Research Article
Toward an IT-enabled Business Model for Perishable Food Transportation

Sichao Lu and Xifu Wang
School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China

Abstract: Nowadays, technological innovations and developments in the Internet of Things, cloud computing and other related technologies have facilitated better management throughout perishable food transportation, which contributes to reduction of food spoilage and prevention of food poisoning. Due to these technological advancements, the business model for perishable food transportation has been evolving to reap more economic and societal benefits. In this study, we present an IT-enabled business model by specifying value architecture, value network, value proposition and value finance respectively. Through this business model, how value is created and appropriated to various stakeholders can be indicated for future research.

Keywords: Business model, cloud computing, food transportation, internet of things, perishable food

INTRODUCTION

Maintaining an appropriate environmental condition plays a vital role in reducing spoilage risks in perishable food storage and transportation, because refrigeration can reduce or stop microbiological changes, physiological changes and physical changes of perishable foods (James and James, 2010). International Institute of Refrigeration found that poor temperature control is relevant to over 90% of foodborne illnesses which could be fatal and estimated that over 200 million tonnes of perishable foods had been lost in developing countries due to lack of sufficient refrigerated equipment (International Institute of Refrigeration (IIR), 2009). In recent years, with growing consumer awareness about food safety and quality, cold chain has received extensive attentions. Traditional tools for cold chain management include chart recorders, time indicators, time temperature indicators and temperature data loggers (Aung and Chang, 2014). However, none of those tools can enable online monitoring due to lack of real-time communication mechanism. Therefore, many cold chain logistics companies have tried to use Internet of Things (IoT) applications and cloud computing to monitor food quality in a cost-effective way. Furthermore, various vehicle routing problems can be optimized by artificial intelligence techniques, which contributes to the improvement of profitability.

In this technical trend, not only have many commercial applications been developed, but also there exists a wealth of studies on how to leverage those technologies to improve perishable food transportation management. For example, Lee with others used USN (Ubiquitous Sensor Network), ZigBee, GPS and mobile communications to gather and transmit environmental information in real time (Lee *et al.*, 2013). Aung with others presented a cold chain management system which is implemented by RFID and WSN (Aung and Chang, 2014). Consequently, the business model of food transportation is evolving towards IT enablement.

A business model not only indicates how a firm leverages the technology to execute inter-organizational collaborations with its partners (Rai and Tang, 2014), but also explains how value is generated and appropriated. Therefore, the business model is of vital importance for a firm to achieve its strategic goals. However, over one thousand peer-reviewed academic articles tried to definite the business model from 1995 to 2011 (Zott *et al.*, 2011), which resulted in the lack of consensus regarding the general academic definition of it. To find the underpinning of the business model, Al-Debei and Avison proposed the V^4 ontological structure, which explains the concept of business model with value network, value architecture, value proposition and value finance (Al-Deibei and Avison, 2010).

Therefore, the objective of this study is to develop a novel and flexible business model for perishable food transportation against the background of radical changes in information technology and the boom of digital services. Based on the V^4 ontological structure, this study attempts to propose the technological architecture, the IT-based core competencies, the multi-party stakeholder network structure, the flow communication mechanism, market segmentation, the IT service offerings and their business values, the IT impacts on cost reduction and revenue growth, which are fundamental elements of this business model.
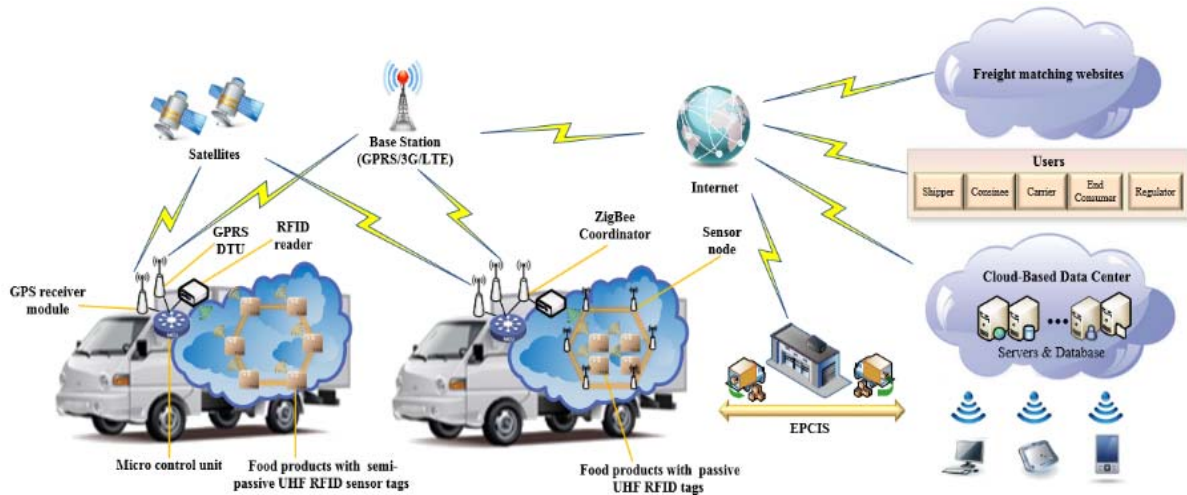
Fig. 1: Conceptual framework of the cloud based internet of things platform

$GPGGA,075049.00,4004.7328,N,11614.1673,E,1,10,1.1,65.50,M,-9.70,M,,*49
        Time   Latitude   Longitude
$GPVTG,226.863,T,226.863,M,0.069,N,0.128,K,A*27
                                    Speed(km/h)

Fig. 2: Sample NMEA data string of $GPGGA and $GPVTG sentences

MATERIALS AND METHODS

System framework of the value architecture: As the business environment has been moving toward the world of ubiquitous computing (Lee and Kim, 2007), where computing services could be provided anywhere and anytime, we propose the conceptual framework of the cloud based IoT platform for perishable food transportation, which is shown in Fig. 1.

Information of perishable foods can be stored and retrieved with RFID technology, which allows the foods to be identified and counted wirelessly. Through the Electronic Product Code Information Services (EPCIS), the perishable foods can be traced throughout their distribution processes. However, traditional RFID technology has limitations in detecting environmental conditions around the foods. Therefore, integrating RFID with wireless sensors to monitor the shipment along the entire cold chain has become an industrial trend.

In many applications, a cheap passive UHF RFID tag is attached to each perishable food and wireless sensors are fixed at different locations inside the refrigerated vehicle to sense the temperature and humidity. Although this solution is cost-effective, sometimes it is incapable of recording the accurate data because the temperature at the perishable food and the sensor node tend to be different due to temperature gradients and behaviors such as opening of the vehicle door and moving food products. Recently, many cold chain logistics companies utilize the relatively expensive but powerful UHF RFID tag embedded with sensors to monitor perishable foods, because the RFID sensor is capable of sensing environmental conditions

and reading the data stored in the RFID tag simultaneously. Given that the air temperature differs from the real temperature inside the transported perishable foods, Carullo *et al.* (2009) with others designed a measuring node which can be inserted into the plastic cap of a bottle to sense the real temperature of the food products and transmit it through the WSN.

Through a GPS receiver module, the location of a refrigerated vehicle can be pinpointed. Figure 2 shows the messages which are based on the NMEA 0183 standard protocol.

When perishable foods are in transit, the RFID reader will transmit each food's data from the RFID sensor tag to the Micro Control Unit (MCU) at intervals. The MCU will continue to transmit the food's data along with the location data to the cloud based IoT platform through a GPRS data transmission unit.

Cloud computing is another popular technology which makes applications run on the Internet rather than on the local information infrastructure. Based on the cloud computing, the platform can provide on demand service provision, ubiquitous access, resource pooling and elasticity (Biswas and Giaffreda, 2014). The commonly provided backup and disaster recovery services can improve resiliency and redundancy of the platform, which greatly reduces the risk of data loss.

Core competency of the value architecture: Through the cloud based IoT platform, the cold chain logistics provider can develop core competencies of awareness and real-time visibility. Awareness empowers the refrigerated vehicle and perishable foods with
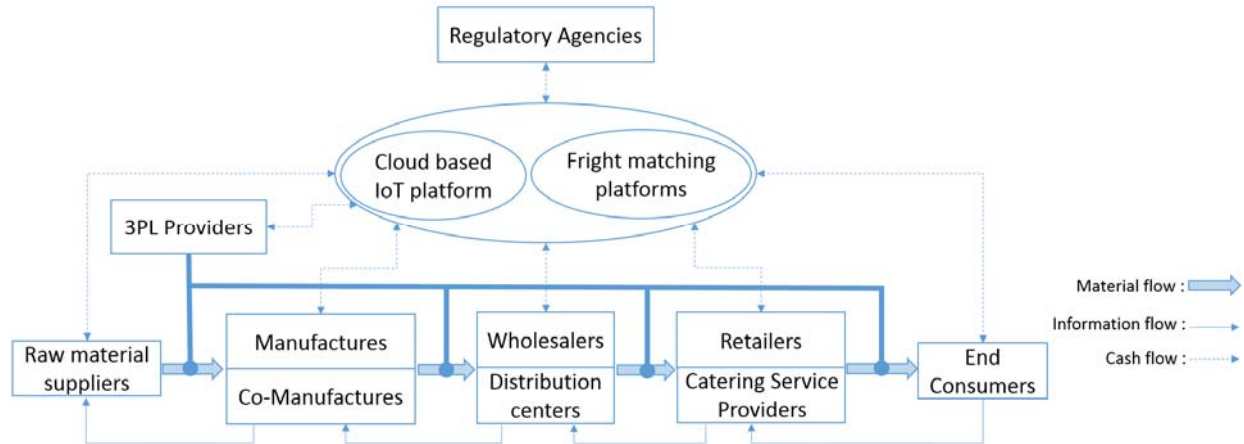
Fig. 3: A simplified IT-enabled value network of perishable food transportation

intelligence devices to collect environmental data and detect changes quickly, which helps in reducing and preventing a variety of risks such as temperature violation and route deviation. Real-time visibility contributes to synergy among the logistics participants and facilitates timely responses to various unexpected and unanticipated incidents.

Network structure of the value network: Value network depicts how groups of participants cooperate and collaborate with each other to generate economic value. A general value network of perishable food transportation is shown in Fig. 3. Seamless integration of material flows and information flows must be guaranteed to maintain the integrity of a cold chain, because it will cause irreversible damages to perishable foods if the cold chain is broken. Through the cloud based IoT platform and fright matching platforms, critical information of food products could be shared among various actors connected in this value network to prevent cold chain failure and enhance profitability.

Material flow optimization of the value network: Generally, perishable food transportation is more expensive than standard transport, because the refrigerated vehicle includes a refrigeration unit, which consumes fuel to keep the shipping container cool. Therefore, route optimization is crucial to cost reduction of perishable food transportation. With respect to the route planning, there exist a number of studies. For example, Hsu *et al.* (2007) with others proposed a VRPTW (Vehicle Route Problem with Time Window) based model for delivering perishable food. Chen (2015) used genetic and graph cluster scheme algorithm to optimize food logistics distribution routes. Given that most vehicle routing problems are NP-hard, the evolutionary computation which is a subfield of artificial intelligence can be quite efficient to deal with these problems.

Information sharing mechanism of the value network: By extending the Internet to the ubiquitous sensor networks of perishable food products, the cloud based IoT platform enables critical information to be shared to multiple users with intelligent devices anytime and anywhere. For example, if a shipment is expected to be delayed or cancelled, notification messages will be generated and sent to the mobile phones of consignees. Fright matching platforms such as landstar.com and getloaded.com are quite valuable for cold chain logistics companies. Because according to the Metcalfe's Law, it can be inferred that those platforms can provide more opportunities to facilitate transactions as they attract more users.

Market segmentation of the value proposition: The cold chain market is in a state of fast expansion in China. It can be divided into the chilled food market and the frozen food market by food product type. In terms of applications, it involves fish, meat, seafood, bakery, confectionery, fruits, vegetables, dairy, frozen desserts and others (MarketsandMarkets, 2014). Given that the optimum storage condition varies among those perishable foods, IT enabled service offerings should support diverse user requirements. For example, ethylene sensors could be added for continuous ethylene measurement in fruit transportation and a hall effect sensor could be used to indicate whether a vehicle door is open or closed.

Service offering of the value proposition: Based on the information technologies, a typical food transportation management system is capable of providing a wealth of services, of which the representative ones are shown as follows:

- **Master data management:** Create and maintain master data in a cloud-based database system.
- **Location tracking:** Display the location together with the speed of a refrigerated vehicle on the digital map.

- **Geo-fence:** Generate and send notification messages when a refrigerated vehicle exits a predefined zone.
- **Automatic monitoring:** Monitor and control the storage condition by gathering, transmitting and analyzing ambient data of perishable foods in real time.
- **Information tracing:** Trace the information of perishable foods' entire distribution processes.
- **Vehicle route planning:** Optimize vehicle routes to minimize distance and hours travelled subject to certain constraints.
- **Business Intelligence:** Compile useful information from raw data to make statistical inference, KPI reporting and forecasting to give decision support.

Value elements of the value proposition: value creation occurs when the benefits associated with services are equivalent or exceeding the offering's total costs (Slater and Narver, 2000). Value offered to actors in the value network of perishable food transportation can be broadly categorized as follows:

Improved food safety and quality for end consumers: With the service offering of automatic monitoring, reliability on safety and quality with respect to perishable foods can be provided, which contributes to reduction and prevention of food poisoning and food spoilage. Furthermore, the RFID-based traceability can resolve the asymmetry information problem and improve customer confidence to a large extent.

Improved efficiency for employees: Data collection, transmission, storage and analysis can become highly automated and hands-free, which enables proactive management and greatly reduces human intervention. Thus, employees could be less error-prone, especially when they process repetitive data or perform repetitive operations. Furthermore, by using any web-based intelligent devices such as PCs, tablets and smartphones, users are capable of accessing the cloud-based platform anytime and anywhere.

Enhanced decision support for managers: Details of each process of perishable food transportation can be analyzed and visually displayed in real time, which help managers make decisions to achieve better operational excellence.

Better collaboration for logistics partners: Through the cloud-based information sharing mechanism, the joint efficiency and effectiveness of logistics partners could be improved and the joint cost could be reduced. For example, a supermarket is capable of estimating the arrival time of each refrigerated vehicle via GIS to avoid emergence of long queues, which facilitates

reduction of meaningless fuel consumptions and waiting time.

RESULTS AND DISCUSSION

IT impacts on cost reduction of the value finance: Costs of perishable food transportation include many items, such as fuel consumption, tolls and parking, vehicle maintenance and repairs, depreciation, insurance, etc. The operating costs can be saved to a large extent due to the IT services, the main reasons are twofold. Firstly, route optimization and real-time traffic flow visualization from GIS services are helpful in reducing fuel consumption. Secondly, economic losses of food spoilage and theft can be reduced by the IoT based technologies. Furthermore, in terms of IT spending, investment and maintenance costs relate to hardware, software and personnel can be reduced to a large extent due to the cloud computing (Kenji and Gurgen, 2014).

IT impacts on revenue growth of the value finance: Company revenues can be improved by information systems (Hamilton and Norman, 1981). Through the cutting-edge technologies, revenue of a shipment can be gained by punctual delivery, decreased food spoilage and optimized distribution routes, which play a pivotal role in customer satisfaction and contribute to long-term revenue growth and market expansion.

CONCLUSION

It is notable that dimensions of the business model are interrelated rather than absolute independent, which has significant implications to create new strategies. For example, to achieve a higher joint profit among some retailers, refrigerated vehicles have to pick up some unsold products from one retailer and transport them to another one when they delivers new products, which make the route planning become an integration of VRPTW and VRPPD (Vehicle routing problem with pickups and deliveries). This example shows how value finance and value network affect each other.

In conclusion, information technologies such as the IoT and cloud computing enable full visibility and intelligence across the perishable food transportation. By leveraging those technological advancements, both efficiency and effectiveness can be improved greatly. Therefore, to develop a business model which represents how to create and appropriate value by absorbing information resources is quite beneficial for a cold chain logistics company to achieve its strategic goals. To this end, this study explores how to establish an IT-enabled business model to achieve operational excellence by specifying value network, value architecture, value proposition and value finance respectively. Through this business model, cold chain

logistics providers can improve their management and competitiveness and also end consumers can be satisfied with reinforced confidence towards the perishable food quality.

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