development and implementation of a successful e-fulfillment process. This process implies that some current practices may disappear to give rise to new ones, using new logistic approaches in function of the local circumstances and users (including some reverse logistic options).

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