EDI AND INTELLIGENT AGENTS INTEGRATION TO MANAGE FOOD CHAINS

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Abstract

Electronic Data Interchange (EDI) is a type of inter-organizational information system, which permits the automatic and structured communication of data between organizations. Although EDI is used for internal communication, its main application is in facilitating closer collaboration between organizational entities, e.g. suppliers, credit institutions, and transportation carriers. This study illustrates how agent technology can be used to solve real food supply chain inefficiencies and optimise the logistics network. For instance, we explain how agribusiness companies can use agent technology in association with EDI to collect data from retailers, group them into meaningful categories, and then perform different functions. As a result, the distribution chain can be managed more efficiently. Intelligent agents also make available timely data to inventory management resulting in reducing stocks and tied capital. Intelligent agents are adoptive to changes so they are valuable in a dynamic environment where new products or partners have entered into the supply chain. This flexibility gives agent technology a relative advantage which, for pioneer companies, can be a competitive advantage. The study concludes with recommendations and directions for further research.

Keywords: Food chain, EDI, Intelligent Agents.

1. Introduction

This paper presents the design of a new intelligent software system that integrates information systems developed for relationships between enterprises and the final consumer (Business to Consumer or B2C) and between suppliers (Business to Business or B2B). The proposed theoretical model uses Agent Technology and will assist both the producing firm and the customer to look automatically for an increase in the data exchange rate through the upgrade of EDI. The latter is a type of inter-organizational information system, which permits the automatic and structured communication of data between organizations

Within this paper the term 'agent' corresponds to the software problem-solving entities, which are situated in a particular environment, with specified functions, in order to process the inputs received related to the problem domain. The agents have the ability to control their internal state and their behaviour, to exhibit flexible problem-solving techniques in pursuit of their design objectives. The intelligent agent software system is designed to fulfil the specific purpose of analysing the information about the customers that is available currently at the retailers’ databases.

Usually each software agent is a different specialist, able to accomplish certain tasks, thus providing co-operative members in a society. In this work, the scenario of knowledge co-operation on our study will illustrate how certain components (i.e. food supply agents) can be monitored from a multi-agent software system, by using intelligent specialised software agents, which will simulate the procedure of data analysis to extract useful information for the relationships between commercial partners.

This study illustrates how agent technology can be used to solve real food supply chain inefficiencies and optimise the logistics network. For instance, we explain how agribusiness companies can use agent technology to collect data from retailers, group them into meaningful categories, and then perform different functions. Additionally, through the use of mobile handheld devices the distribution chain can be managed anytime, anywhere more efficiently. Intelligent agents also make available timely data to inventory management resulting in reducing stocks and tied capital. Intelligent agents are adoptive to changes so they are valuable in a dynamic environment where new products or partners have entered into the supply chain. This flexibility gives agent technology a relative advantage, which for pioneer companies, can be a competitive advantage. The study concludes with recommendations and directions for further research.

2. EDI

Electronic Data Interchange (EDI) is a type of inter-organizational information system, which permits the automatic and structured communication of data between organizations. Although EDI is used for internal communication, its main application is in facilitating closer collaboration between organizational entities, e.g. suppliers, credit institutions, and transportation carriers [1]. The basic components of EDI are:

- Structured messages developed on common platforms and to common standards, e.g. UN/EDIFACT, ODETTE, VDA, X.12, or TRADACOMS.
- An electronic communication network that delivers data and documents to the required destination in a secure way. Initially, Value Added Networks (VANs) were used as the communication network, but they have being gradually superseded by the Internet.
- Translation software to encode/decode the structured messages. The translation software interfaces with the in-house application software in order to permit direct application-to-application communication between different organizations. For example, the sales information system of a retailer could automatically trigger the reordering system of a supplier [2]. The software also facilitates electronic storage and retrieval of data and information.

When EDI is to be employed as an inter-organizational system, then its design requires cooperation between two or more organizations, thus many researchers have found it useful to characterize EDI as a cooperative information system (i.e. Ratnasingam [3]). By doing so, they have been able to highlight the distinction between EDI and other inter-organizational information systems, which do not involve proactive cooperation between the communicating parties. An example would be an e-mail system whereby inter-organizational information communication can take place without any overt cooperation in the design of the medium.

EDI provides a faster, more accurate, and less costly method of communication with customers compared to other methods, such as mail, telephone, and personal delivery. The adoption of EDI can have many benefits including faster processing, speed, greater accuracy, reduced costs, competitive advantage, improved operations, security, tracking and control, intra and inter company communications, and customer service [4]. Figure 1 depicts the applications of EDI in food supply chain and presents examples of EDI messages.

2.1 Current State of EDI Diffusion in agriculture & food industry

There is consensus that the use of Electronic Data Interchange (EDI) increases the efficiency of transactions in terms of cost, accuracy, and speed, and that this, in turn, strengthens the competitiveness of the involved parties [5]. However, EDI is an inter-organizational system and the level of its diffusion within an industry depends on its network externalities, which is how quickly companies that evaluate EDI finally decide to adopt it. Unless a critical mass of EDI users is created, diffusion rates will remain low. The diffusion of EDI follows two patterns: the customer–supplier(s) pattern and the supply-wide pattern.

According to the customer–supplier(s) pattern, two or more trading-partners that have frequent and voluminous business transactions decide to exchange data and information electronically. More often than not, a specific diffusion pattern takes place, which is called the ‘hub and spokes’ phenomenon, characterized by a large partner that imposes the adoption EDI onto its smaller trading partners. A typical example would be a large retailer or manufacturer being the ‘hubs’ and their suppliers the ‘spokes’. Although the diffusion effect of ‘hub and spokes’ phenomenon seems to be rather limited to few companies, Jimenez and Polo [6] who examined the diffusion of EDI in the retailing sector of a number of European countries, found that it often serves as the seed for an industry-wide diffusion of EDI.

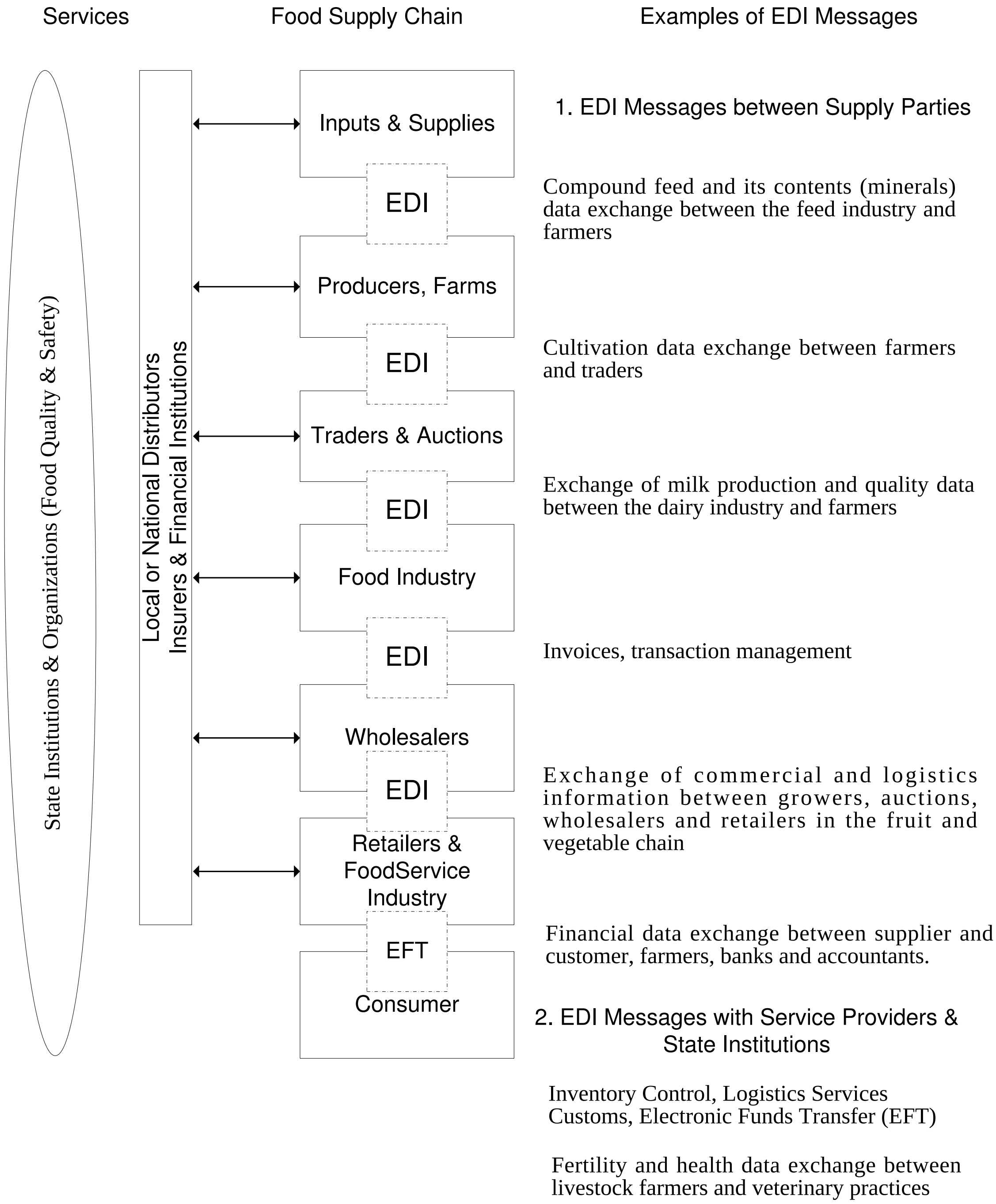

Figure 1: Example of EDI

Increasing collaboration between distribution and retail chains creates an enabling environment for the application of electronic business communications. Van Heck and Van Bon [7] urged that exporters should pay special emphasis to information technology and inter-organizational systems particularly in order to improve the performance of the food distribution chains. Collins et al. [8] argue that EDI could contribute significantly to improving the time dimension of agribusiness' customer service.

The application of EDI systems to increase the efficiency of the agri-food chains is characteristic of the supply-wide pattern. Following to this diffusion pattern, trading partners seek to achieve a systematic, holistic optimization of the food chain, which begins before the farm gate and connects all the forward entities up to consumers' plate. The holistic optimization and integration of the food supply chain often requires the re-engineering of supply processes. EDI facilitates the smooth information flow and the seamless integration of heterogeneous processes. Conversely, the use of EDI, without the integrating supply chain activities, simply speeds up an existing process [9].

The ECR initiative was developed in order to handle the inherent demand distortion and amplification found in supply chains, known also as industrial dynamics or the Forester Effect ([10]; [11]). Thomas et al [12] gives a detailed analysis of demand distortion and amplification in the grocery supply chain, which are linked to inefficiency within this supply chain. The grocery industry uses buying practices, such as forward buying, that exacerbates the Forrester effect to a considerable 40–50% account of distributors' inventories [13]. ECR deals with chain dynamics by coordinating the supply chain using EDI to link the supply partners electronically. ECR could potentially ECR can have huge cost savings and has already shown exceptional results in US grocery industry [14].

Following the ECR, Efficient Foodservice Response (EFR) is an initiative that aims to enable foodservice industry to achieve profitable growth by eliminating inefficient practices. EFR also relies upon electronic exchanges of data and information to create a win-win situation for each supply partner.

Fostering the use of EDI in the farm level is essential for enhancing the total food value chain. In this way, EDI provides value to all partners from farm to fork e.g. wheat-grower, miller, bread manufacturer, and foodstuffs retailer. Two factors have contributed to the EDI diffusion at the farm level: (a) Governmental and institutional support in terms of research, infrastructure, and direct or indirect financial support. For example, EDI-Europe is an EU project aiming to promote awareness of the importance of EDI among farmers and agribusiness in general as well as to function as Pan European group for the EDIFACT organization in agriculture. (b) The increasing diffusion of information technologies and the usage of Internet among farmers have unlocked the farm gate to advanced information & communication technologies, including EDI. Gin et al. [15] pointed out that there are two potential uses of EDI by farmers: (a) Internal Usage, for recording technical information in the field as well as quantity and identity of inputs used and exchanging them using control devices, mobile equipment, and process computers, and (b) External Usage, between the farm and its partners i.e. cooperatives, manufacturers, and traders.

3. Intelligent Agents

Agent technology has successfully been used in the past for in managing business processes, as described in ADEPT (Advanced Decision Environment for Process Tasks) from Jennings [16]. Based on the functionality of decision making from the company managers, the business process involves a combination of judgement and information from marketing, sales, research, development, and manufacturing and finance departments. Ideally all relevant information should be brought together before judgement is exercised. The ADEPT solves problems related to this process by viewing it as a community of negotiating, service-providing agents. Each agent represents a distinct role or department and is capable of providing one or more services.

Within this paper the term 'agent' corresponds to the software problem-solving entities, which are situated in a particular environment, with specified functions, in order to process the inputs received related to the problem domain. The agents have the ability to control their internal state and their behaviour, to exhibit flexible problem-solving techniques in pursuit of their design objectives. The intelligent agent software system is designed to fulfil the specific purpose of analysing the information about the customers that is available currently at the retailers' databases. In a more general way as in Wooldridge [17], the term 'agent' can be used, as a software-based computer system, which has the properties:

- Autonomy: It means simply that an agent is a computer system, which is situated in some environment, and it is able to act without the intervention of humans (or other agents), and should have control over its own actions and internal state and have some kind of control over their actions and internal state.
- Social ability: Agents can interact with other agents (or humans) via agent communication language (ACL) as described from Labrou [18].
- Reactivity: agents perceive their environment and respond in a timely fashion to changes that occur in it.
- Pro-activeness: Agents do not simply act in their environment, but they can also take initiatives. The application domain of applying agent technology is crucial as we always have to balance between risk and trust when working with software-based systems.

Usually each software agent is a different specialist, able to accomplish certain tasks, thus providing co-operative members in a society. In this work, the scenario of knowledge co-operation on our study based on [19], will illustrate how certain components (i.e. food chain requirements) can be monitored from a multi-agent software system, by using intelligent specialised software agents, which will simulate the procedure of data analysis to extract useful information for the food logistics and send the appropriate messages to each level. The general architecture of each individual intelligent software agent includes the body, head and the communication abilities. The body contains all the centralised processes, tasks given to each agent to accomplish, which can be different, depending on their role. The head includes the information provided either from the user or the other software agents and the rest includes all the functions required in order for the agents to be able to communicate and as a result co-operate with other members of the agent society. This successful combination of several autonomous intelligent agents working together is called a multi-agent system.

4. Upgrading EDI with Social Intelligence

The EDI literature can be classified into three research streams based on different theoretical paradigms taking different assumptions [20]. One views the adoption of EDI as an innovation adoption, another takes an organizational behavior perspective, and a last one considers it diffusion dependent on network externalities. Following the extant literature on EDI adoption, a conceptual framework of the EDI adoption factors was developed. Table presents the conceptual framework, which includes 17 factors categorized into three groups according to the three research streams: the innovation adoption, the organizational behavior, and the critical mass, accordingly.

Theory	Factors	Description
1. Adoption of Innovations	1.1 Compatibility	The degree to which EDI is perceived as being consistent with existing technologies (technological compatibility) and operations (operational compatibility)
	1.2 Complexity	The degree to which EDI is perceived as relatively difficult to understand and use
	1.3 Cost	Cost includes implementation, and operational, transaction costs
	1.4 Observability	Visibility of EDI's results.
	1.5 Relative advantage	The degree to which EDI is perceived better than the system it supersedes
	1.6 Trialability	Availability to experiment with EDI on a limited basis
2. Organizational Behavior	2.1 Championing	The existence of a charismatic individual who supports EDI to overcome plausible resistances towards its adoption
	2.2 Competitive advantage / necessity	The desire to gain an advantage over competition as a result of EDI adoption / the pressure to adopt EDI as a result of competition.
	2.3 Inadequate resources	Lack of resources often restrict SMEs from adopting EDI
	2.4 Limited education	Personnel might need further training in EDI systems
	2.5 Organizational size	Size is commonly measured in terms of number of employees, revenues, and profits.
	2.6 Organizational readiness in SME	The availability of the needed organizational resources for EDI adoption
	2.7 Productivity	An increase of productivity will be the result of lowering inventories levels, reducing transaction costs, and facilitating supply chain management.
	2.8 Top management support	In large corporations top management often has to support initiatives like EDI adoption
3. Critical mass	3.1 Dependency	Being in a position not able to exert control over transactions.
	3.2 External pressure	EDI is adopted as a result of pressure from business environment (trading partners, suppliers, customers)
	3.3 Power	The capacity of an organization to exert influence on another organization to act against its will.

Table 1 An Conceptual Framework of the factors impinging upon the adoption of EDI

The philosophy of this work is based on a dynamic multi-agent software system, which employs communication skills, with decision-making functions for data interpretation in marketing. In the past, a number of stand-alone intelligent systems have been constructed, all of which employ some intelligent system technique for data interpretation. However the information environment within any large organisation and the use of EDI is extremely complex. Describing who holds what information, how it is used and from where, how it can be better interpreted to derive meaningful conclusions, are very complex tasks but their importance has been accepted from all the companies in the market. Systems that can help aid the process of data interpretation and recognition of the types of information within a retailer and its value in relation to the business process are therefore extremely important. In order to explore the relationship between the performance of companies, customers' needs and information related to the products, a theoretical framework is being proposed as shown in Figure 2. Specialised software agents will be able to automatically process the data and give information about the different levels of the electronic marketplace, based on certain attributes (i.e. cost, quality, safety, trace-ability, competitive advantage etc.), and act as mediators between the EDI messages sent through the different layers of the supply chain.

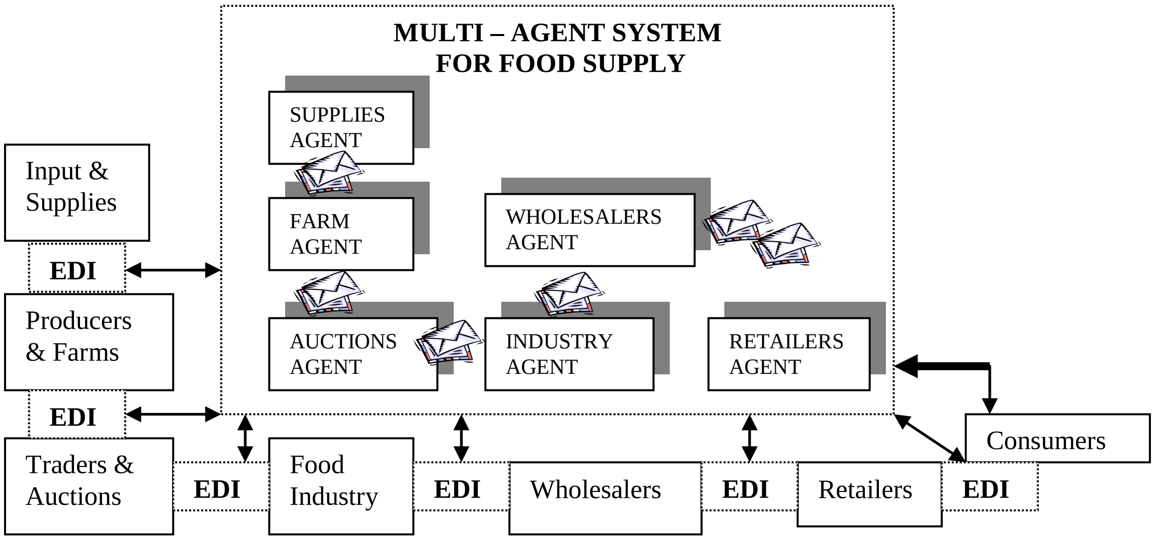

Figure 2: Enhancing EDI with the use of MAS

Agent technology is very suitable to support collaboration in supply chain management. The rationale for adopting agent technology is based on achieving the following three goals ([21]; [22]):

1) Data, control, expertise, or resources are inherently distributed;
2) The system is naturally regarded as society of autonomous cooperating components;
3) The system contains legacy components, which must be made to interact with other, possibly new software components.

Supply chain management by its very nature has all the above domain characteristics. Parties involved in the supply chain have their own resources, capabilities, tasks, and objectives (1st goal). Supply parties cooperate with each other autonomously to serve common goals but also have their own interests (2st goal). Supply chains and particular food supply networks are typically dynamic in nature characterised by the incessant flows of information, materials, and funds across multiple functional areas both within and between chain parties. Supply flows are usually managed by various information systems but the effectiveness of supply chain is impeded by the lack of coordination and integration between these systems (3rd goal). Table 2 summarises the similarities between supply chain management and a multi-agent system.

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Properties	Supply Chain Management		Multi-Agent Systems
Structure	A Supply Chain consists of multiple parties working on multi-stage tasks.	←→	A multi-agents system consists of different types of agents with different roles and functions.
	Each entity in a supply chain has its own objectives, capabilities, performs certain tasks, and follows certain business rules.	←→	Agents have their own objectives, resources, tasks, and decision rules specified by the user they represent.
Flexibility	There is no single authority. Knowledge is distributed among members in supply chain. Decision making in Supply Chain is through multiparty negotiation and coordination.	←→	Agents are autonomous. They are responsive to monitor changing environment, proactive to take self-initiated action, and social to interact with human and other agents.
	The structure of the supply chain is flexible. It can be organized differently to implement different strategies.	←→	Agent system is flexible. Agents can be organized according to different control and connection structures.
Transaction Harmonization	There is a need to coordinate material, information, and financial flows between and among all the participating entities.	←→	Agents coordinate with each other through communication and interaction with each other in a network.
	Learning and reasoning is needed for supply chain members to make individual or joint decisions for operation and planning.	←→	Intelligent agents are capable of reasoning based on the rules given by the user or knowledge learned from an open environment.
	Information is distributed. Each entity has incomplete information. Information need to be shared across organizational, functional and system boundaries.	←→	Agents can communicate with human, with other information system, and with other agents. They can share information and knowledge through message exchange between agents.
Simplicity	Supply chain is dynamic. Supply dynamics create inefficiencies.	←→	Agents can be created or discarded from a multi-agent system to avoid inefficiencies
	Tasks in supply chain can be decomposed to subtasks or multiple tasks can be composed to a large function.	←→	Agent can delegate its task to other agent or coordinate other agents' tasks to form a higher level system.

Table 2 Property Linkages between SCM and Multi-Agent Systems
Source: Adopted from Yuan et al. [22]

The proposed software system overcomes today's problems, as it supports the use of more than one computational intelligence technique through agents' technology. The key function is the application area of interpretation of the available data. Considering a software system responsible for data interpretation, and message exchange between the different organisations, there can be distinguished a number of interesting characteristics:

- The process is distributed. There can be distinguished a number of autonomous processes (data gathering from retailers, data grouping etc.), which interact with each other to end up with a meaningful conclusion.
- The distributed problem domain denotes the development of an hierarchical layered software system, which results in the construction of a structured society of agents, with different groups, each one specialised and with different functionality.
- The software system as a whole has to be easily maintained, as new agents might be included, if new products or manufacturers have entered the market.
- Finally, the requirements of such an automatic system for data interpretation in marketing are high, as it deals within a dynamic environment, where any change is possible, and the system has to be accurate.

5. Discussion

The novel idea of this framework is the construction of an agent society, in groups, based on the hierarchical reasoning during the interpretation procedure, which benefits from the agent technology in terms of decentralisation of execution, decentralisation of control and existence of co-operation. The whole procedure of communication between these different kinds of agents also offers at the end the positive result of improved interpretation, a flexible architecture and adaptability. This framework also builds on Wray [23] and Bejou [24] methodological ideas of using agents to learn and predict information. The above researchers used Neural Network Approach to measure the quality experienced in the relationship between consumers and financial service providers, a method that allows them to predict determinants of relationship quality. This method can be also adapted for food supply chains, where the consumer can have access to certain information of the different layers in the chain and retrieve knowledge for future production, anytime, anywhere using wireless network and handheld devices. Future research should aim to quantify the advantages of agent technology as discussed above. We suggest the simulation of the different types of agents and further research on the social behaviour of the agents' society within the rules and restrictions of a food supply chain.

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