A cloud-based responsive replenishment system in a franchise business model using a fuzzy logic approach

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Abstract
In today's volatile markets, increasingly unpredictable customer demand is exerting great challenges to responsive replenishment. The complexity of responsive replenishment is higher when the business is global in which demand in both domestic and overseas markets has to be catered for. The emergence of cloud computing has eased the difficulties as it allows nearly real-time access to a universal platform for information sharing between franchisors and franchisees, creating huge opportunities for understanding global market needs for responsive replenishment. Considering the existence of uncertainties due to the fluctuating demands, fuzzy logic is useful in providing decision support for replenishment in uncertain environments. This paper presents a cloud-based responsive replenishment system to manage operation data of a franchise business using cloud computing, and for analysis using fuzzy logic in order to provide franchisors with the required inventory levels. To the best of our knowledge, this is the first study that applies cloud computing and artificial intelligence techniques in franchising. A pilot run of the system is conducted in an education company which is considered to be a good representation of an industry operating with a franchise model. The results show that the system allows franchisors to formulate effective responsive replenishment strategies.

Keywords: Replenishment; franchise; cloud computing; fuzzy logic; customer relationship management

1. Introduction
In recent decades, business requirements are being focused on responsiveness to the market. In order to fulfill the demands of dynamic markets, responsive replenishment is recognized as a vital means to allow customers to have easy access to products or services. However, it is a challenging task in a worldwide business as each geographically dispersed market has its unique market features which need to be taken into consideration when formulating replenishment strategies. Compared with other business strategies, franchising is a more effective and efficient business strategy for entering new markets and expanding operations. Therefore, it can be unexpectedly difficult to achieve responsive replenishment in a franchise business environment.

Franchising involves the granting of a license by a franchisor to a franchisee to use a particular name or trademark for business according to the agreed terms. Traditionally, franchisors have to give access to franchisees to all of the operational tools and systems needed to run the business. To ensure consistency in the quality of products or services, they have been responsible for all replenishment processes which require consideration of all data from diverse franchisees. This highlights the importance of a collaborative platform for exchanging information between business units and the franchise network. With the widespread availability of the Internet, cloud computing is an appropriate tool to create a location-independent platform connecting franchisors with its franchisees for exchange of information. It is a model for enabling convenient and on-demand network access to a shared pool of computing resources, both hardware and software, so that users are not required to have control over or even knowledge about the physical location of the resources provided (Mell & Grance, 2009; Mulholland et al., 2010). With the use of cloud computing, many business applications such as Enterprise Resource Planning (ERP) or Customer Relationship Management (CRM) can be run on hosted servers and delivered to franchisees as a cloud service via a web browser. With this cloud environment, franchisees in markets such as third-world countries, that may have traditionally lacked information technology (IT) resources, are also allowed to enjoy IT services at a low cost. It thus becomes convenient for franchisors to have collaboration with franchisees in a location-independent way.

However, merely having a cloud-based platform does not fully guarantee the decision quality in responsive replenishment. Many uncertainties arise from fluctuating customer demands, so franchisors may not be able to respond to the demands in a timely manner, thus lowering their responsiveness to the market. Fluctuation in an industrial environment could arise from diverse sources such as the market demand, time and costs. Therefore, it is more convenient for the decision makers to describe uncertain variables by using natural language such as “low” and “high”, instead of using the quantitative values of the variables. For instance, the replenishment quantity should be large when the lead time and sale of a particular item are long and large, respectively. However, there are always no clear-out theories to judge whether the lead time is long or whether the sale is large. Thus, it is important to have a decision support model which can take the fuzziness of data into consideration so as to determine the quantity for replenishment. To address the needs in practice, fuzzy logic is a popular artificial intelligence (AI) technique to imitate the human capability of making decisions under uncertainty. In particular, including the principle of fuzzy logic in any replenishment systems can help deal with the uncertain parameters by virtue of its fuzzy rules reasoning mechanism. This paper presents a cloud-based responsive replenishment system (CRRS), which applies both cloud computing and fuzzy logic to provide decision support for managing inventory levels in franchised businesses. Decisions supported by the system are based on the qualitative description of the parameters.

In the CRRS, a cloud-based CRM application is designed to act as a collaborative platform for information sharing among franchisees and franchisors. Operational data from domestic and overseas markets can be accessed remotely for the purposes of replenishment. In order to provide direct guidelines for the making of replenishment decisions, fuzzy logic is applied to determine the required inventory levels, thereby leveraging the responsiveness of the replenishment system. To validate the feasibility of the CRRS, a case study is conducted in an education enterprise which is operating in a franchise business model. The rationale for selecting the education industry for a case study is that the frequent changes in public examination syllabuses and education reformation policies are posing great challenges to franchisors when they are determining the order quantity for replenishment. From the case study results, it is found that the CRRS is useful in providing important assistance to franchisors in their attempt to formulate responsive replenishment strategies and enhance customer satisfaction.

This paper is organized as follows. In Section 2, the past literature related to this study is presented. In Section 3, the architecture of the proposed system is described. In Section 4, a case study in a Hong Kong-based education company, operating in a franchise model, is presented. Section 5 contains the results and discussion of the system. The conclusion and suggestions for future work are presented in Section 6.

2. Literature Review

In today's competitive business environment, it is vital to provide customers with easy access to their desired products. Replenishment has to be responsive enough for assuring the right supply of goods to stores in a timely manner (Leung et al., 2003). However, when the stores are located in different geographic markets, customer demand on same items in each store could also be different. The difficulties in dealing with the fluctuating market demand increase with the scale of a worldwide business. Franchising is widely accepted as one of the successful business strategies for entering new markets and expanding operations (Saleh & Kleiner, 2005). It involves an organizing firm, as a franchisor, selling a proven business format that entitles a semi-autonomous franchisee to the rights to market goods or services under the organizer's brand name (Davies et al., 2011). Because of its benefits, such as brand name development and sustainability, it is moving rapidly from early adopters to mainstream organizations. Recently, many organizations operating in a franchise environment have expanded with franchisees all over the globe. To ensure the consistency of the quality of products or services provided by each franchisee, franchisors supply essential materials to franchisees for daily operations. A responsive replenishment system is needed for providing decision support to franchisors when they have to determine the order quantity for replenishment.

One of the main obstacles to achieving responsive replenishment in franchising is the need to collect and analyze huge sets of data originating from diverse franchisees in an efficient way so as to meet the rapidly changing market need. The emergence of cloud computing has eased such difficulties by providing location-independent platforms for collaboration. Valilai & Houshmand (2013) proposed a cloud-based platform to enable different manufacturing agents to collaborate with each other when they are distributed all over the globe. Their study has demonstrated the ability of cloud computing to create a universal platform for information exchange among different business partners which are geographically widely distributed. However, the unpredictable customer demand was not considered in their study which was also limited to the manufacturing industry.

In fact, with the widespread availability of the Internet in recent years, many common business applications such as Enterprise Resource Planning (ERP), Customer Relationship Management (CRM) and Supply Chain Management (SCM) have been delivered as cloud computing services which are accessible from a web browser. According to Rimal et al. (2011), these cloud-based business process management (BPM) systems have enhanced flexibility, deployability and affordability for complex enterprise applications. From a business perspective, one of the functions supported by cloud-based BPM systems is business analytics. Enterprises can use the vast amount of computing resources to understand customers, buying habits, supply chains and so on from voluminous amounts of data (Marston et al., 2011). Understanding these, could be helpful in determining responsive replenishment decisions. Specifically, to cope with the needs of franchising, these systems are useful as they are capable of tracking customer purchasing, monitoring levels of inventory, and reporting franchisee sales to franchisors instantly (Saleh & Kleiner, 2005). Because of the nearly real-time access to cloud computing power and data, franchisors using cloud computing are allowed to collaborate and adjust the flow of inventory with franchisees so as to meet fluctuating market demand responsively (Hugos & Hulitzy, 2011).

In addition, considering that one of the unique characteristics of franchising is the ease of rapid business expansion, it is believed that the high scalability of cloud computing can offer franchising more benefits, such as cost saving, apart from the provision of collaborative platforms. In a traditional franchise model, enterprises have to make large capital investments in plant and equipment so as to run their business. However, due to the fact that customer demand is increasingly unpredictable in today's volatile markets, enterprises with high fixed costs are much riskier than they used to be (Hugos & Hulitzy, 2011). As a result, any technologies which can turn fixed costs into variable costs are creating new opportunities for business survival. Cloud computing has been recognized as a promising technology for reducing operational and capital costs. Due to its pay-as-you-go cost structure, the cost of cloud computing resources is variable, depending on the usage amount (Grossman, 2009). This has lowered the cost of business entry and further eased the expansion of the franchise business model. Franchisors are allowed to scale their business according to demand under the cloud computing infrastructure. According to Espadas et al. (2013), this is done by creating a variable number of virtual machine instances depending on the application demands. Nonetheless, despite its capabilities in contributing a collaborative platform with high scalability but low costs, cloud computing deployed in franchise systems are scarce. Most studies investigated franchise contract terms (Klein, 1995; Vázquez; 2007; Lapiedra et al., 2012), franchise relationships (Blut et al., 2011; Lawrence & Kaufmann, 2011) and knowledge management in a franchise organization (Paswan & Wittmann, 2009; Minguela-Rata et al., 2010). To the best of our knowledge, research attention on how cloud computing improves franchising, has been limited.

On the other hand, considering that there are many uncertainties existing in a replenishment process, such as the procurement lead-time, quality control time from the moment when the order arrives until it replenishes the stock (Petrovic & Petrovic, 2001), having solely a cloud-based platform is not fully applicable for dealing with the uncertainties. Artificial Intelligence (AI) techniques are thus recommended as decision support tools. Fuzzy logic is effective in managing uncertainties as a rule base (Tso et al., 1999; Pham and Chen, 2002; Hung and Chung, 2006). A number of researchers have proven the ability of fuzzy logic in dealing with inventory control (Petrovic & Petrovic, 2001; Leung et al., 2003; Syed & Aziz, 2007; Dutta & Kumar, 2012; Tantatemee & Phruksaphanrat, 2012). The major similarities between these studies and the proposed approach in this paper are that the variables considered are described in linguistic terms formally defined as fuzzy sets, and their goals are to improve the replenishment process. However, there are some differences regarding the assumptions made in these studies. Syer and Aziz (2007) and Dutta and Kumar (2012) determined the optimal order quantity and the optimal total cost under the assumptions of constant demand and instantaneous replenishment. On the contrary, Leung et al. (2003), Petrovic and Petrovic (2001), and Tantatemee and Phruksaphanrat (2012) assumed that the demand was uncertain and the customer demand was confined to a single type of products. While Leung et al. (2003) determined the optimal inventory change, Petrovic and Petrovic (2001) determined the fill rate, the total holding cost and the regularity of replenishment orders. In this study, the proposed approach considers that the customer demand is uncertain and the replenishment quantities are received with a lead time. Furthermore, a critical difference between this study and the abovementioned work is that only this study considers the data collection method. The abovementioned papers did not focus any data collection tools or platforms, and the data inputted to their approaches were historical data or based on estimation. This can be a drawback in generating accurate and reliable suggestions for replenishment. On the other hand, cloud computing is deployed in this paper to build a collaborative platform for facilitating the data exchange process before decision making. Consequently, a vast amount of data from diverse sources can be collected in a nearly real-time manner to generate more updated results.

In summary, the deployment of cloud computing is creating new opportunities for franchise businesses. Cloud-based systems can act as a communication and coordination platform in which business units within the franchise business model can be connected with high scalability but low costs. The cloud-based responsive replenishment system (CRRS) in this study is designed in a way such that a cloud-based CRM application is used to help franchisors manage inventory while an AI technique, namely fuzzy logic, is applied to support their decision making for replenishment.

3. Cloud-based Responsive Replenishment System

The CRRS is designed to support CRM functions using cloud computing and to analyze data by fuzzy logic approaches to determine intelligent replenishment decisions. The system, as depicted in Fig. 1, is composed of two modules, namely Cloud-based Customer Relationship Management Module (CCRMM) and Intelligent Replenishment Module (IRM). The CCRMM involves customized CRM applications which are run on a hosted server by a service provider and are accessible by franchisees via the Internet. This eliminates the need to install and run the CRM application on the franchisees' computers, lowering the upfront costs. In order to collect data which are crucial for responsive replenishment decisions, the CCRMM allows franchisees to place replenishment orders and check stock availability via any interfaces connecting to the cloud. These individual data sets from franchisees are remotely stored in the cloud. Franchisors are able to access the consolidated data from the cloud-based CRM application for business analysis. With all the data managed in the cloud, the CCRMM acts as a common platform for information sharing among franchisees and franchisors. Franchisors are allowed to access the desired data stored in the cloud via a web browser without any integration with in-house applications. Data supporting their replenishment decisions are then transferred to the IRM where fuzzy logic is applied for data analysis. In the IRM, input data are fuzzified to obtain fuzzy solutions according to the stored expertise knowledge. Such knowledge can be obtained from the business analysis performed by franchisors and the knowledge is represented in terms of fuzzy rules so that fuzzy inference reasoning can take place. Because exact numerical values are used in replenishment decisions, defuzzification is performed for converting the fuzzy solutions into numerical values, for instance, in the percentage change in the inventory level. Details of each module are presented in the following sections.

3.1 Cloud-based Customer Relationship Management Module

This module requires franchisors and franchisees to purchase a pre-packaged CRM software application that is hosted remotely by a cloud service provider. The CRM application is customized to support various functions which can assist in the replenishment procedures and provide necessary information to the IRM. Under the cloud infrastructure, franchisees have the ability to access the CRM from various client interfaces or devices such as smart phones, laptops, PDAs, and web browsers. For instance, they can input new customer data, place replenishment orders and check and update the stock availability via their devices so that the data are sent and stored remotely in the cloud. These data sets, through input by individual franchisees, are consolidated and accessible by the franchisors who are connected to the cloud, in their attempt to analyze the business. Hence, with the use of this module, both franchisors and franchisees do not have to pay for any hardware, software and maintenance. Instead, the service provider pays for all equipment and maintenance. Furthermore, when the franchising business is expanded with new franchisees, the service provider adds extra computing resources as parts of the cloud. This provides more flexibility in operation for both franchisors and the provider.

As the CCRMM provides a collaborative and location-independent platform for information exchange among franchisees and franchisors, authorized users such as the franchisors and the management are allowed to have access to the desired data from diverse franchisees for business process management, including the replenishment process. In order to assist franchisors in formulating any replenishment strategies which are responsive to the actual market needs, critical data stored in the CCRMM, such as lead time, sales and the number of customers, which can influence the decisions, are extracted for transfer to the IRM for analysis.

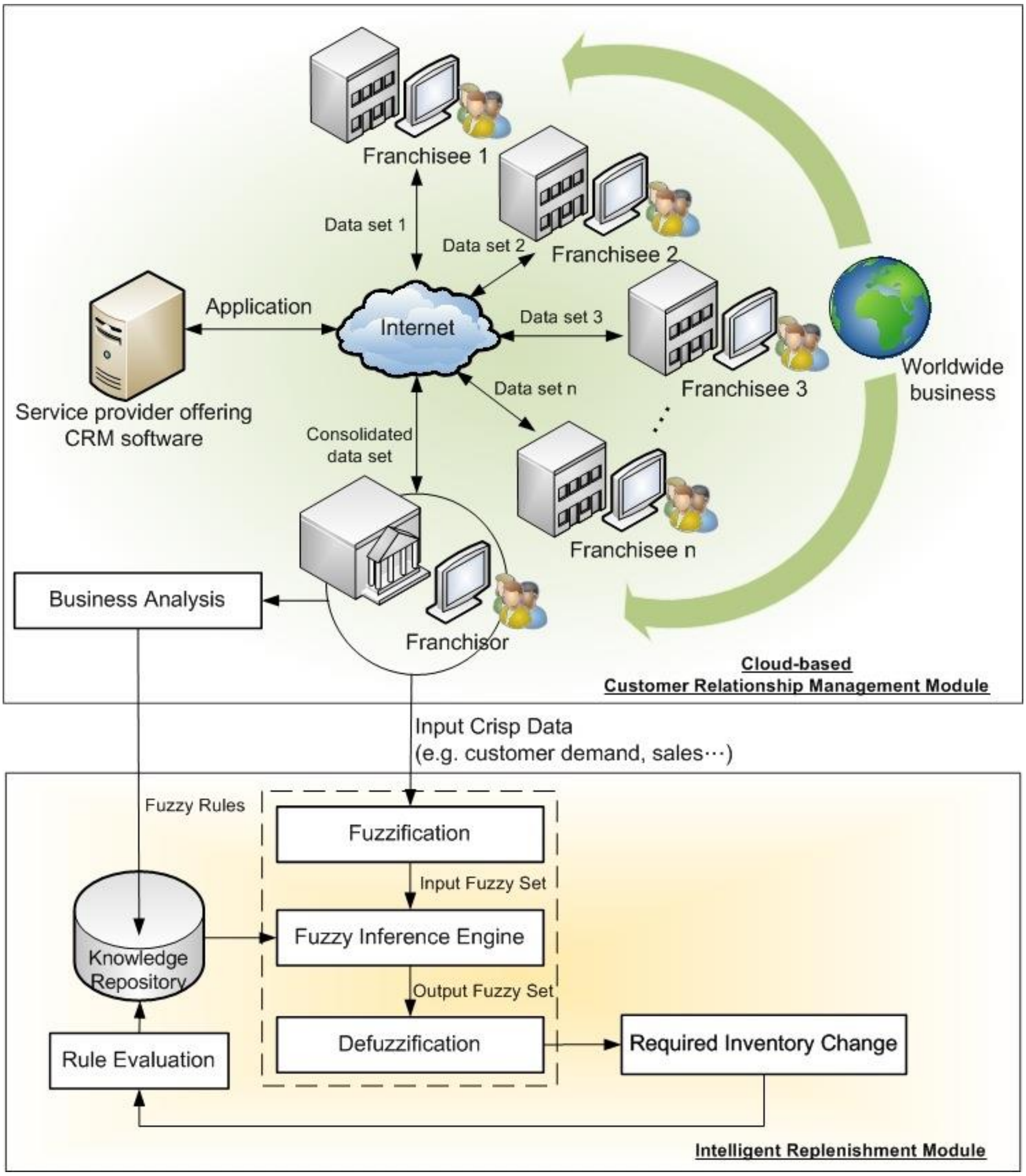


Fig. 1 – Architecture of CRRS

3.2 Intelligent Replenishment Module

The IRM is responsible for providing decision support to franchisors who are attempting to formulate responsive replenishment strategies which require the manipulation of data from diverse franchisees. With the integration of CCRMM and IRM, it is now convenient to gather all the necessary data for replenishment from franchisees. The IRM is a fuzzy system which consists of three main components: (i) fuzzification, (ii) fuzzy inference engine, and (iii) defuzzification. As the data input from the CCRMM are in crisp values, they are converted into fuzzy sets through fuzzification so that the concepts of fuzzy set theory can be applied. The fuzzification is based on the predefined classification of fuzzy regions and predicates of each input and on the membership functions. After the input fuzzy sets are obtained, they are sent to the fuzzy inference engine which is connected to a knowledge repository where the fuzzy rules are stored. The fuzzy rules are a set of "IF-THEN" rules representing the relationship between input and output parameters of the IRM. They are defined by franchisors based on their business analysis. To enhance the quality of the fuzzy logic results, the rules are evaluated regularly and adjusted if need be. Finally, after the fuzzy inference process, the output fuzzy sets are defuzzified for the conversion from fuzzy sets to crisp values. In the CRRS, the output parameter is defined as the required inventory change. Based on the output crisp value, franchisors are able to determine their order quantity for responsive replenishment.

4. Case Study

In this section, a case study is conducted in a Hong Kong-based education organization. Practical data provided by the case company, Dr I-Kids Education Center (DKEC), are used as a demonstration to show the feasibility of the proposed system. The rationale for selecting DKEC as a case company is that it is considered as a good representation of a particular industry operating in a franchise business model. In addition, the frequent changes in education policies have been an obstacle for franchisors in the education industry in achieving responsive replenishment.

4.1 Case Overview

In today's knowledge economy era, much attention has been given to the education industry as it has a great impact on how the next generation gains knowledge. In particular, Hong Kong's Education Industry has undergone several reformations after Hong Kong's return to China in 1997, though its education policies remain controversial. In 1998, the adoption of Cantonese, the native language as a medium of instruction was implemented. This meant that many teaching and learning materials had to be translated from English into Chinese. In 2012, a new academic system leading up to the Hong Kong Diploma of Secondary Education Examination (HKDSE), was implemented. Students are expected to complete three years of junior secondary education followed by three years of senior secondary education (Hong Kong Examinations and Assessment Authority, 2013). They no longer had to sit for the Hong Kong Certificate of Education Examination (HKCEE) or the Hong Kong Advanced Level Examination (HKALE). Teaching materials for the HKCEE and HKALE thus became obsolete, while new materials for HKDSE had to be published.

In addition, because of the frequent changes in the education policies, teachers and students are facing difficulties in adapting to the new curriculum and assessment methods. Numerous education organizations, in the form of tutorial schools and education centers, have entered into the education industry to help students improve performance in school and in examinations. To increase their market share within a short period of time, they have taken the role of a franchisor and have established different branches which can operate individually in a franchise model. To support daily operations, they have to manage not only the needs of end customers, but also that of their franchisees. One of their major tasks is to ensure that there are sufficient teaching materials for franchisees. However, the demand for teaching materials is hard to forecast due to unpredictable changes in the industry, making it difficult to determine the inventory levels. The risk of having high inventory levels in the education industry is greater than that in any other industry as the time when stocks become obsolete is unknown, depending on the policies launched by the government.

4.2 Company Background

Dr I-Kids Education Center (DKEC), established in 2004, is a one of the largest education organizations in Hong Kong, focusing on preschool to elementary education. Its teaching courses range from training in regular homework tutorial and examination skills to fundamental language competence training. It operates 22 tutorial centers in Hong Kong, 19 of which are franchised. Its business is still expanding at a rapid rate with new franchisees all over the world. Specifically, the management of DKEC has decided to enter to the China market within three years.

In the education industry, the quality of teaching materials is of great importance as it will affect the loyalty of their customers, i.e. students. Therefore, DKEC, as a franchisor, supplies teaching materials to franchisees with the aim of ensuring consistency of the education services it offers in its diverse branches. While the business has been expanding, an important problem that DKEC has to address is how to replenish the required teaching materials to different franchisees responsively. In its current practice, DKEC publishes its own teaching materials such as Chinese, English and Mathematics exercises for primary students and mock papers for public examinations. Apart from these, DKEC orders extra materials, such as Cambridge textbooks from overseas, to cater for the needs of their students. The existing replenishment process in DKEC is shown in Fig. 2. It starts with the enrollment forms from students to the franchisees. When the franchisees receive enrollment requests from students, they check if there are sufficient teaching materials for fulfilling the demand created by the enrollment. If there are sufficient teaching materials, they will distribute them to the students immediately. Otherwise, they will send replenishment requests to the franchisor. After the franchisor receives orders from franchisees, the back office counts the quantity of inventory on-hand. If there are enough teaching materials, the required materials are delivered to the franchisees. On receipt of the materials the franchisees endorse the delivery receipts. The entire process ends when the back office receives the delivery receipts. Nevertheless, if the back office finds that there are not sufficient teaching materials to complete the replenishment request from franchisees, the staff place purchase orders with the publishers and deliver the teaching materials to franchisees after receiving the teaching materials from the publishers.

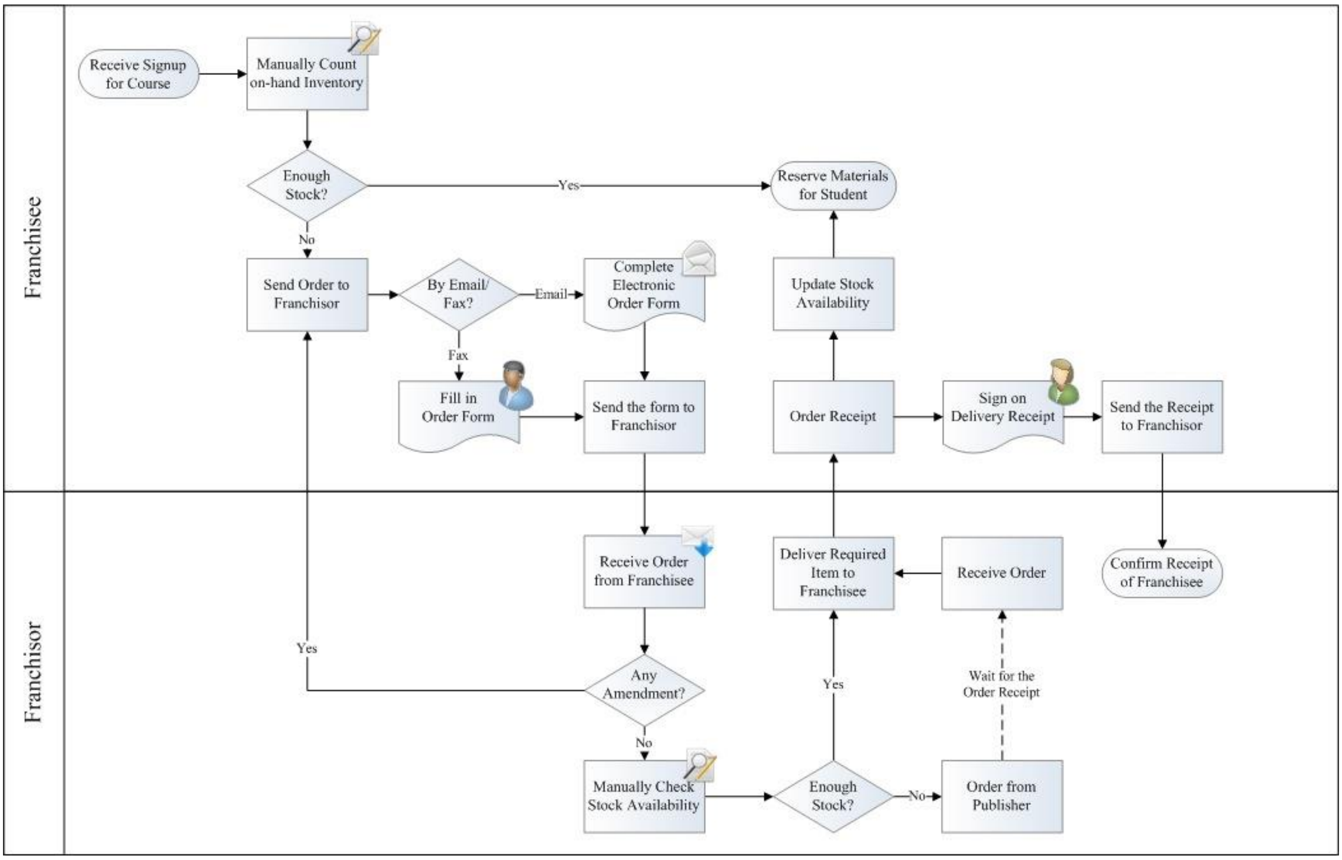


Fig. 2 – Existing replenishment process in the case company

4.3 Existing Problems Faced by the Company

It was observed that the existing replenishment process in the case company has two problems:

(i) Low visibility of information between the franchisor and franchisees

The franchisor and franchisees do not know the amount of inventory kept by other franchisees on a real-time basis. Occasionally, some franchisees might keep high inventories while some might suffer from low inventories. The lack of a collaborative platform has lowered the information visibility, which eventually results in ineffective inventory management. When the franchisor has to consolidate data from all franchisees, a lot of time and effort have to be spent on data collection before a centralized replenishment decision can be made, As a result, the replenishment lead time is long, affecting customer satisfaction.

(ii) Reliance on human experience in replenishment decisions

Due to the low visibility of inventory related information, the franchisor cannot perform accurate demand forecasts. Replenishment decisions are solely based on the experience of individual staff. Therefore, decision quality cannot be guaranteed and the chance of having unwise decisions is high. As the customer demand is getting more unpredictable in the relentless market, this current human-driven decision making process is hindering the company from achieving responsive replenishment.

In order to solve the above problems, the CRRS is implemented in the franchise system of DKEC. In addition to DKEC, some of the franchisees are invited to take part in the system implementation by adopting a cloud-based CRM.

4.4 Application of the CRRS in Education Business

The architecture of the CRRS implemented in the franchise system of DKEC is shown in Fig. 3. The CCRMM acts as a collaborative platform to connect business units in the franchise system. Information exchange is immediately allowed where there is access to the cloud. The customized CRM application supports such functions as daily operation of the branch, stock management, and replenishment as well as searching for information. With these supporting functions, the replenishment process is restructured, as shown in Fig. 4, with increased visibility of inventory information between the franchisor and franchisees.

Firstly, franchisees can register new students via the CCRMM. The student information is stored remotely in the cloud. After student enrollment, franchisees access the CRRMM in order to know if sufficient teaching materials can be delivered to the students. They are allowed to check the stock availability in each branch. If there is insufficient inventory, franchisees order the required items through the system instead of using fax and email. They will receive notification from the franchisor when their orders are received. From the CCRMM, the franchisor immediately knows if there is sufficient inventory to meet the demand of franchisees. If possible, the franchisor arranges the delivery. Otherwise, the franchisor places replenishment orders with publishers and simultaneously notifies the franchisees through the system. The operation flow of the CCRMM is shown in Fig. 5. The visibility of the inventory in diverse franchisees is increased as data from all over the globe are stored remotely in the cloud. Nevertheless, using the CCRRMM solely may not be enough to help the franchisor deal with the uncertain customer demand. In view of this, the replenishment decisions are supported by the IRM where fuzzy logic approach is applied.

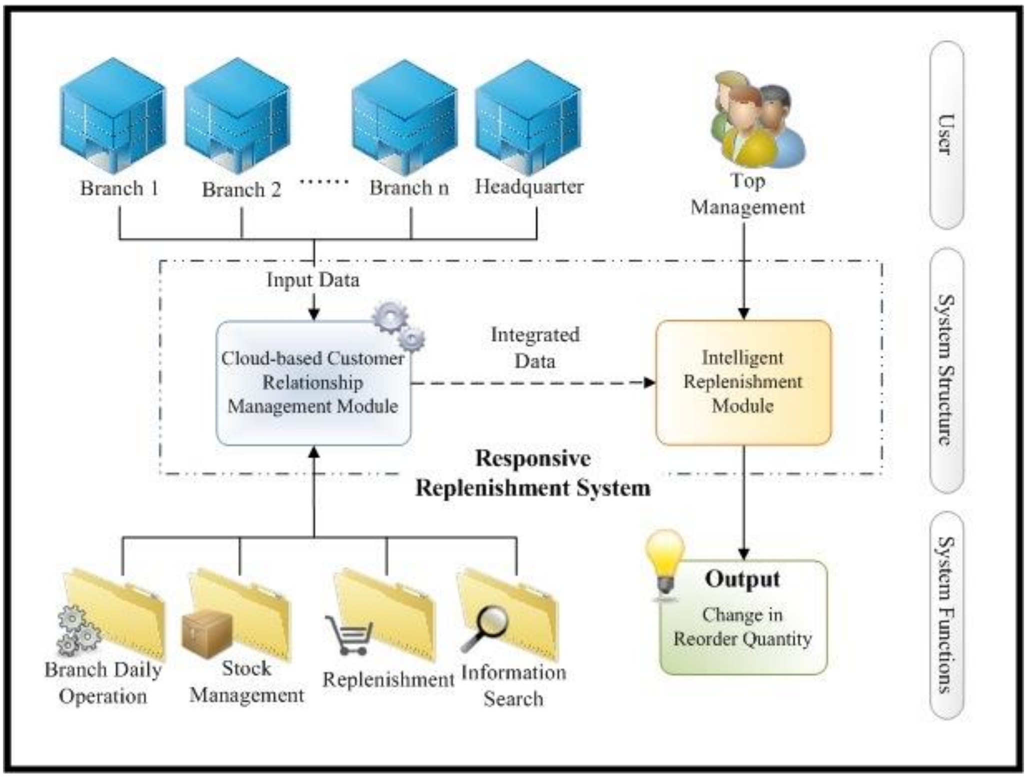


Fig. 3 – The architecture of CRRS in the franchise system of the case company

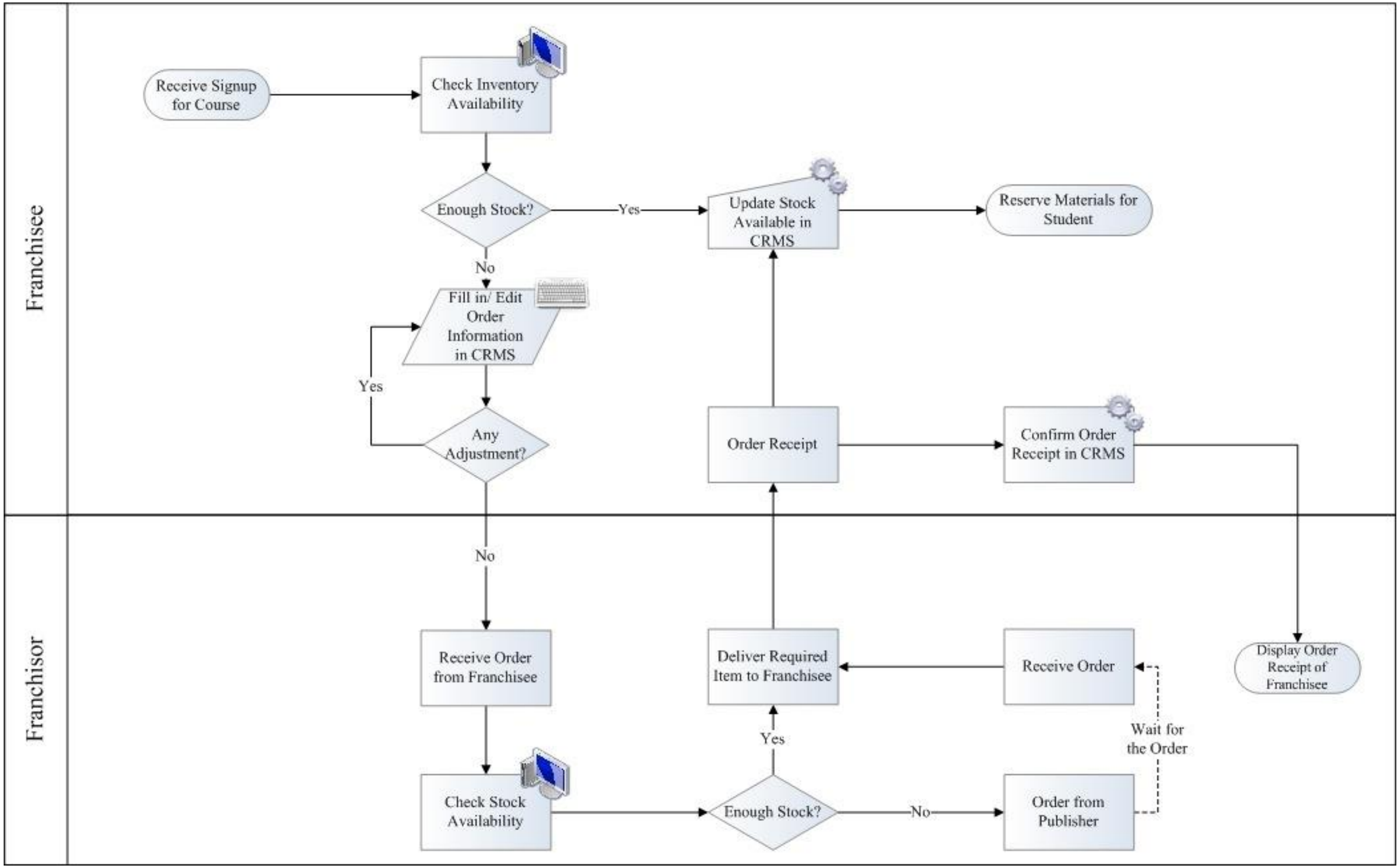


Fig. 4 – Restructured replenishment process with the use of CRRS

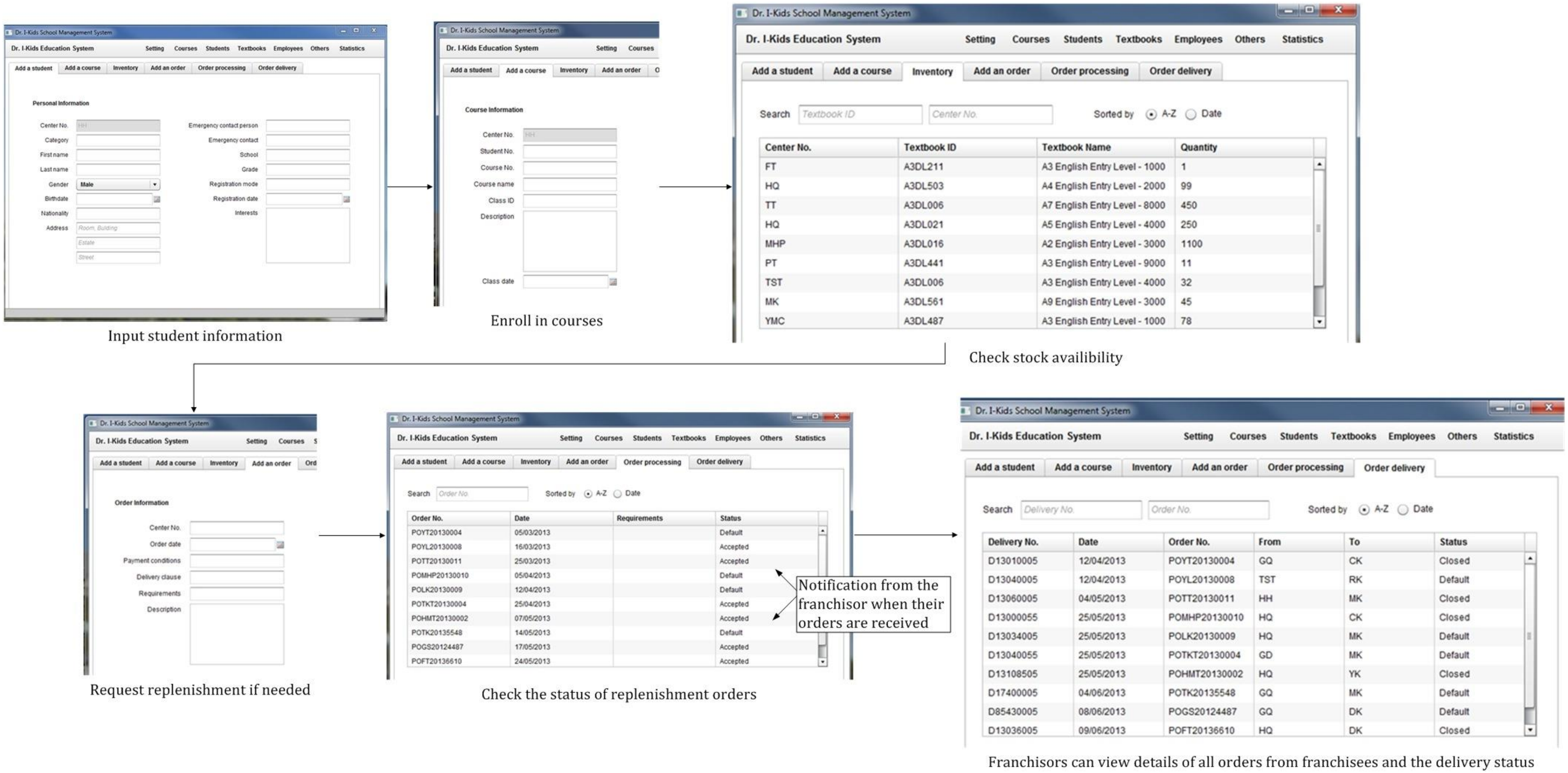


Fig. 5 – Operation flow of the CCRMM

Before the adoption of IRM, knowledge acquisition from domain experts is performed in DKEC. Firstly, domain experts are required to identify both input and output parameters for replenishment decisions, as shown in Fig. 6. For each parameter, its fuzzy characteristics are defined in terms of the fuzzy set and membership function. In this case study, only the most popular teaching materials are referred to in the pilot run of the system. However, parameters related to other types of teaching materials may possess different fuzzy characteristics. It is thus necessary for the domain experts to judge whether the fuzzy characteristics of the parameters, such as the membership functions, are suitable for other teaching materials before they expand the scale of the system to a global one. In addition, with the real-time information provided by the CCRMM, the franchisor can perform business analysis effectively, which is useful for defining fuzzy rules to indicate the relationship between the input and output parameters.

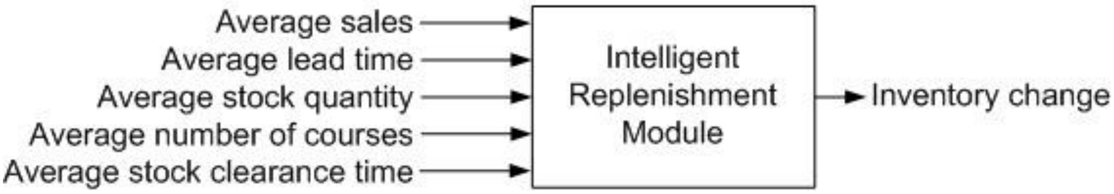


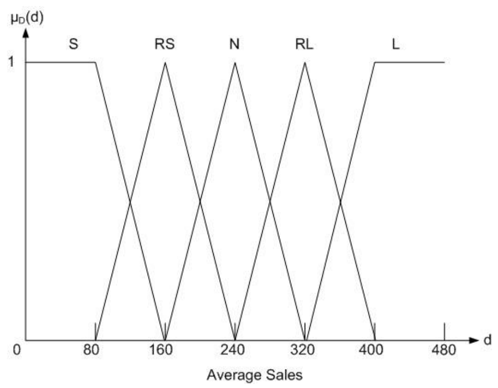
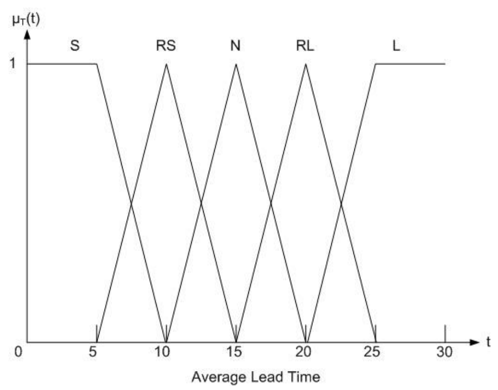
Fig. 6 – Input and output parameters of IRM

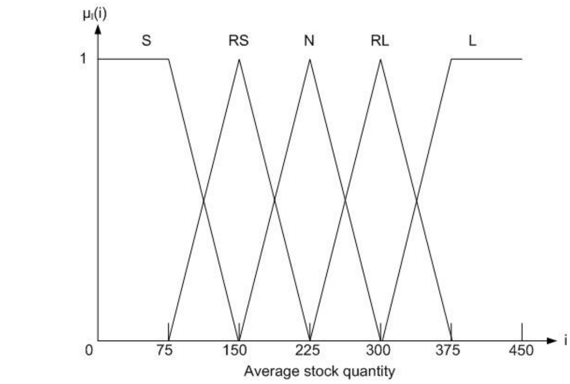
In order to demonstrate how fuzzy logic is used for supporting responsive replenishment, a case scenario is used for demonstration. Fuzzy sets and membership functions of the parameters used in the case scenario are shown in Table 1. In order to determine the fuzzy sets and the membership functions, the domain experts were firstly invited to define linguistic terms and the universe of discourse of each parameter. Compared to other methods, the fuzzy logic approach uses qualitative descriptions to provide quantitative values. Therefore, it is essential to determine some conventional linguistic terms for describing the parameters. There is no restriction on the number of linguistic terms for each parameter, however, the linguistic terms determined have to be easily interpreted by the domain experts, otherwise, there will be difficulties when constructing a set of fuzzy rules. In addition, domain experts have to define a range of the values in which there are no clear-cut boundaries to associate most values to one single linguistic term. Within this range, membership functions are positioned in such a way that the input values can be associated with more than one complementary membership function. The choice of membership function is based on subjective judgment, and the initial values rely heavily on trial and error methods. Considering that most domain experts have limited technical knowledge, only triangular and trapezoidal membership functions are provided for their selection. It is believed that people who lack AI knowledge will find it easier to understand triangular and trapezoidal membership functions, compared to other smooth functions such as Gaussian functions. Furthermore, since the suggested inventory change is obtained by rounding up the defuzzified outputs, precise membership function positioning is not essential in this case. Therefore, though the choice of membership function becomes limited, the accuracy of the system will not be significantly affected.

There are 5 linguistic terms to describe each of the five input parameters. If every combination of the parameters in different linguistic terms has to be considered in the rules, there will be 5^5 = 3125 rules generated, which is time consuming and not very practical for the case study. In view of this, there are no constraints on the number of parameters appearing in a rule. If the number of parameters considered in a rule is too large, the chance of having inconsistencies between multiple experts will also be high. In this case study, domain experts have meetings and discussion to generate relevant rules, and a total of 445 rules are obtained based on their opinions. The rules are then verified by the management, and fine-tuning of the individual rules is performed, if needed. If there are any inconsistencies among the rules, a discussion among domain experts is conducted again until they reach a consensus on the content of the rules.

Given that input crisp values of (i) average sales and (ii) average lead time, are 220, and 16, respectively, the resulting membership values of the input fuzzy sets are calculated as shown in Fig. 7. When the value of the average sales is 220, it has a membership value of 0.25 for Relatively Small and 0.75 for Normal. Similarly, when the value of the average lead time is 16, it has a membership value of 0.2 for Relatively Long and 0.8 for Normal. Given that there are two rules fired in the fuzzy inference engine as shown in Fig. 8, the composite membership values in each rule is the minimum of the membership values among the input fuzzy sets. Thus, the composite membership value of Rule 1 is the minimum of the values of 0.25 and 0.8, which is 0.25. Similarly, the composite membership value of Rule 2 is the minimum value of 0.75 and 0.2, which is 0.2.

Table 1 – Fuzzy sets and membership functions of parameters

Parameter	**Fuzzy sets**	**Membership functions**
Average Sales (D)	D = {S, RS, N,RL, N} where S is small, RS is relatively small, N is normal, RL is relatively large and L is large	
Average lead time (T)	T = {S, RS, N,RL, N} where S is short, RS is relatively short, N is normal, RL is relatively long and L is long	

<table>
<tr><td>Average stock quantity
(I)</td><td>I = {S, RS, N,RL, N} where S is small, RS is relatively small, N is normal, RL is relatively large and L is large</td><td>
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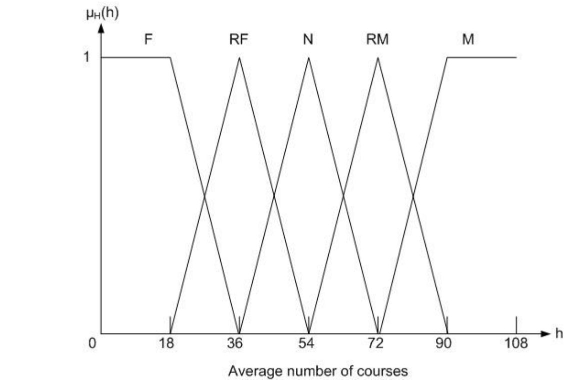
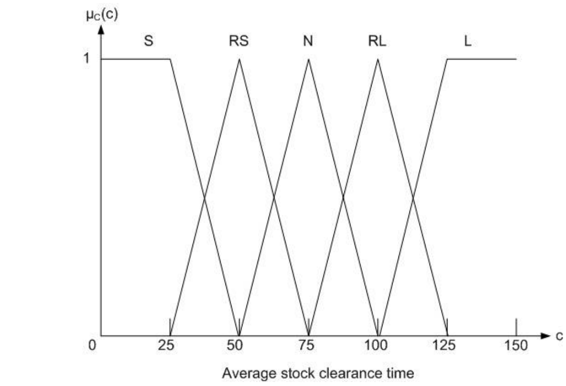
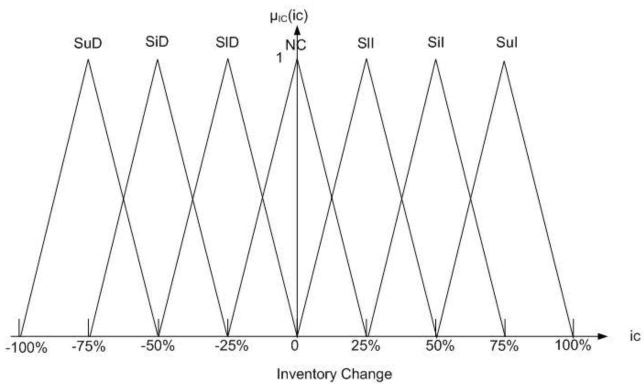
<tr><td>Average number of courses
(H)</td><td>H = {F, RF, N,RM, M} where F is few, RF is relatively few, N is normal, RM is relatively many and M is many</td><td>
</td></tr>
<tr><td>Average stock clearance time
(C)</td><td>C = {S, RS, N,RL, N} where S is short, RS is relatively short, N is normal, RL is relatively long and L is long</td><td>
</td></tr>
<tr><td>Inventory change (IC)</td><td>IC = {SuD, SiD, SlD, NC, SlI, SiI, SuI} where SuD is substantially decreased, SiD is significantly decreased, SlD is slightly decreased, NC is no change, SlI is slightly increased, SiI is significantly increased and SuI is substantially increased</td><td>
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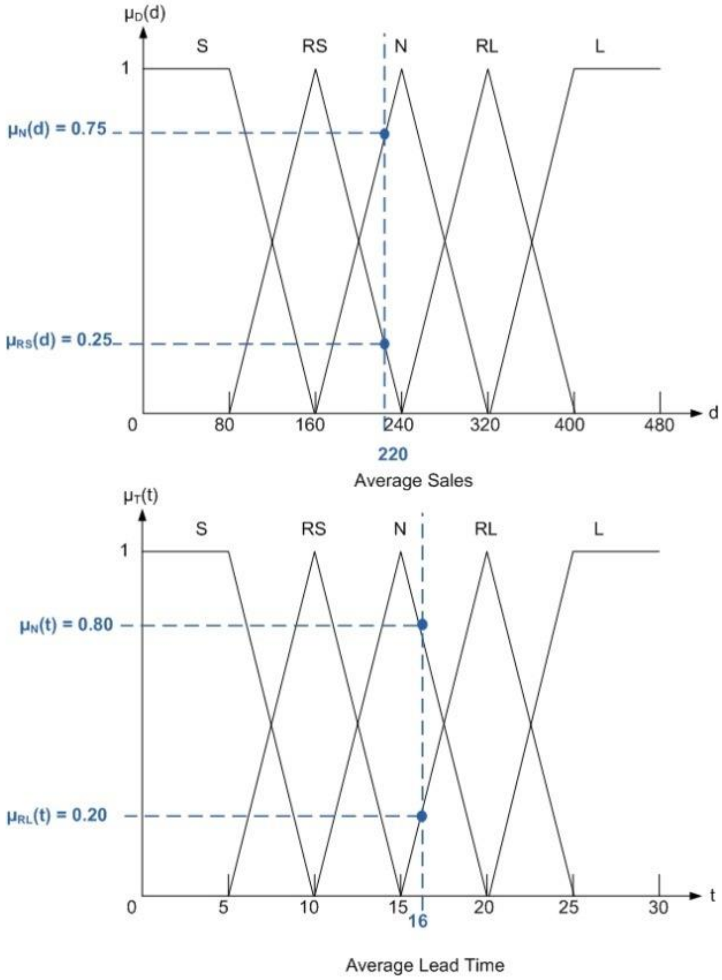

Fig. 7 – Membership values of input fuzzy sets

Rule 1	
IF	Sales **IS** *relatively small* **AND**
	Lead Time **IS** *normal*
THEN	Inventory change **IS** ***no change***

Rule 2	
IF	Sales **IS** *normal* **AND**
	Lead Time **IS** *relatively long* **AND**
THEN	Inventory change **IS** ***slightly increased***

Fig. 8 – Examples of fuzzy rules

Based on the composite membership value, an individual fuzzy region of the output fuzzy set is constructed in each rule. A consequent fuzzy region is then obtained by combining the individual fuzzy regions in all rules as shown in Fig. 9. The center of area method is responsible for converting the output fuzzy set into a crisp value. It returns the center of area (Y) of the consequent fuzzy region by the following equation:

$$Y = \frac{\sum_{i=1}^{N} W_i \overline{C_i A_i}}{\sum_{i=1}^{N} W_i \overline{A_i}}$$

where *w*, *C* and *A* denote the weight, center of gravity and area of the individual fuzzy region of rule *i*, respectively. In the case scenario, the center of the area of the consequent fuzzy region is 10.9. Therefore, it is suggested that the franchisor increase its inventory by 10.9%.

In the CRRS, the IRM function is supported by MATLAB Fuzzy Logic Toolbox as the fuzzy logic application. Fuzzy sets, membership functions and a set of fuzzy rules are initially input into the MATLAB Fuzzy Logic Toolbox. For instance, the obtained fuzzy rules can be input into the Toolbox using the rule editor as shown in Fig. 10. When a set of data, as listed in Table 2, is collected from the CCRMM and input into IRM, fuzzy logic results generated by the MATLAB Fuzzy Logic Toolbox suggest that the inventory should be increased by 46.1% as shown in Fig. 11.

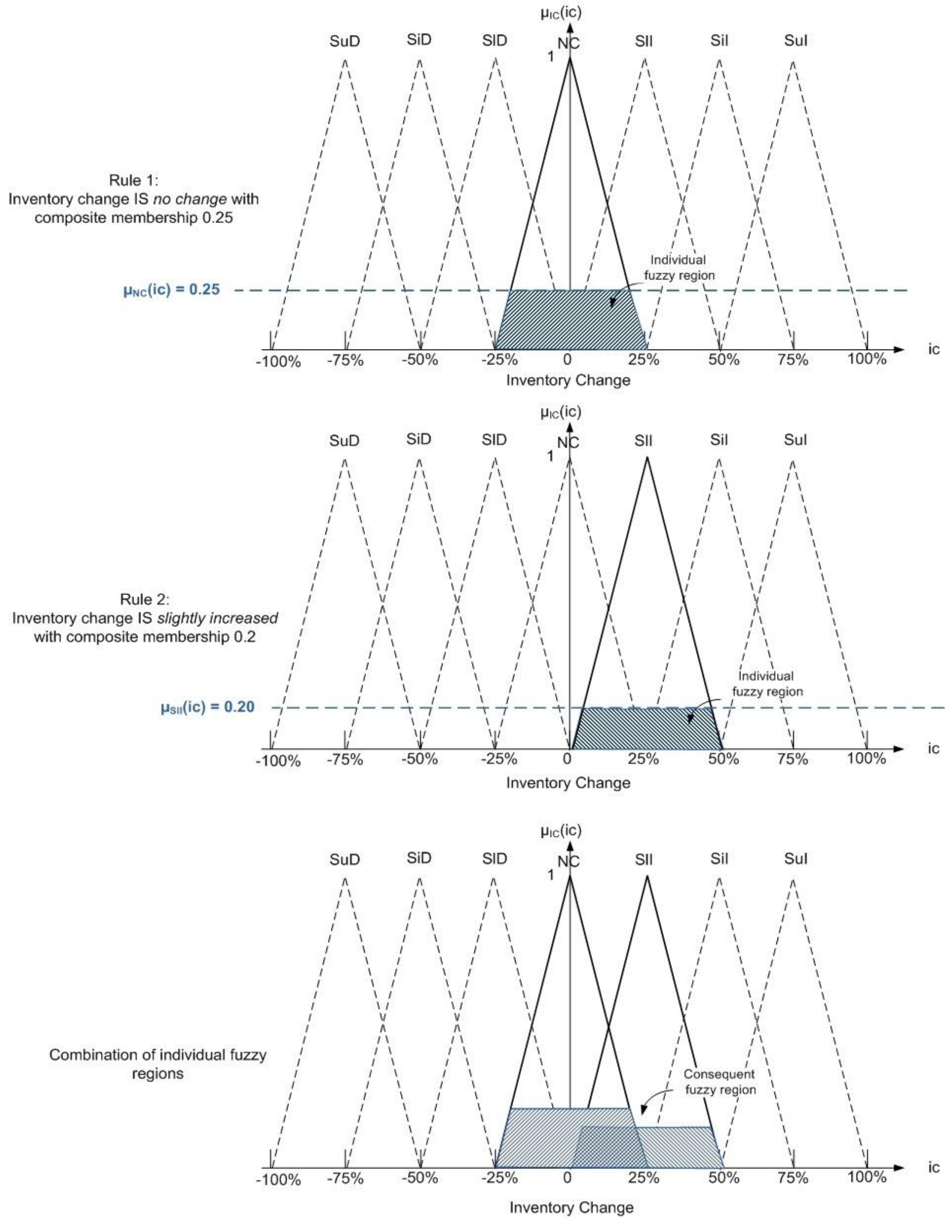

Fig. 9 – Consequent fuzzy region of the output fuzzy set

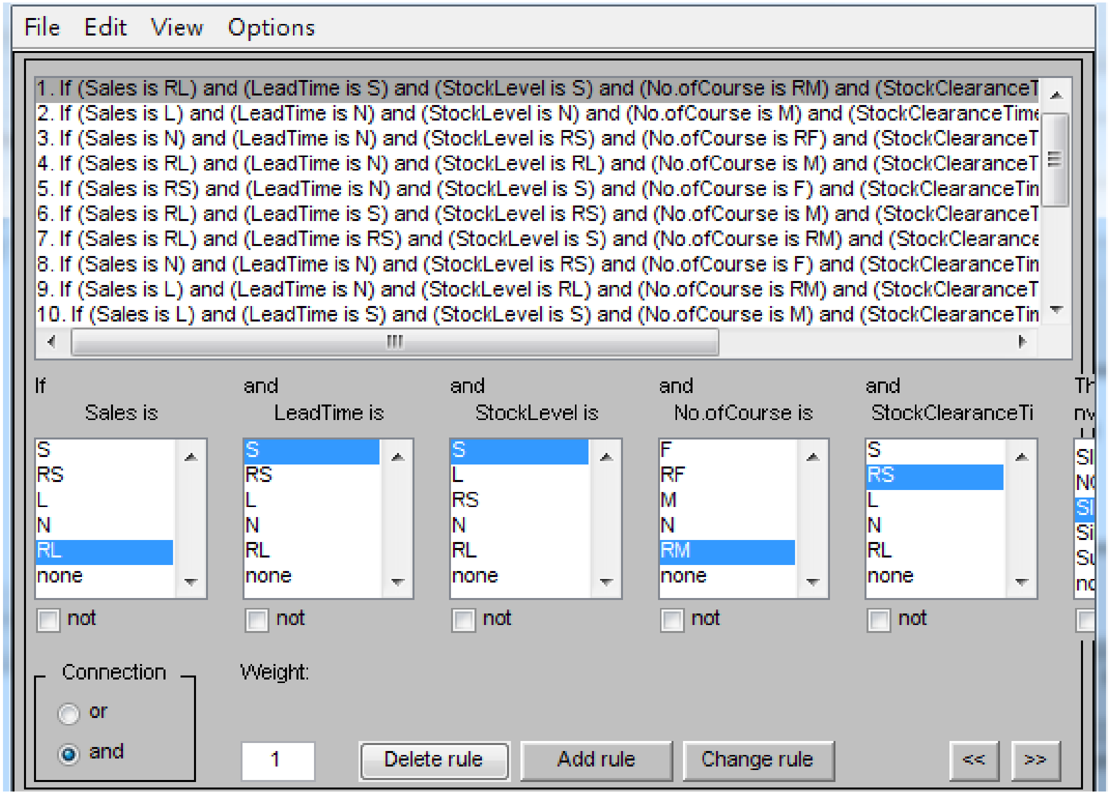

Fig. 10 – Rule editor in MATLAB Fuzzy Logic Toolbox

Table 2 – Data collected from CCRMM for transfer to IRM

Input Parameter	Crisp Value
Average Sales (unit/month)	351
Average lead time (day/order)	11
Average stock quantity (unit/month)	131
Average number of courses (courses/month)	80
Average stock clearance time (day/order)	61

5. Results and Discussion

Based on the feedback from the management level, the replenishment suggestions determined by the CRRS has proven to be helpful in optimizing the inventory level and responding to the global fluctuating customer demand. Three key performance indicators (KPIs), namely (i) inventory cost, (ii) replenishment cycle time, and (iii) out-of-stock occurrence are selected for measuring the effectiveness of the system. According to the historical data, the average values of each KPI over the past year before system implementation are calculated and serve as the benchmarks when evaluating the system improvement. After the implementation of the CRRS, the KPIs are measured every three months. During a nine-month pilot run of the system in the case company, the benchmarks and the KPIs averaged over 3 months, 6 months and 9 months after the implementation are compared. Consequently, the evolution of KPI improvement over time can be monitored. The improvement achieved by the use of the CRRS is shown in Table 3.

The replenishment cycle time is improved due to the use of the cloud platform. Since the cloud platform shortens the information exchange time between franchisees and the franchisor, the replenishment cycle time is improved, in particular, the time for gathering essential data from diverse franchisees is eliminated. On the other hand, the inventory cost and the out-of-stock occurrence are improved due to the decisions suggested by the fuzzy rule-based system. Based on the fuzzy rules stored, the franchisor is provided with decision support in determining a nearly optimal inventory change. This can prevent the franchisor from keeping excessive inventory, and thus the inventory cost can be reduced. In addition, having an appropriate amount of inventory, the franchisor can provide replenishment to the franchisees within a shorter time, if needed. As a result, the out-of-stock occurrence is reduced.

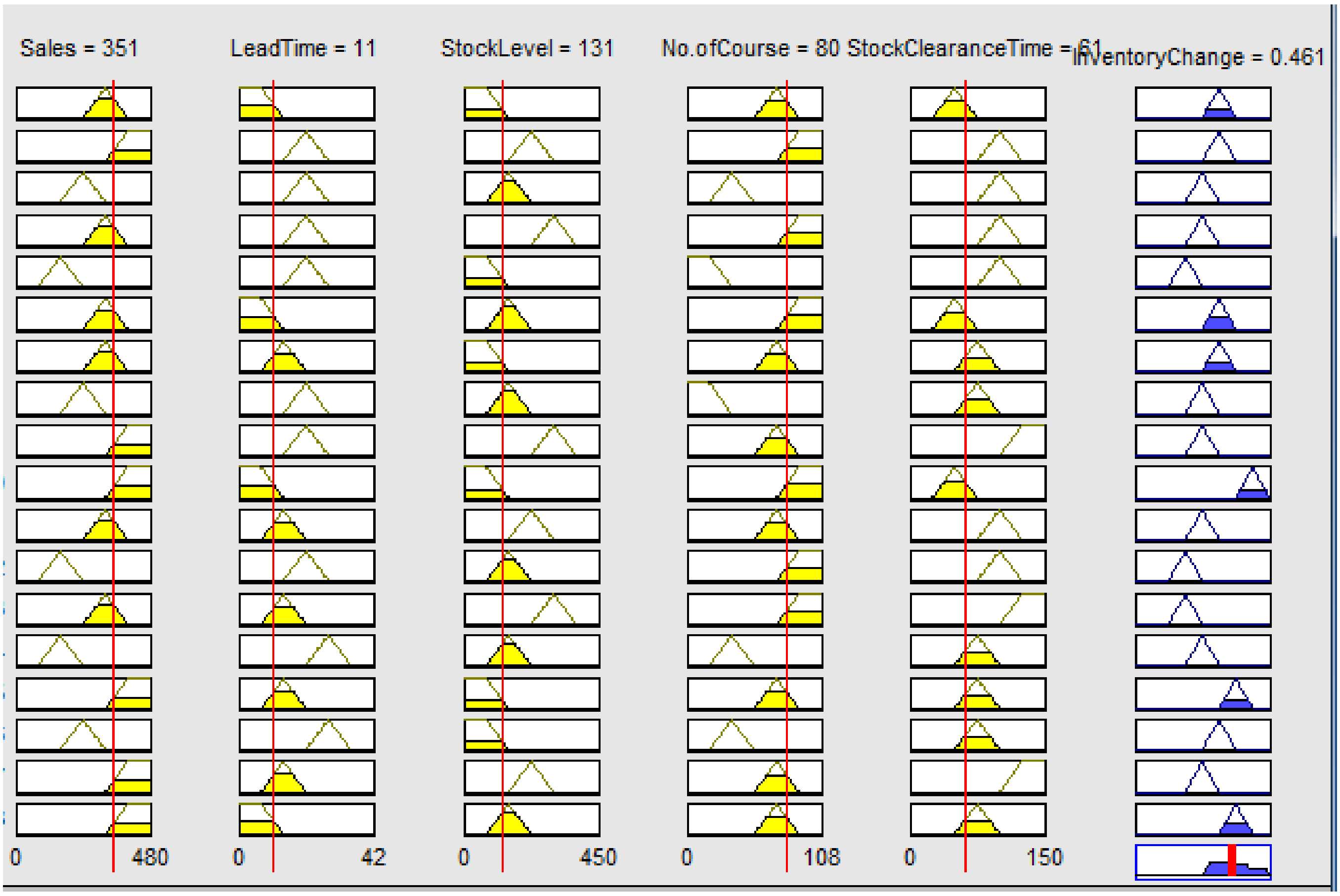

Fig. 11 – Inventory change determined by MATLAB Fuzzy Logic Toolbox

Table 3 – Percentage of improvement achieved by the use of the CRRS

KPI	3 months	6 months	9 months
Inventory cost	3.9%	5.7%	6.3%
Replenishment cycle time	11.6%	15.2%	18.1%
Out-of-stock occurrence	7.1%	12.0%	14.6%

It can be seen in Table 3 that substantial growth in the improvement is achieved in terms of the inventory cost, replenishment cycle time and out-of-stock occurrence.

Specifically, the inventory costs are improved by 3.9%, 5.7% and 6.3% after the three-month, six-month and nine-month pilot run of the system, respectively. At the same time, the replenishment cycle times are improved by 11.6%, 15.2% and 18.1% after the three-month, six-month and nine-month pilot run of the system, respectively. The out-of-stock occurrences are also improved by 7.1%, 12.0% and 14.6% after the three-month, six-month and nine-month pilot run of the system, respectively. Based on the results achieved, the benefits offered by the CRRS are discussed below.

(i) Reduced inventory cost

After the adoption of the CRRS for a nine-month period of time, the operation cost improved by 6.3%. Such an improvement is contributed to by the reduction of surplus inventories by each franchisee. Since the CRRS visualizes the inventory status in each franchisee, franchisors are able to make wise decisions, supported by fuzzy logic approaches, without incurring high inventory costs for the franchisees. Compared with the decisions made by individuals, the decisions determined by the CRRS contain no biases and are of better quality. In addition to the reduction of the inventory cost, the chance of having human errors in inventory management is lowered, as the inventory related data in diverse franchisees are stored in the cloud remotely. This high visibility of data allows the franchisors to conduct a reliable business analysis. Their feedback is useful for evaluating the fuzzy rules used in the IRM, thus improving the quality of decisions.

(ii) Shortened replenishment cycle time

As the CCRMM provides a collaborative platform for information exchange among franchisees and franchisors, the efficiency of replenishment is significantly increased. Firstly, the entire replenishment cycle time is improved by 18.1% as time spent on data collection from diverse franchisees and communication between the franchisor and franchisees is greatly reduced. Franchisors are allowed to gather essential data for replenishment whenever they have access to the cloud in which all the data are stored remotely. In addition, the decision making time for replenishment is shortened with the adoption of fuzzy logic approaches in the IRM. The traditional human-driven decision making process, which is a time-consuming task, is now eliminated by the CRRS which can provide franchisors with suggested inventory changes within a few seconds. Thus, the overall replenishment efficiency is improved with a shortened replenishment cycle time.

(iii) Reduced out-of-stock occurrence

In today's time-sensitive markets, it is important to enable customers to get their desired products or services without a long waiting time. Considering that the CRRS improves the replenishment decision quality, out-of-stock can be avoided, with its occurrence reduced by 14.6%. Franchisees are given sufficient inventory for fulfilling their customer demand so that customers can get easy access to their desired items, enhancing their satisfaction. Meanwhile, the use of cloud computing also enhances the franchisees' satisfaction as their upfront costs for business are reduced. The customized CRM application in the CCRMM hosted by the cloud service provider can eliminate the need to pay for any hardware, software or maintenance. The reduction of fixed costs helps reduce the risk for franchisees operating the business. Hence, the satisfaction of franchisees is improved as well.

In this case study, the continuous business improvement is contributed by the regular evaluation of the fuzzy rules during the nine-month period. In the early stage of the application of CRRS, the fuzzy rules are solely defined by domain experts. They cannot be fully responsive to the actual market need. For instance, domain experts might tend to be rational and not reveal inconsistency even though it exists in reality. Therefore, it is essential to evaluate the rules regularly so that the rules can be adjusted and made responsive to the actual market need. When the quality of the rules is improved, the rules become more adaptive to the actual business environment. As a result, based on the improved rules, decision makers are allowed to determine better order quantity solutions, improving the inventory cost, and replenishment cycle time, as well as out-of-stock occurrence in long term.

In addition, rule assessment and validation is carried out in the company on a monthly basis based on the feedback from the franchisees. This allows the fuzzy rules to be recursively challenged and revised until better ones are obtained. For instance, if the franchisees observe that an out-of-stock situation always occurs after system implementation, it implies that the rules stored could be underestimating the replenishment quality required. Based on the out-of-stock level reported by franchisees, the franchisor can extract relevant rules and assess them. In particular, changing the linguistic terms appearing on the rules and adjusting the positioning of the membership functions can be done for improvement. After making changes to the rules and inputted them into the MATLAB Fuzzy Logic Toolbox, the franchisor can obtain a new solution. The new solution is then referred to in the actual replenishment process for validation. If improvements are observed in terms of KPIs, it is believed that the quality of rules is improved. On the other hand, even though improvements are observed, it does not imply that all rules are useful. Therefore, it is necessary to improve the rule base by removing insignificant ones. The elimination of the non-firing rules after validation reduces the total number of fuzzy rules from 445 to 421. Subsequently, it is found that the generated outputs after rule elimination are identical to those before rule elimination. This illustrates that eliminated rules are redundant or not significant to the company's replenishment process. With fewer fuzzy rules stored in the system, it is expected that future rule assessment and the validation process will become less complicated.

In fact, various types of uncertainties and imprecision that inherently exist in real inventory problems cannot be appropriately treated by the usual probabilistic models (Syed & Aziz, 2007). Uncertainties in the replenishment process include procurement lead-time, and quality control time from the moment when the order arrives until it replenishes the stock (Petrovic & Petrovic, 2001). It thus becomes more convenient to solve problems under uncertain environments with fuzzy set theories instead of probability theories (Jain, 1976). Unlike classical set theories that classify the elements of the set into a crisp set, fuzzy sets have an ability to classify elements into a continuous set using the concept of degree of membership (Tahera et al., 2008). Therefore, compared with non- fuzzy-based systems, fuzzy-based systems are capable of imitating human capability in making decisions under uncertainty. In a franchise business model, the impact of uncertainties in the market demand is more obvious because demand in both domestic and overseas markets has to be catered for. Therefore, a fuzzy-based system is a better choice to support replenishment decisions than a non-fuzzy-based system. In addition, unlike simple rule-based systems, fuzzy-based systems store knowledge in terms of fuzzy rules. This allows the uncertain customer demand to be described by vague linguistics terms such as "high" and "low". It is an advantage for applications in real-life situations as the knowledge is represented in a structure which can be easily understood by system users, such as the warehouse operators. In real-life situations, there are two ways for applying the proposed system when more complex processes or materials are involved. Firstly, considering that the number of rules will increase when the variables become more numerous, the rule base of the system has to be more extensive so as to deal with complex information. However, this will require a more frequent rule evaluation to maintain the quality of rules. Secondly, the structure of the rules can be modified by adding more variables to the existing rules instead of additional rules. In this way, the complexity of the rules will be increased while the size of the rule-base of the system can remain the same. In addition, in order to deal with the increased complexity of processes and data, there has been extensive discussion in the literature about the learning of fuzzy rule-based systems from data. In fact, it is an option for industrial practitioners to incorporate the system with AI tools for automatic learning when more complex processes or materials are involved. For example, genetic algorithms (GAs) can be used to optimize the fuzzy rules (Cordón et al., 2001; Herrera, 2008). After encoding the rules into chromosomes, GAs generate new solutions by performing a random change on chromosome information. Only rules supporting decisions with better quality will be automatically stored in the rule-base, providing the system with a learning capability to enhance the quality of decisions in the long run.

6. Conclusions

In this paper, a cloud-based responsive replenishment system is introduced for supporting replenishment activities in a franchise business environment. To have replenishment responsive to the rapid market changes, understanding of customer demand is important but this is, as yet, difficult to achieve in a global business, with customers coming from different geographic locations. To overcome this challenge, the system applies cloud computing to ease the difficulties in managing operational data in a location-independent way. The cloud-based platform allows a nearly real-time consolidation of essential data for the application of fuzzy logic with the aim of determining the necessary inventory changes. Regular adjustments of the fuzzy rules are performed according to the actual business environment so that the knowledge stored in the system for decision support purposes is recursively improved, assuring the responsiveness of the system. There are two main contributions made by this study. First, cloud computing is adopted to create a universal platform connecting both franchisees and franchisors. Previously, how cloud computing can be applied in franchising has never been investigated. The case study presented in this paper has proven the capabilities of cloud computing in enabling effective and efficient information exchange within a franchise business model. Second, this study demonstrates the incorporation of cloud computing and AI techniques in providing decision support for franchisors in their attempt to make responsive replenishment decisions. Though fuzzy logic approaches have been widely applied in formulating replenishment strategies, limited research effort has been made to collect the prerequisite data, a phase which can be unexpectedly time-consuming in a worldwide business. Thus, the incorporation of cloud computing and AI techniques presented in this paper is a novel technique for improving the overall efficiency of the fuzzy logic approach. Future research should focus on hybridizing the proposed system with data mining techniques for analyzing customer behavior in different markets. This would be meaningful for the formulation of truly responsive replenishment strategies.

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