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ITS for E-grocery Business: the Simulation and Optimization of Urban Logistics Project

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Abstract

In this paper we investigate the delivery of fresh food by developing an ITS solution and proposing a framework to assess the performance related to its integration in a mobile application, with particular attention to the benefits and diffusion of such tool. The application allows users to monitor the flow along the entire supply chain and enables real-time optimization of route planning and traffic congestion mitigation. The work gives to the e-grocery distribution systems not only technical solutions but also a general approach to directly analyze their effectiveness and to test possible business policies.

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Keywords: Intelligent Transportation System; e-grocery; supply chain; business model; mobile commerce

1. Introduction

The need for mobility that has emerged in the last decades has led to an impressive increase in the number of vehicles as well as to a saturation of transportation infrastructures. This is particularly true in urban areas whose population has been steadily growing since the 50s. Consequently, traffic congestion, accidents, transportation delays, and polluting emissions are some of the most recurrent concerns transportation and city managers have to deal with (Dimitrakopoulos and Demestichas, 2010). However, just building new infrastructures, as new roads or high capacity highways, might be not sustainable because of their cost, the land usage, which usually lacks in

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metropolitan regions, and their negative impact on the environment (Crainic et al., 2009). Therefore, a different way of improving the performance of transportation systems while enhancing travel safety has to be found in order to make people and good transportation operations more efficient and cost effective and support their key role in the economic development of either a city or a whole country.

In such a context, Intelligent Transportation Systems (ITSs) have been conceived as the application of information and communication technology to the transportation arena at the system, vehicle, and individual use levels (Haynes and Li, 2004; Román et al., 2013; Pan et al., 2014). ITSs have the potential to optimize the use of road capacity, save manpower, reduce the number of traffic accidents, and decrease the level of pollution (He et al., 2010). ITSs can be in the form of Advanced Transportation Management Systems, Advanced Traffic Management Systems, Advanced Traveler Information Systems, Commercial Vehicles Operation Systems, Advanced Public Transportation Systems, Advanced Vehicle Control Systems, Advanced Urban Transportation Systems, or Advanced Rural Transportation Systems to mention the main practical implementations of this concept (Zhang et al., 2011).

ITSs may help managing logistics in multiple industrial and service sectors. This work focuses on electronic grocery (e-grocery), namely ordering groceries from home in an electronic way and either having them delivered at one's house or collecting them at pick-up points. E-grocery is more convenient and timesaving than the traditional grocery channels because consumers do not have to leave their home to buy products and can do that at any time of the day. Nevertheless, the e-grocery market finds it hard to expand due to a lack of an appropriate control on the information flow and of physical logistics connected to delivery (Punakivi and Saranen, 2001). As proved by Colla and Lapoule (2012) choosing an efficient logistics model and being able to manage it are critical factors for the success of e-commerce in this industry, together with the adoption of updated supporting software tools. Therefore, in order to provide final consumers with a valuable option to grocery stores, the e-grocery business should improve purchase transactions and the physical distribution process, use electronic/mobile communications for activities other than placing orders, and re-engineer the logistics process by connecting all the supply chain (SC) members with real time information. ITSs may help in achieving these goals by enabling a structured organization and management of logistics activities and associated information flows.

Based on the outcomes of the Simulation and Optimization of Urban Logistics (SOUL) project, sponsored by Telecom Italia, the present paper develops a ITS assisting in the management of the e-grocery SC. The ITS is embedded in a mobile application that allows producers, retailers, and consumers of fresh food to monitor the flow along the entire SC (e.g. order placement, inventory control, freight tracking, dispatching, receiving) and enables the exchange of real-time shipping and traffic-related information for the optimization of route planning of an heterogeneous fleet of vehicles and traffic congestion mitigation. Additionally, a framework to assess the benefits and the diffusion pattern of the mobile application is proposed, thus enabling a thorough analysis of its operational and economic impacts on every SC echelon in order to support feasibility evaluations.

Despite the recognized importance of investigating the impact of introducing ITS projects and of understanding how adopters experience and respond to them (He et al., 2010; Vlassenroot et al., 2010), to the authors' best knowledge, contributions are usually devoted to developing either ITSs or methodologies. Thus, the focus is on assessing their effects and there is a substantial absence of works combining these two complementary aspects. However, when an appropriate evaluation framework is associated to an ITS architecture, both decision-makers and users can benefit from the possibility of directly analyzing the effectiveness of the tool and of testing the related business policies that might be implemented. This enables a prompt evaluation of the suitability of an ITS and allows to choose the most effective solution according to the context where it should operate.

The reminder of the paper is organized as follows. Section 2 reviews pertinent literature with the purpose of highlighting the lack of studies integrating both an ITS solution and an assessment framework. Section 3 describes the ITS architecture, while Section 4 presents the evaluation framework by applying it to the mobile application including the ITS. Section 5 discusses the benefits, limitations, and implications of the proposed approach by giving particular attention to the value brought by combining an ITS solution with a methodology for its evaluation. Finally, Section 6 reports conclusions.

2. Literature review

In order to frame the work in the literature and motivate it, papers proposing ITSs and contributions about evaluation methods have been analyzed. It is worth mentioning that the authors do not intend to provide a comprehensive overview of the existing ITS solutions rather to support the claim that ITS assessment is usually considered separately from the design and development of specific architectures.

2.1. Developing ITS solutions

ITS architectures have been debated since the 70s. Among recent papers, several streams of research can be identified. The advances in road telematics facilitate the availability of a large amount of data that can be easily collected from a variety of sources and processed in multiple forms for the benefit of different stakeholders. Therefore, ITSs are currently changing from technology-driven to data-driven systems. Such systems would allow users to interactively exploit a number of data resources in order to more efficiently manage transportation activities. Significant is the work by Zhang et al. (2011) who discuss the relevant components of data-driven ITSs and define a roadmap for future research by stressing the importance of preserving people privacy. The possibility of gathering and processing data with a limited effort also poses the issue of effectively combining them. Data fusion offers a collection of techniques by which information from multiple sources is coordinated to reach a better inference. To this end, El Faouzi et al. (2011) focus on road traffic and provide a survey of the most significant applications of data fusion to ITSs, such as for example automatic accident detection, advanced driver assistance, traffic forecasting and monitoring, and position estimation.

The need for coordinating multiple data is also the foundation of research about information platforms in ITSs, whose purpose is collecting, processing, storing, and sharing transportation information among users. Focusing on the most recent literature, Bin et al. (2013) discuss the objectives, requirements, and the structure of the intelligent transportation information platform of Hangzhou City, China, while Pan et al. (2014) design a platform of data exchange for an ITS able to receive data from several types of equipment external to vehicles, repackage, and dispatch them to different devices inside vehicles.

Also, several ITS applications rely on real time traffic information, such as advanced traffic management systems or advanced traveler information systems. Among the various works on the topic, Dong and Paty (2011) apply an adaptive weight method to an ITS and introduce an information feedback strategy assuring high efficiency in controlling spatial distributions of traffic patterns.

Moreover, wireless sensor networks (WSNs) are a fundamental driver of ITSs improvement due to their competitive advantages in terms of easiness of deployment and maintenance compared to traditional wired sensors. Li et al. (2007) introduce a novel two-tiered ITS network architecture based on WSNs and peer-to-peer networks providing drivers with traffic information in order to support their decision-making process while travelling. Tacconi et al. (2010) put forward a system architecture for enabling mobile nodes to query a WSN part of an ITS operating in an urban setting. Simulations allow evaluating the performance of the proposed solutions. Finally, Dimitrakopoulos and Demestichas (2010) design a ITS framework based on cognitive systems and WSNs able to provide drivers and elements of the transportation infrastructure with valuable information for an efficient and safe mobility.

Several other concepts have been applied to the development of ITSs. Among them, the internet as the communication link in road traffic management systems has been explored by Barrero et al. (2010) who present a prototype of an electronic equipment offering web services to the users of transportation infrastructure. In particular, due to the continuously enhancements of the efficiency of cellular networks (CN), this communication technology could easily cover the requirements of most vehicular services and is usually applied in internet-based ITS solutions (Santa et al., 2008). Wang (2010) presents an overview of architectures, processes, components, and applications of parallel transportation management systems, where there is a parallel interaction between an actual transportation system and its corresponding artificial counterparts. Román et al. (2013) design and develop a Service Oriented ITS architecture that is scalable and allows the progressive inclusion of new components.

2.2. Evaluating ITS solutions

ITSs have multiple goals and embrace different aspects, from policy objectives like decreasing congestion, increasing efficiency and safety, and improving the environment, to indirect implications such as technology development, economic growth, and regional change. Therefore, the evaluation of the economic, social, and environmental impacts of ITSs as well as of their risks and costs is a quite complex issue, yet essential to assure feasibility and success of such tools. Many works have been proposed in literature analyzing or presenting assessment methods.

According to Zhicai et al. (2006), the evaluation of ITS projects should include technical assessments, user acceptance assessments, traffic impact assessments, environmental impact assessments, and socio-economic assessments. However, although important for policy decisions, the last aspect is not often tackled. Thus, after reviewing ITS evaluations based on cost-benefit analyses, cost effective analyses, and multi-criteria appraisals, they propose a method to study the socio-economic impacts of convoy driving systems.

He et al. (2010) stress the fact that several evaluation frameworks are organized in a bottom-up and part to whole way and are scarcely suitable for real cases other than the one for which they have been defined. They propose an approach to assess the societal profitability of ITS projects and apply it to the intelligent transportation management and control system in Beijing. The intelligent traffic management system of Beijing is also analyzed by Wei et al. (2012), who employ Data Envelopment Analysis (DEA) to assess its efficiency and investigate its coordination with the urban development. DEA is an effective tool in measuring the efficiency and productivity of public agencies involved in ITS projects as explained by Nakanishi and Falcocchio (2004).

Haynes and Li (2004) state that the traditional cost-benefit analysis may not properly address the value-added and system perspectives as well as the uncertainties affecting ITS development and deployment. To fill this gap, they elaborate two extensions of cost-benefit analysis plus an alternative cognitive approach.

Despite the significant number of studies evaluating operational tests and other ITS developments, Thill et al. (2004) highlight a lack of tools for benefits and costs evaluation at the program stage and for this reason they design a computer based decision support system for the capital planning and programming efforts of the New York State Department of Transportation.

Finally, in recent years Cantarella (2013) proposes a dynamic model to determine the effects on users of the introduction of ITSs like advanced traveler information systems or advanced driver assistance systems.

The performed literature review reveals that while considerable bodies of literature do exist around the problem of developing new ITS solutions and the issue of their appraisal, these two topics are seldom addressed together. Nevertheless, the integration between an ITS architecture and a model to evaluate its impacts and assess possible business strategies to support its diffusion would enhance the value of the tool by highlighting its implications and suggesting effective levers to stimulate its application. Also, it could foster refinements in case the model reveals substantial weaknesses of the ITS. Ultimately, such an evaluation framework would be of great help for the choice of the best ITS to be implemented according to the characteristics of the reference context.

In order to contribute to fill this gap while providing a practical solution to increase the effectiveness of e-grocery distribution operations, the next sections present a ITS together with a mobile application supporting SC management and an evaluation framework to predict their adoption by a community of potential users.

3. The proposed ITS

The proposed ITS for e-grocery is based on the vehicle-to-infrastructure (V2I) architecture in which vehicles transmit their own speed and location to a central server accessible via ad hoc application for mobile devices connected to CN. The server, thus, processes a large amount of data on demand (Abolfazli et al., 2013), moving the computing power and data storage away from the vehicle and providing an environment for ITS applications, such as determine the fastest paths for vehicles and detect congestions in the urban area.

3.1. Architecture

The aim of the proposed architecture is twofold. On one hand, it maintains information about users of the reference market, elaborates traffic data from public and non-public sources and provides an ITS core able to process and distribute these information for better use of the transportation system. On the other hand, the architecture provides an open platform for hosting mobility services, developed by different operators, which can benefit from the traffic forecasting and the congestion detection and at the same time can provide additional features for the ITS. Moreover, this architecture helps to ensure that a network of mobile elements can exchange information and coordinate activities in a flexible and scalable manner.

The key blocks of the ITS are the Traffic Handler Service (THS) and the Central Unit (CU), which provide two main functionalities: traffic management and real-time control of fleets of vehicles. More in detail, THS periodically receives data about traffic conditions from external sources and aggregates them in order to detect the congestion of urban streets. Aggregated data are also used to the computation of the matrix of costs (and paths) for the routing of vehicles corresponding to the distances and travel times between depots of logistic providers and destinations of deliveries. The CU is the operative core of the architecture, specifically designed for managing heterogeneous vehicle fleets in urban area. It is an intelligent real-time vehicle routing system (Deflorio et al., 2012; Perboli et al., 2008) able to build optimized routes for the transportation of freight, by taking into account changing traffic conditions. The key technological features of the CU are its optimization components: a routing optimizer and a post-optimizer. First, the routing optimizer is based on a tabu search heuristic able to address the Heterogeneous Vehicle Routing Problem with Time Windows (HVRPTW), which designs least cost routes for a heterogeneous fleet of vehicles from one depot to a set of geographically scattered points considering the time windows within which the deliveries must be made. Second, the post-optimizer allows managing a Dynamic Vehicle Routing Problem (DVRP) in which the source of dynamics is the arrival of customer requests for goods and the changes of time-windows of deliveries during the operations. Thus, while customer requests appear dynamically during the day, the post-optimizer dispatches and routes subset of vehicles able to deal with such requests. Finally, the CU takes into account the congestion events detected by THS updating in real-time the routes computed during the day.

Other essential components of the architecture are the Data Broker Layer, the Hosting Servic and the Enabling Technologies. Data Broker Layer collects and facilitates the access to data of ITS (e.g. vehicle positions, deliveries, routes, traffic events) through standard implementations and access policies. The Hosting Service provides hosting system for applications and tools (e.g. Supply Chain Management Unit) and a standard interface to support interactions between services and users. Finally, the Enabling Technologies are able to enhance the decision making process of ITS such as map providers, localization system. Moreover, the architecture includes an asynchronous notification system to manage real-time events (e.g. accidents, traffic jam, and new orders).

3.2. Mobile application

With seamless access to the vast amount of information from the large network of data sources, information presentation and navigation becomes a key capability in the management of contents and ensure that the information are being presented within the context of the user. For this reason, we explored the way of presenting information on small handheld device like smartphones and tablets. The mobile application works as the interface that connects users (consumers, retailers, and logistics providers) to technology infrastructure of the ITS, allowing them the access to services of the proposed architecture. It is designed on the Android 2.3 software stack produced by Google. The choice of Android is because of its ability to implement and integrate several applications and services getting data from GPS and accelerometers, interfacing with users and map handling/display. Economically speaking, it is justified because it is a free and open source platform. The proposed application allows users to monitor the flow along the entire SC and enabling different operations including order placement, order management and optimization of the routes of vehicles, inventory control, freight and vehicle tracking, dispatching, and receiving management.

4. The evaluation framework

The design of the ITS embedded in the mobile application is completed by a framework to study its benefits and potential diffusion in a reference SC, also considering the revenue for the company providing the associated services. In addition, the approach allows analyzing the effects on the application adoption of additional services such as enabling product traceability management, electronic payments via Near Field Communication (NFC) technology, and the management of time sensitive deliveries, meaning deliveries whose time-window can be changed by the customers even shortly before their scheduled time.

4.1. Methodology

In order to assure a systemic perspective on the issue, the evaluation framework is based on the System Dynamics (SD) methodology. SD is a modelling and simulation approach aimed at understanding the behavior of a complex system to support policy design. This methodology enables to graphically represent a system of interrelated stock, flow, and auxiliary variables, define the mathematical equations describing the relationships among them, and perform a computer-based simulation to determine the trends of the investigated variables over a preset time interval. Model validation is performed through historical data and sensitivity analysis (Sterman, 2000).

With the aim of understanding the diffusion of the new mobile application and of its ITS within a community of prospective adopters a phased approach is used. First, semi-structured interviews are conducted with main SC players to create a knowledge base on the industry mechanisms. The interviews also identify a clear willingness to adopt the services and provide quantitative data for running simulations. Then, a simple SD model is designed to capture the most important flows, state variables, and feedback loops. Finally, a detailed SD model is calibrated and simulation results are analyzed to draw policies to stimulate the diffusion of the mobile application. Moving steps from Sterman's work (2000), the Bass diffusion model (Bass, 1969) and an inventory management model have been combined in a single SD framework in order to capture the mutual connections between the adoption of the services and the SC behavior. The Bass model has been used given its recognized ability to represent the dynamics of diffusion of ICT-based and mobile services. Also, it has been already applied together with the SD approach to study product diffusion, for instance by Chen and Chen (2007). In this analysis the reference market for the mobile application and its ITS is composed of 3,750 farms, 750 retailers, and 75,000 consumers of fresh food, such as fruits and vegetables, in a target urban area of 1.5 million inhabitants in Italy.

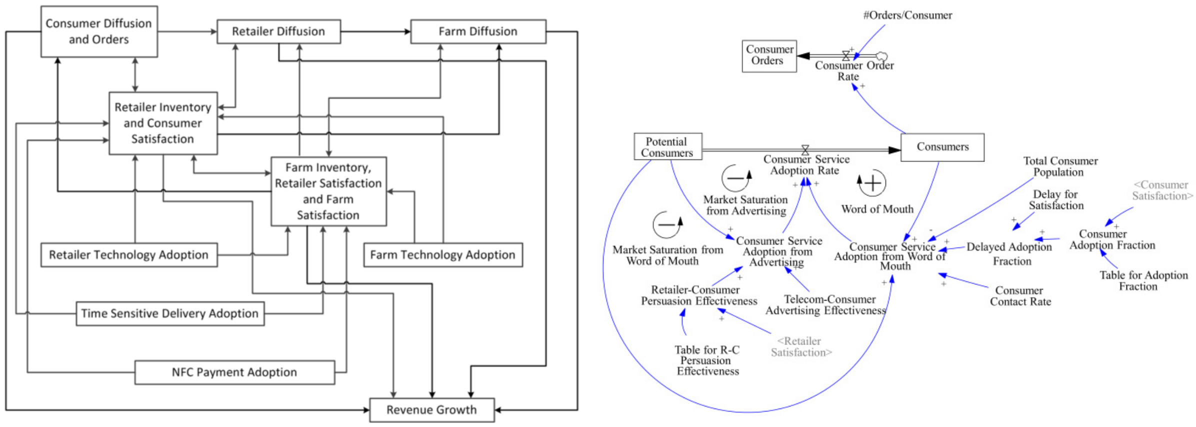
4.2. The SD model

The SD model forming the core of the proposed evaluation framework is structured in ten interconnected sub-models concerned with the diffusion of the mobile services among consumers, retailers, and producers, order issuing, inventory management, user satisfaction, and the revenue for the company providing such services (Fig. 1). Among the offered services, the product traceability system makes use of Radio Frequency Identification (RFID) and NFC technologies (Retailer/Farm Technology Adoption sub-models). Each SC player may adopt either the basic mobile application, without the additional services, or the application plus at least one of the three optional services.

Since space constraints prevent from detailing all the sub-models in Fig.1a, the complete model is available from the authors. The main relationships among variables responsible for the mobile application adoption and determining the associated benefits will be here described together with one representative sub-model.

A growth in the number of consumers adopting the mobile services increases the rate of orders to retailers issued by means of the application. How successful these actors are in fulfilling such augmented orders, together with the efficiency of the online service, determines the consumer satisfaction that, in turn, influences the growth of the adopting consumers' population through the "word of mouth" effect.

A similar situation can be observed for retailers and farms. Also, all the other variables remaining equal, a growing number of orders to the farms make the order rate to each single farm go up. The possibility of increasing the business volume with the new services is perceived by the retailers that are stimulated to adopt. Finally, the more the adopting farms, the more the products that can be ordered by retailers through the mobile application, and the higher the retailers' satisfaction. This, in turn, increases the number of adopting farms thanks to the interaction between these two SC echelons. Additionally, the greater the number of adopting consumers, retailers, and farms, the more the SC transactions performed through the mobile application and the more the revenue for the company providing the services. In fact, a dispatching and a receiving unit fee are associated with each order managed through the mobile application. Finally, the three optional services, product traceability, electronic payments, and time sensitive deliveries, basically increase the satisfaction of the adopting SC members thus stimulating other players to adopt both the basic mobile application and its additional features. Such satisfaction is induced by the increased SC efficiency due to a better exchange of real time information as well as to an inventory optimization consequent to the implementation of product traceability.



(a) (b)

Fig.1. (a) Overview of the SD model; (b) Detail for the consumer diffusion and orders model

Fig.1b shows the Consumer Diffusion and Orders sub-model. Stock, flow, and auxiliary variables can be observed. The stock variable "Potential Consumers" is decreased by the flow variable "Consumer Service Adoption Rate", which in turn increases the stock variable "Consumers". Consumers may adopt, thus entering the SC of the service users, as a consequence of either advertising or "word of mouth". In this model, advertising is performed by both the suppliers that have already adopted the mobile services, through verbal persuasion to use it because of its efficiency and easiness of use, and the service provider company, by means of formal campaigns, whereas "word of mouth" is pursued by adopting customers and members of a same SC echelon. All these interactions are represented by auxiliary variables. The number of adopting consumers, together with the average number of orders per consumer in each single time step, determines the flow variable "Consumer Order Rate" which feeds the stock variable "Consumer Orders". The orders at issue are faced by the retailers. It is important to highlight that the present SD model is based on a standard order composition and does not consider the variability of the products that form an order. For the sake of clarification following the key model equations governing the mobile application adoption process:

Potential Consumers = INTEG (-Consumer Service Adoption Rate, Total Consumer Population)

Consumer Service Adoption Rate = max (0, Consumer Service Adoption from Advertising + Consumer Service Adoption from Word of Mouth)

Consumers = INTEG (Consumer Service Adoption Rate, 1)

The Consumer Diffusion and Orders sub-model brings important feedback loops among its variables. First of all, the more the consumers adopting the mobile application (variable “Consumers”), the more effective their “word of mouth” action to consumers that still not use the application, thus the higher the value of the auxiliary variable “Consumer Service Adoption from Word of Mouth”, which increases the value of the variable “Consumer Service Adoption Rate”. An augmented adoption rate makes the number of adopting consumers further increase. This is the “Word of Mouth” reinforcing feedback loop that is counterbalanced by two negative loops. In the “Market Saturation from Advertising” loop the more the consumers that can potentially adopt the mobile application (variable “Potential Consumers”), the more the consumers that will adopt as an effect of advertising (auxiliary variable “Consumer Service Adoption from Advertising”), which increases the “Consumer Service Adoption Rate”. As a result the number of potential consumer adopters will go down. The “Market Saturation from Word of Mouth” feedback loop works in a similar way.

4.3. Main results and suggested policies

The SD model was calibrated by using the data from the interviews and simulated over a time horizon of 156 weeks through the Vensim DSS software by Ventana Systems. Results show that the market saturation times equal 12.6 weeks for consumers, 9.4 weeks for retailers, and 82.4 weeks for farms when the three additional services are not available and 11.6 weeks for consumers, 8.8 weeks for retailers, and 79.6 weeks for farms when the additional services are offered. Thus, complementing the mobile application with the possibility of managing product traceability, electronic payments, and time sensitive delivery stimulates the diffusion of the mobile application. The diffusion processes of the additional services are very similar to the diffusion dynamics of the basic mobile application and, which is even more important, guide the adoption of the application by all the three SC echelons. As a matter of fact, the slower the adoption processes of the additional services, because for example users are not enough aware of their benefits, the slower the diffusion of the basic mobile application and vice versa. Furthermore, the increased availability of real time information along the SC, mainly consequent to the implementation of the product traceability system, allows fulfilling orders with lower inventory levels. Since the demand for the kind of fresh food at issue can be considered steady, this means that SC players will issue orders more frequently. Such increase in the order frequency implies more online information exchanges by means of the mobile application and thus more revenue for the company providing the services. Finally, sensitivity analysis proved that the efficiency and reliability of the mobile application services have a moderate impact on the adoption by farms and consumers while they do not significantly affect the adoption by retailers who in any case enjoy the greatest benefits from the application using it both upstream with customers and downstream with farms. From a pricing point of view, the dynamics of the diffusion of the mobile application is not affected by changes in the dispatching and receiving unit fees and in the application price. Therefore, users are willing to pay even a slightly high price in order to get efficient and reliable services.

The outcomes of the evaluation model suggested two main policies in order to stimulate the diffusion of the mobile application and the embedded ITS. First, given the importance of the adoption of the additional services to both the diffusion of the mobile application and the service provider’s revenue, it is highly recommended conducing campaigns to make all the SC echelons aware about the advantages of adopting product traceability systems, electronic payment systems, and time sensitive deliveries. Second, a considerable level of efficiency and reliability of the mobile services should be ensured in order to stimulate the adoption of the application especially by farms and consumers. Thus, the service provider could increase the reliability of data transmission through the 3G and 4G networks. Farms and consumers, through persuasion and word of mouth actions, will stimulate the adoption of both the mobile application and its additional services by retailers. In a similar way, the retailers will in turn act to increase the community of farms and consumers and by means of emulation they will also make their adopter community growth.

5. Discussion

The present paper puts forward and integrated approach including both the development of an ITS architecture for e-grocery and the definition of a framework for forecasting its effects and diffusion. The combination of these two elements is not so frequent in the current literature although the authors think it is highly desirable because it can complement technical solutions with approaches to directly analyze their effectiveness and to test the associated business models that might be implemented. Moreover, such integration offers appropriate methods for comparing different ITSs in order to choose the one that best fits the particular needs and characteristics of the environment where it should be implemented. This is of great value in the e-grocery market where new solutions for making logistics and the related informational flows more reliable and efficient are being experimented.

In particular, being funded on SD, a methodology for studying the behavior of complex systems in a systemic way, the proposed assessment framework satisfy the need for taking a systemic perspective on ITS projects (Haynes and Li, 2004). It includes a user acceptance assessment, as recommended by Zhicai et al. (2006). Furthermore, the adopted approach is general and scalable and can be adapted to different situations thus overcoming one limitation of traditional evaluation frameworks organized in a bottom-up and part to whole fashion (He et al., 2010). Additionally, it is quite flexible since it can be implemented with different degrees of information availability and even when quantitative data are scarce. In that case, it will be possible to understand qualitative cause and effect relationships among the introduction of an ITS and the main variables of the system where it operates. Finally, the assessment framework could be adapted to be integrated in the discussed ITS architecture as a service to assist users in order, inventory, and delivery performance evaluation. This would effectively support SC planning.

The present contribution is of great relevance from both an academic and a practical point of view. On the one hand, the performance assessment framework, and especially its underlying methodology, can support researchers in developing specific evaluation procedures tailored to particular kinds of ITSs. Also, the provided framework could help identifying the most relevant characteristics ITS systems for e-grocery, or for electronic or mobile commerce in general, should include. Thus, the evaluation approach can assist in simulating the expected effects of alternative features in the design phase of an ITS. On the other hand, the SOUL project provides a complete ITS solution that can be applied to different e-grocery and m-commerce contexts.

Of course, some limitations can be identified. The assessment tool requires a strong interaction with potential users, which might not be possible in some ITS design and development projects depending on the degree of stakeholders' commitment. Moreover, the SD model requires further validation in order to test its ability to forecast the diffusion of the mobile services under different SC conditions. Finally, the present research has just focused on the economic impact the diffusion of the mobile application and of its embedded ITS might have on the company providing the services, without analyzing the effects on the profit margins of retailers and farms.

This is where future research will be focused on: improving the SD model validation and going on with exploring the benefits of the combination between ITS architectures and assessment methods. A further goal will be completing the developed assessment tool by enabling the analysis of how the advantages brought by using the application can affect the profit margins of retailers and farms. Also, the authors are planning to incorporate the evaluation model as a functionality of the presented ITS system.

6. Conclusions

This work proposes an integrated approach including both the development of an ITS architecture and the definition of a framework for evaluating its effects and forecasting its diffusion. Such combination gives many theoretical and practical benefits because it offers a tool to directly analyze the effectiveness of an ITS solution and to test the associated business policies that might be implemented. The case for e-grocery is considered. Further research efforts are needed to fully explore the advantages of combining ITSs with specific evaluation frameworks.

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