# An ICT-based reference model for E-grocery in Smart Cities

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**Abstract.** *E-grocery is a new emerging and challenging business channel for the food and beverage market, enabling consumers to purchase grocery products online. It combines the issues of last mile distribution with those related to the perishability of foods, affecting the success and profitability of several e-grocery companies. The Local Food Supply Chain (LFSC) concerns the local production and delivery to food consumers, in a more economically and environmentally efficient way, but it remains a less explored business. The paper discusses whether a new LFSC model for e-grocery is useful and proposes an innovative solution based on ICT and mobile applications.*

**Keywords:** E-grocery, Last Mile, Supply-Chain, City Logistics.

## 1 Introduction

E-commerce is drastically changing the way business is managed. In particular, B2C e-commerce represents a new channel that completely replaces physical shops, enabling consumers to purchase products and services online. While e-commerce revolutionized the retail business of travel, clothes, and consumer electronics as the big online sellers, e-grocery is still at an early stage. This does not refer to a temporal dimension, in fact according to [1], the grocery industry is considered pioneer in home delivery service, but e-grocery has not been still able to find the model of success that ensures profitability to their businesses. This paper deals with the e-grocery distribution in urban areas and proposes a model specialized for the Local Food Supply Chain (LFSC) and the Smart Cities environment. The project, named Simulation and Optimisation of Urban Logistics (SOUL), develops in collaboration with Telecom Italia, a prototype for urban B2B freight distribution fleet routing management system in integration with business modeling and near field communications technology for LFSC. In details, SOUL has a twofold purpose. First, reduce with the use of ICT based solutions, the issues that affect the e-grocery (e.g., the inefficiency of the picking and delivery operations), determining the failure of the majority of pioneering e-grocery retails. Second, to deal the e-grocery with an innovative point of view, paying the attention on fresh food and LFSC, which are less considered in literature, as we will discuss. The combined usage of a Decision

Support System and mobile application let us provide a solution to increase the effectiveness and the efficiency of the e-grocery operations. The paper is organized as follows. Section 2 examines the literature, providing some references about the industry state-of-the-art and an overview of LFSC. The proposed model is introduced and discussed in Section 3. Finally, Section 4 reports some results.

## 2 Literature Review

The literature of e-grocery retailing can be split into two different main streams. The first one includes the analysis of the retailer's point of view focused on the efficiently design and management of the e-grocery supply chain, taking into account the relevant factors that determinate the successful of the business model. The second stream concerns the potential benefits in terms of externalities reduction and the impact of e-grocery on the more comprehensive urban freight distribution. For a more general discussion about the different aspects of Smart Cities application, the reader can refer to [2]. Regarding the retailer's point of view, some papers investigate on the definition of efficient operational models, by proposing an analysis of different models with a comparison of existing e-grocery companies ([3], [4]). A great attention is paid for individuating the main reasons of the failures that occurred, which are classified in economical and perishability related factors. First, when designing the business and operational models, the key issues discussed in the literature are picking and delivery operations. A crucial point is in fact that the overall efficiency of these operations is essential for e-grocer retailers, due to lower gross margins that affect the e-grocery than in other markets. The reason are mainly economical, in fact for traditional bricks-and-mortar, retailers that enter the Internet market as multi-channel grocery retailers, order picking and home deliveries represent additional costs (see Fig. 1). In traditional supermarkets, the customer picks the

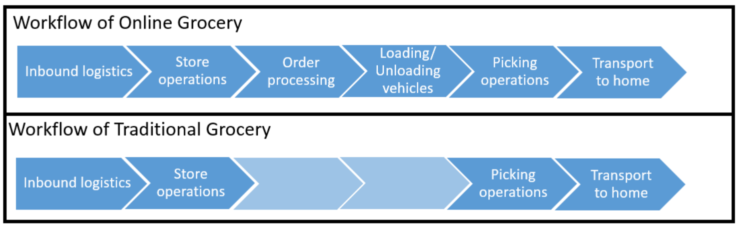


**Fig. 1.** Comparison of traditional and online grocery shopping activities.

desired products and bears the transportation costs from the store to home. By contrast, in online grocery the retailer incurs the picking and last mile logistic costs. Generally, these additional costs are higher than the fees customers are willing to pay for delivery, which is between euros 4 and euros 7 per transaction, depending on the market [5]. This means that only efficient picking and delivery processes would make the e-grocer business profitable as well as strike the right balance between cost and service [6]. Other issues, strictly related to the design of successful fulfillment and delivery options, affect the economical efficiency of the e-grocery supply chain, as the transportation costs related to the location of distribution centers, and the investment required (e.g., investment for highly automated centers). The second critical point for the failure of e-grocery solutions is the difficulty to guarantee the food temperature during the entire chain and the perishability of the food. In particular, according to the definition proposed by the International Air Transport Association, a shipment is perishable if its contents deteriorate over a given period if exposed to harsh environmental conditions, such as excessive temperature or humidity. This peculiarity increases the complexity related to the management of these parcels, about the need to guarantee their health, safety and economic value. The retailers must guarantee that frozen and perishable foods maintain their temperature all along the supply chain. While in attended home delivery service this can be easily achieved, in unattended delivery refrigerated containers are required. To solve this problem, different packaging solutions have been proposed. The reception box is a refrigerated and locked box installed in the customer's garage or yard. The delivery box is a secured box with a docking mechanism delivered to the customer and retired at the next delivery. Another type of complexity occurs when it is expected a transit to a distribution centre (DC). In fact, it is necessary particular attention for layout planning of DC, because the preservation of perishable goods required that there should be at least three different temperatures: room temperature, chilled and frozen [7]. The second literature stream is strictly related to the impact of e-grocery on the Last Mile distribution. It includes several studies ([8], [9], [10]), focused on the potential benefits, in terms of vehicles miles traveled and Green House Gas (GHG) emissions reductions, generated by the e-grocery home delivery compared to the case in which individuals use their own car for shopping trips. These papers estimate CO2 emissions reductions in the range between 18% and 87%, where the level depends on the home delivery model and the routing strategy used. Small reductions of GHG are observed when no scheduling rules are defined and customers to serve are selected randomly. On the contrary, larger reductions occur when the proximity assignment selection policy is used, i.e., the deliveries are first clustered in zones and then the trips associated to each zone are computed. [4] identify and analyzes the impacts of the last-mile delivery strategies adopted by e-grocery retailers. They show as Click & Collect service appears to be the most suitable, compared to HD service and hybrid HD and Click & Collect service, with almost a 9% GHG emission reduction. From a holistic vision, the e-grocery emerges as a new challenging business channel for the food and beverage market. It combines the issues of distribution in urban areas included in the last mile logistics field with the problems arising in the manage of fresh and perishable foods. Moreover, it emerges a lack in the state-of-the-art of e-grocery applied to local food distribution. In particular, a framework of e-grocery LFSC combined with a business model has not been proposed yet. In fact, we can state that today e-grocery represents an additional channel for food distribution and it is used to create an online version of traditional grocery retailers (e.g., Walmart and Publix) who dominates the USA and European e-grocery-retailing. Moreover, consumer interest in local foods has increased sharply in recent years [11], also due to the policy programs promoted by the European Commission [12]. In this context a higher level of ICT could overcome the complexities that affect LFSC and help small local producers to be more competitive.

In the next section, we present a project named SOUL, which aims to response to this issue, with the integration of ICT and mobile application.

## 3 The e-grocery distribution model

As stated in Section 2, there is a lack of ICT application to the e-grocery LFSC. Therefore, the short food business would do well to improve the physical distribution process and re-engineer the logistics process by connecting the supply chain with ICT and real-time information. The ICT of the supply chain offers two main advantages: to provide final consumers with a valuable alternative to grocery stores and to support actors involved in the LFSC with an efficient distribution system. ICT helps to achieve these goals by solving problems related to the cost and the effectiveness of logistics operations, the management of B2B and B2C segments, the packaging of fresh products and the occurrence of unexpected events during the distribution (e.g., road congestion). In this context, ICT and Decision Support Systems (DSSs) have the potential to optimize the use of road capacity, save manpower, reduce the number of traffic accidents, and decrease the level of pollution [13], enhancing the quality and efficiency of the service. The proposed DSS for e-grocery is developed in the SOUL project field. SOUL is an attempt to consider multiple retailers that share the distribution of fresh food in urban areas. The DSS is embedded in a mobile application that allows retailers and consumers of fresh food to monitor the flow along the entire supply chain (e.g., order placement, inventory control, freight tracking, dispatching, delivering) and enables the exchange of real-time shipping and traffic-related information for the optimization of logistics operations and traffic congestion mitigation. We use in our DSS a vehicle-to-infrastructure (V2I) system, in which vehicles transmit their own data to a central server. The server aggregates data from external sources, including real-time data. Thus, it moves the computing power away from the vehicle and provides real-time information for third party applications, such as the fastest paths for vehicles and the detection of congestion in the urban area. This means that SOUL is able to retain information about users of the reference market, to elaborate traffic data from public and non-public sources, and to provide an intelligent core capable of processing and distributing this information for a better use of the transportation system. Moreover, SOUL ensures the exchange of information on the mobile network and the coordination of activities in a flexible and scalable manner. Fig. 2 illustrates the main blocks of the SOUL architecture, responsible for the execution of the process described. More attention is paid to the analysis of the two key elements: Traffic Handler Service and Central Unit. On the contrary all blocks are briefly described in this section:

- Central Unit (CU): it is the operative core block that provides two main functions, traffic management and real-time control of fleets of vehicles.
- Traffic Handler Service (THS): it is a key block that aggregates traffic information in order to detect the congestion of urban streets and communicate the traffic events to the CU, which deals with them by updating in real time the routes of the vehicles.
- Data Broker Layer (DBL): it manages and facilitates the access to information through standard implementations and access policies. Using integration rules, it also supports the aggregation of data sources, preserving the meaning and the context of information. Finally, it guarantees data integrity and concurrent updating from different sources.
- Hosted Services: they provide a hosting system for applications and tools, and an interface to support interactions between services and users. For example, the Supply Chain Management Unit receives orders from users and sends them to the associated suppliers, manages information and tools for delivery planning and execution, allows electronic monetary transactions, updates inventory levels, and collects statistics about orders, deliveries and stocks to support distribution activities. Specific XML formats are defined to enable the exchange of information.
- Third Party Services: they do not need a hosting system and, on the one hand, can benefit from data aggregation and forecasting and, on the other hand, provide functions to services hosted in the architecture (e.g., cartography).
- Enabling Technologies: internal and external enabling technologies enhance the decision making process of ITS (e.g., map providers, localization system). In particular, high-speed local and/or geographic networks (e.g., LAN, internet) that enable the exchange of information between the various software and hardware modules.
- External sources: traffic data are available not only from the vehicles, but also from private or public networks of sensors (e.g., institutional and non-institutional portals). For the city of Turin, an important source is constituted by a broad traffic sensor network carried out by the Traffic Operation Centre 5T and its public portal [14], which provide data about the road network in real time.
- Mobile devices: they access the services hosted in the SOUL architecture. Moreover, the smartphones of logistic providers represent possible sensors of traffic data as they are directly in contact with the situation in real time.

### 3.1 Central Unit

It is an intelligent real-time vehicle routing system able to build optimised routes for the distribution of fresh and perishable food, by taking into account chang-

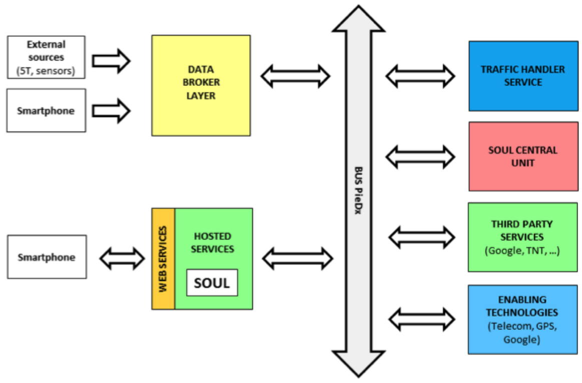


**Fig. 2.** Main blocks of the SOUL architecture.

ing traffic conditions ([15], [16]). The goal of SOUL optimisation tools is to make the e-grocer business profitable reducing the costs and the criticisms of the home delivery services, through its components: a routing optimiser and a post-optimiser. The first is based on a Tabu Search heuristic able to address the Vehicle Routing Problem with Time Windows (VRPTW) [17]. It computes the cheapest routes for a heterogeneous fleet of vehicles from a single depot to a set of geographically scattered points and considers the time windows within which the deliveries must be made and the capacity of vehicles. SOUL also provides solutions for the consolidation of foods from different retailers in distribution centres [18]. The outcomes of the routing optimiser are then stored in the DBL and retrieved by the application when the vehicles are ready. The post-optimiser manages a Dynamic Vehicle Routing Problem (DVRP) in which the source of dynamics is the online arrival of customer requests for goods during the operations. Once the SOUL CU has optimised the VRPTW, logistic operators or the retailer with equipped vehicles can use the navigator provided by the application. The navigator, based on Google Maps and navigation API defined in Android, uses the GPS navigation device to acquire position data and to locate the user on a road. The driver selects the vehicle from the application, which downloads the optimal route and draws it on the map. Upon selection of the vehicle, an association is made between the vehicle and the International Mobile Equipment Identity code of the on board mobile device guaranteeing the identification of the vehicle in the system for the entire duration of the deliveries. Moreover, dynamic and real-time navigation data are sent to the Traffic Handler Service, in order to aggregate them and to provide new estimates of the urban congestion by means of a crowd sensing aggregation module.

### 3.2 Traffic Handler Service

The Traffic Handler Service (THS) has two important functions. First, THS collects data from external sources and aggregates data to provide real-time traffic information. In particular, the sensory system of the traffic center (5T in the case study of Turin [19]) periodically monitors the rate of flow (cars/hour) and speed (km/hour) on the main roads and makes them available online. Then, THS retrieves the data from the public portal, collects them and performs statistical analyses (e.g., minimum, maximum, average), useful to report congestion on routing paths. We develop a simple detection tool based on the theory of traffic flow on freeways ([20, ?]) and adapted to the characteristics of roads in cities. Periodically, THS checks conditions of roads under monitoring and, in case of congestion, communicates a new traffic event to the notification. On the contrary, when the congestion ends, THS eliminates the event from the system. The insertion of traffic events can be made in two other ways: (1) an administration screen allows placing traffic events directly from the map and (2) vehicles involved in congestion can report their position through the mobile application. The second function provided by the THS is the computation of the matrix of costs for the routing model corresponding to the distances and travel times between depots of logistic providers and destinations of delivery. Also, it computes alternative routes only for the vehicles affected by the congestion events.

### 3.3 Mobile application

To represent the information to the user, SOUL uses a mobile application designed on the Android, written in Java, and uses db4o databases to store persistent data. It allows users to monitor the flow along the entire supply chain and enables different operations (e.g., order placement, inventory control, freight tracking, and receiving management). The mobile application connects users (consumers, supplier, retailers, and logistics providers) to the technology infrastructure of the DSS, allowing them access to services of the proposed architecture. [22] evaluated the DSS by a framework based on the System Dynamics methodology, which assesses the potential of and facilitates policies for benefits of SOUL. The outcomes of the evaluation model underline the importance of the adoption of the additional services (e.g., product tracing systems, electronic payment systems, time sensitive deliveries) in e-grocery. The advantages originating from the use of ICT in the e-grocery supply chain, in our opinion, should stimulate the use of SOUL-like systems, especially by retailers and consumers, and the diffusion of e-grocery services.

### 3.4 Perishable goods

As discussed in Section 2, perishability of goods represents a crucial aspect related to the e-grocery LFSC and one of the levers of the SOUL project. In particular, for these goods SOUL tracks the position and monitors the temperature during the entire delivery from the depot to the final destination. This information is collected through mobile and remote sensors of the vehicles. This ensures the conditions and the reliability of perishable good, as well as signaling when environmental conditions are not satisfied.

## 4 Results

The analysis of SOUL was conducted by a simulation-optimization approach. In more details, we built realistic scenarios validating them in a focus group with practitioners and fresh food companies of the Turin area. Then, we used those data gathered during the URBan Electronic LOGistics (URBeLOG) Project field [23], to carry out a simulation where the optimization of the service was done by means of SOUL. In particular, we have considered two different scenarios. The first involves small-sized food companies, which are less capable to manage deliveries with an own fleet of vehicles, in an efficient way. On the contrary, the second involves medium-large sized retailers having a more consistent demand and vehicles with a capacity of about 50% greater than the previous. The alternative in which each retailers performs the deliveries is compared with those where the consolidation of foods from different firms in distribution centres occurs. We performed our experiment campaign using data gathered from a database of 16000 customers, considering networks ranging from 3 to 45 customers. The results obtained throught the simulation are summarized in the Table 1, where are presented the amount of deliveries composing the demand for retailers, the percentages of improvement in terms of distances traveled, number of vehicles used, service times and cost savings, that the consolidation generates.

| | **Deliveries** | **Improvement [%]** | | | |
|---|---|---|---|---|---|
| | | **$\Delta$ N. Vehicles** | **$\Delta$ Distance** | **$\Delta$ Time** | **$\Delta$ Cost** |
| Scenario 1 | 30 | - 50% | - 47% | - 40% | - 47% |
| | 50 | - 50% | - 45% | - 35% | - 45% |
| | 100 | - 25% | - 32% | - 23% | - 32% |
| | 150 | - 25% | - 25% | - 17% | - 25% |
| | 200 | - 25% | - 28% | - 19% | - 28% |
| | 250 | - 42% | - 39% | - 26% | - 39% |
| Scenario 2 | 300 | - 33% | - 30% | - 19% | - 30% |
| | 350 | - 38% | - 33% | - 22% | - 33% |
| | 400 | - 31% | - 28% | - 28% | - 28% |
| | 450 | - 40% | - 32% | - 21% | - 32% |

**Table 1.** Simulation Results.

The results highlight that the consolidation of food operated by the logistics providers allow to obtain operative and economical efficiency, in both the scenarios, but mainly for the small-sized retailers. As showed by the cost savings reported in Table 1, an important benefit is the costs reduction, due to the outsourcing of the fleet management and the relative economical efforts. In general, the retailers obtain a better service time, essential in a time-sensitive context as transportation. For example, in the first scenario, considering a small network, the service time improves of about 40%, due to the greater capacity of the logistics provider vehicles combined to the optimization of the routes.

However, considering an equal capacity both for retailers and logistics provider, these benefits are confirmed, though to a lesser extent. In fact, serving a demand of 200 deliveries, the service time and the costs range from respectively the 19% and the 28% with different capacities, to the 5% and the 7% if the vehicles are identical. Notice that the adoption of logistics providers in the LFSC reduces the number of vehicles on the road, up to the 50% as illustrated by the results, with a consequent positive impact on the environment. Finally, according to our results, the dynamics of user growth does not appear to be sensitive to the variation of the service fees, even when all the LFSC players are set to be extremely sensitive to pricing.

## 5 Conclusion

The simulation conducted in this paper underlines that e-grocery literature is affected by some lacks dealing with different aspects (e.g., the organisation of warehouses for multi-channel grocery retailers, the composition of vehicles and the support of decision maker). The SOUL project overcomes these gaps, introducing an ICT solution and integrating the e-grocery Supply Chain with a reference business model, to achieve the efficiency required in the urban context. However, the integration and the synchronization of the entire chain are also required to guarantee cost-effective robust solutions, which optimize logistics operations. The synchronization of handling operations and the fleet of vehicles has a key role in the SFSC, where the perishability of the products requires speedy and accurate operations. These new issues are presently tackled in a new project funded by the Horizon2020 programme called Synchro-modal Supply Chain Eco-Net [24].

## 6 Acknowledgments

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