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Serious Gaming Learning: Supply Chain Multi-Agent Web-based Simulation Game

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SERIOUS GAMING LEARNING: SUPPLY CHAIN MULTI-AGENT

WEB-BASED SIMULATION GAME

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Abstract

High levels of complexity and uncertainty, and various sources of risks, create challenges for supply chain networks in achieving satisfactory performance, but advances in Information Technology can help supply chain decision makers predict the magnitude and impact of the risks related to their decisions. The framework proposed in this paper offers a solution that integrates intelligent-agents, simulation modelling, and optimisation. Its friendly, animated, interactive web-based interface is especially designed to engage the user in a 'serious game' environment. Each user plays a specific role in the supply chain network, and encounters the consequences of their decisions. The optimisation engine embedded in the framework advises users about the optimum decisions and their anticipated performance outcomes. Genetics Algorithm (GA) and Case-Based Reasoning (CBR) are used to enhance the decision quality. A high-level communication protocol has been designed, developed and implemented to facilitate client/server communications, and allow intelligent-agents to inter-communicate easily and efficiently. The tool we develop offers equal value in supporting management decision-making, or in educating trainees in the realities of supply chain management.

Keywords: Serious Gaming, Multi-Agents, Web-Based Simulation.

1   INTRODUCTION

When the business world thinks of risk, they are generally financial, and refer to areas such as insurance, investments, futures, options and swaps [1]. But, since major disruptions to global supply - such as the 9/11 terrorist attacks and Hurricane Katrina in the US, foot and mouth disease in the UK, the SARS and bird flu outbreaks in Eastern Asia, the volcanic ash clouds over Iceland and the tsunami that hit Japan in 2011 - supply chain risk has received ever-greater attention from both academic and industry experts [2-4]. The high level of complexity and uncertainty across supply chain (SC) networks, and the variety in the sources of risk, create challenges for supply chain partners and customers in achieving and sustaining satisfactory performance.

One of the barriers to implement a successful SC risk management plan is the varying levels of awareness and overall knowledge held by different managers and actors throughout the SC network, and the lack of recognition of common terminologies across SCs [5]. Numerous tools are now available to analyse risks and assist in their management, but the supply chain sector lacks interactive educational tools that can give trainees an understanding of a complete SC environment, and develop their ability to identify, asses, manage and control the various processes along the SC network. Many theories and techniques have already been adapted for SC risk management (SCRM), which has opened the door for the development of more tools to computerise the process, helping advance the use of IT within the SCM field. The platform for SCRM advancement is the concept of supply chain collaboration. SCRM research at Cranfield University [6] finds that "the underlying principle of collaboration in the supply chain is that the exchange of information and application of shared knowledge can reduce uncertainty" (pp.47). Knowledge is a very important resource in managing and understanding supply chains,[7] and the transfer and sharing of knowledge along chain is commonly known as Supply Chain Knowledge Management [8].

The ability to gain knowledge through learning has always been the foundation of any successful society: this is not a new understanding, but an age-old subject that has occupied philosophers and academics since the days of Plato and Aristotle [9]. Learning can be defined as the acquisition of knowledge through cognitive processes that lead on to new understandings, behaviours and skills [10]. In today's knowledge driven society, the valuable understandings gained through education are very important resources [11]. It has also been argued that the quality of knowledge transfer in a society's third-level education (TLE) systems has a significant influence on its wider economic wellbeing [12], not just for complex business processes such as SCRM. Many advances were made in the last century in TLE teaching processes to assist in the effective knowledge transfer, from Dewey's introduction of constructivism in the 1930's [13], including (among others) interactive teaching in the 1950's [14]; and more recently, active learning [15] [16]; the learning pyramid [17]; and problem based learning [15, 18, 19]. These advancements had several aspects in common - notably, that group activities, interaction and collaboration are important components of successful learning environments: such learning processes are better known as Collaborative Learning [20].

Advances in technology - such as the internet, computer games and interactive simulations - have added to the momentum gained by collaborative learning over the past few decades. Most importantly, today's TLE students are the backbone of the virtual age, in which online multi-player games, virtual reality and simulations are a part of everyday life, making gaming and simulation a very important catalyst in the learning process [21, 22]. Using games in such a way, i.e. where playing is not a leisure pursuit, but has the end goal of learning, is known as 'serious gaming',[23] and playing such serious games can have great advantages in connecting education to the daily life experiences of player/learners [21], enhancing learning processes, especially in business environments [24]. Serious games can allow students to interact with both the game/learning system itself and with other students, providing encouragement and motivation for collaboration and participation in learning processes [25]. It has been noted that, while serious games are usually simulation models which have game characteristics, they are in fact simulations of real-world events or processes [26].

Using simulation technologies has been proved to be an excellent tool for modelling complex environments [27]. Simulation is seen as an effective means of analysing and portraying complex systems, allowing the effects of processes to be more easily understood and predicted [28]. Simulation software is highly successful in replicating uncertainty, as - mainly through discrete event simulation - it can manipulate the variability and uncertainty of a whole system [29]. In spite of this, there have been very few examples of SCM simulation games being used in education - the most well-known has been the 'beer game' introduced as an exercise in industrial dynamics by MIT in 1960 [30]. Integrating serious games with web-enabling technologies can also provide a powerful educational tool to encourage collaborative learning about SCM management.

Recently emerged modes of online communication (such as social networking) and multi-player gaming structures illustrate the potential high-quality sharing and/or virtual environments offer for improved student interaction [31], and it has been argued that utilizing web technology is an obvious decision when implementing new study materials to make lectures more dynamic and exciting [32]. Web-based education games also have the advantage of being cheaper than expensive simulation software, and of giving students online access beyond the classroom [33].

Studies in the evolution of web-based education (also known as semantic web research) have been complemented by the development of a category of artificial intelligence called web-based multi-agent systems [34], which can be exceptionally successful at modelling complex real-life systems [19]. Such multi-agents are independent software entities that use sensors to perceive their surrounding environment and use knowledge, actuators and information processing to interact with it [35]. Each agent can have both common and conflicting objectives and will compete or cooperate with each other to serve their own interests or to achieve mutual benefits [36]. Multi-agent systems are increasingly used as alternative tools (to discrete event simulation) in supporting decision-making for SC collaboration, especially in the domain of SCRM. As noted earlier, an agent is an autonomous software entity that aims to accomplish its own design objectives, and this software architecture paradigm means SCRM processes "can be perceived as facilitated by several autonomous decision making entities (software agents), each responsible for specific activities and performing different roles" [37]p.23. More importantly, it is the capabilities of those agents to interact, cooperate and learn from other agents to solve problems beyond their own individual knowledge set [38] that is most appealing to SCRM.

In this paper, we present a multi-agent based framework as the conceptual basis for the design of a decision support system to facilitate the collaborative management of SC risk. The framework

supports the process of fulfilling orders and of managing the associated risks in a generic chain involving five typical SC partners; suppliers, manufacturers, distribution centres, retailers and logistics. Section 2 gives a brief account of the main phases involved in designing and developing the framework. Section 3 concludes the paper by describing the framework's implementation and discussing potential future extensions of this research.

2   FRAMEWORK AND IMPLEMENTATION

The proposed framework system simulates a full supply chain consisting of suppliers, manufacturers, distribution centres, retailers and logistics: users can choose one of these network roles to engage in the simulation. A full simulation model has been built to include information, material and capital streams. The framework consists of three main agents; Client, Administrator and Server (see Fig. 1). The intelligent agent's features have been added to their behaviour to realise the environment and generate the optimum reaction, and are activated to help the user taking the right decisions. The internet protocol Hyper-Text Transfer Protocol (HTTP) is used as a wrapper for a special high-level communication protocol so services and results can be exchanged via the internet. The administrator role can control the environment by setting the variables and checking the system status, while the server layer runs the simulation model, executes user services and manages the optimisation and database management functions.
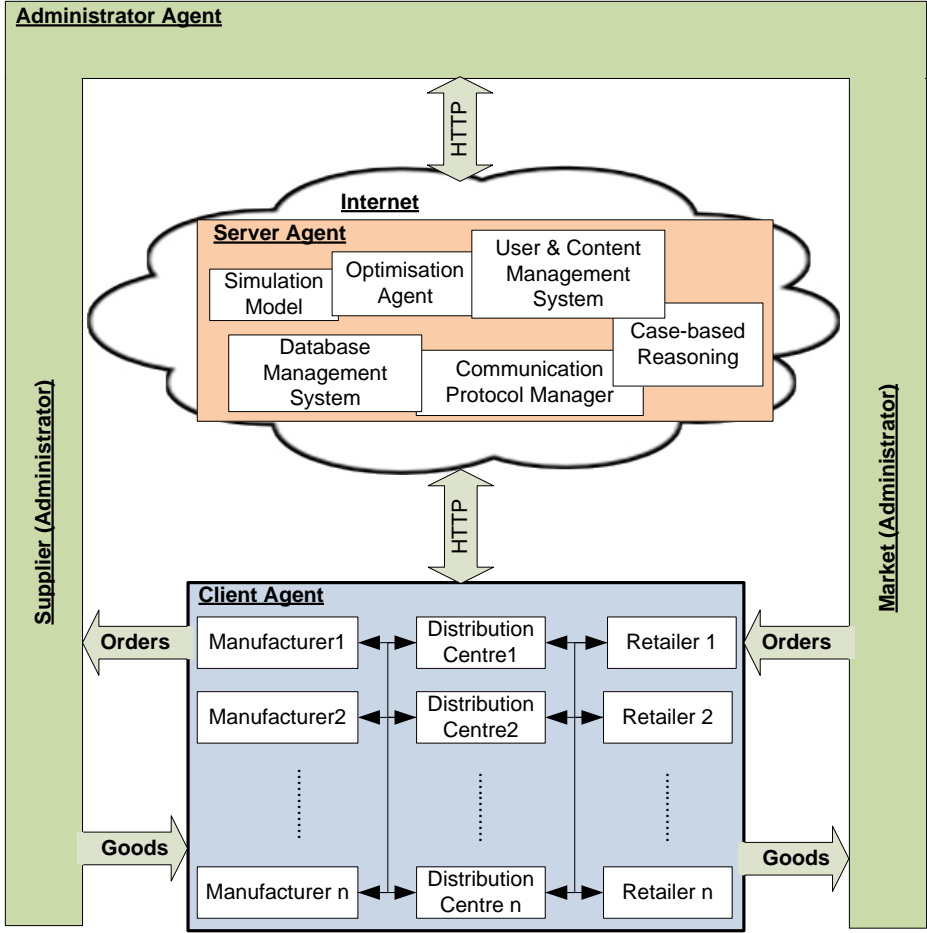

Figure 1: Web-Based Multi-Agents Supply Chain Simulation Framework

2.1   Client Agent:

The client agent refers to the running of the client software on the user machine, allowing it to manage the user's (Manufacturer's, Distribution Centre's or Retailer's) operations: generating demand or orders, warehousing goods and processing updates to materials and capital streams via its interfacing and communication protocols.

2.1.1   Interfacing:

The client interface has been built to allow the user to intervene in the simulation model while it is running on the server to change the simulation variables and get results in informative formats, such as charts and performance measures. The graphical user client interface (see Fig 2) has been designed to attract the user to the environment - which resembles that of a game, with penalties, rewards and goals – and engage them easily – so as to increase the contact hours students spend on the game, so leveraging greater user learning. The system's interface also features a control panel via which the user controls the simulation model, and enhances its usability and user-friendliness. All users are synchronised into a 'global game time', and their status, levels and performance points displayed in the status panel. The warehousing function charts and monitor enhance the user's awareness of historical and current stock levels, enabling them to set and manage warehouse safe and reorder points. A constantly updated statistics panel keeps users informed about their supply chain network performance, their ranking against other 'players', and the best and worst supply chain networks in the system. The system design allows them access to information about other users and their performance, helping them decide which to engage with to build their supply chain network.
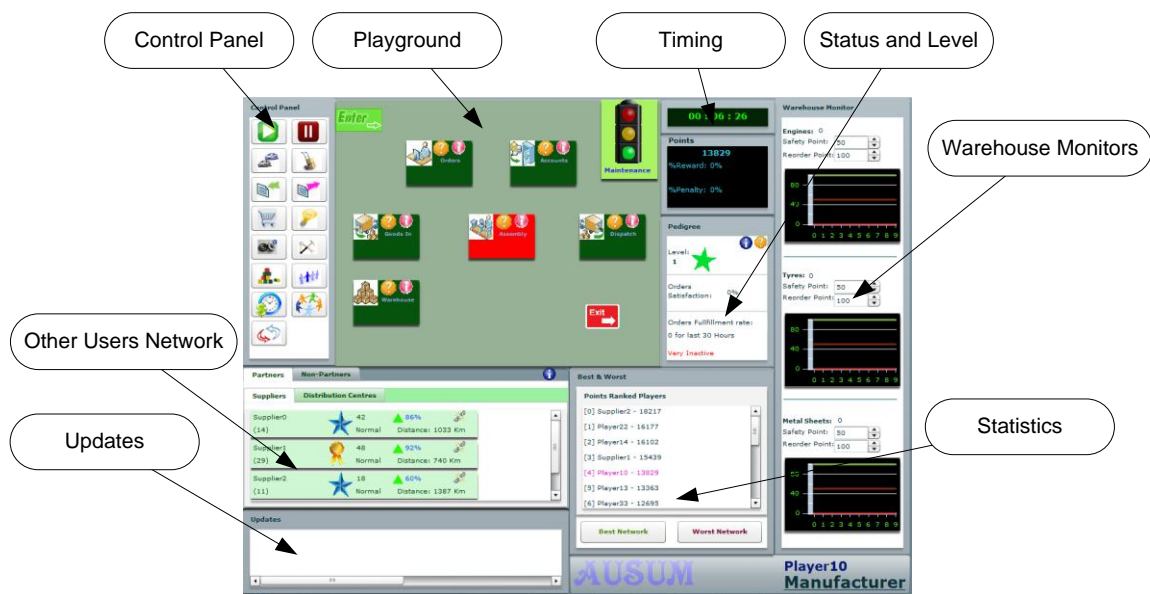

Figure 2: The Client Interface

2.1.2   Communication protocol:

Fig. 3 illustrates the two-way pattern of communications between the client/user environment and the server (all of which are over the internet and use the HTTP protocol) which enable the user to execute functions on the server, access database tables, to trigger or broadcast updates to other users and receive results and responses. The client engine sends updates about the status of its different components (warehouse manager, process manager, goods-in manager, dispatch manager, shipping manager and accounts manager), which are encoded and sent to the server, where they are decoded and passed to the communication manager to distribute to and activate the required service. The results of these activations are then fed to the server's database, and communicated back to the client when the latter generates a 'get updates' signal – which again is routed via client's communication manager to update the relevant components in the client's part of the system.

2.1.3   Administrator Agent:

The administrator role is to configure the simulation variables, create scenarios and follow up the users' results and performance (Fig. 1).

Control — The administrator client is built as a web application to give the administrator the ability to control the game. A comprehensive control panel (see Fig. 4) is developed to enable the simulation administrator to configure and generate demand patterns for the supply chain network, control demand delays and set up the logistic environment. To implement the risk factor in the supply chain

network, random values and distributions can be used in generating values for these factors, and delays and accidents can be applied randomly to delivery and logistic services.
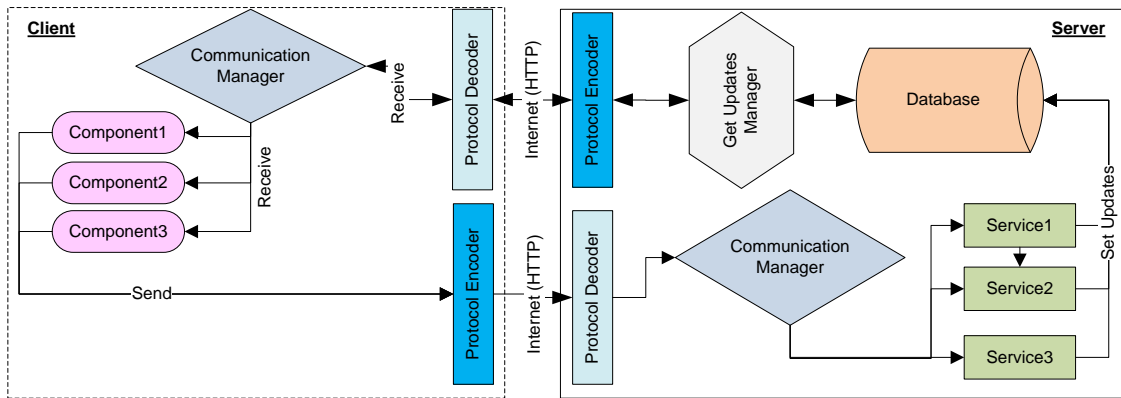

Figure 3: Client-Server Communication Protocol

Statistics — All historical data re- warehouse stocks and order processing are registered in the database and displayed on statistical charts for the administrator, who can analyse them to adjust the network configuration, including increasing or decreasing demand rates or changing uncertainty and risk levels.

Tracking — The system tracks users' performance, checking their current rankings and updating them automatically, as well as that of the best and worst supply chain networks, including tracking their performance over time.
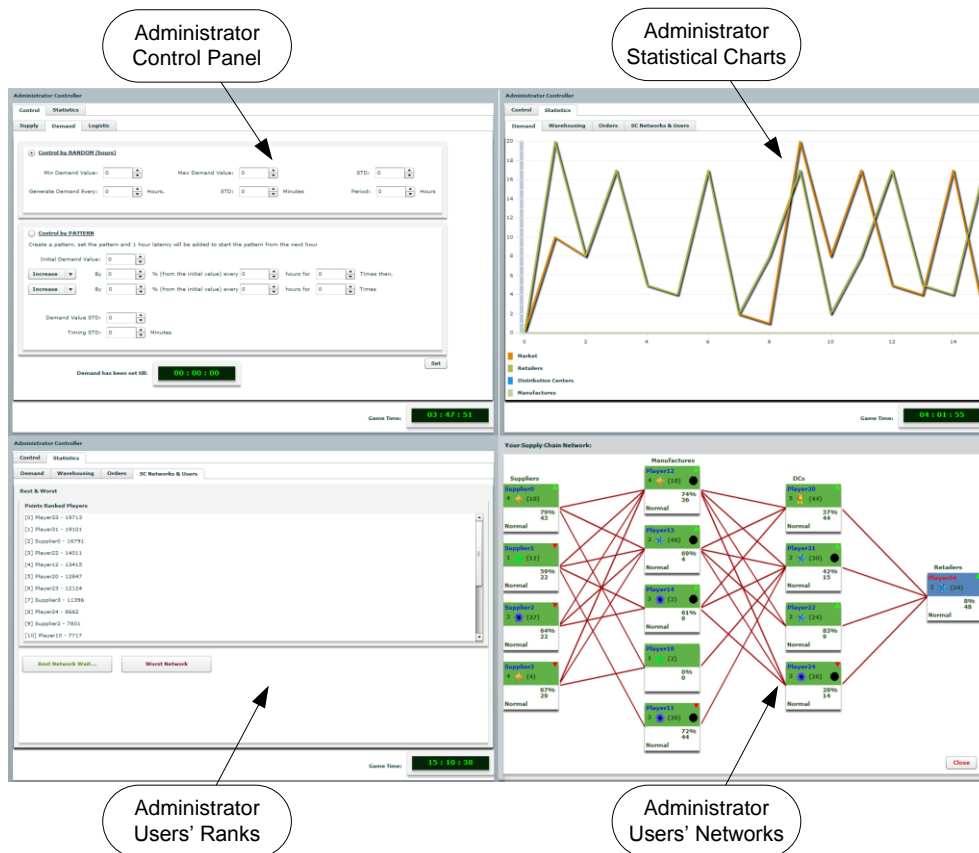

Figure 4: The Administrator Interface

2.1.4 Server Agent:

The system server is composed of different components working together to enable login and communications with the system's users, which are synchronised to a global system time. Fig. 5 shows how the components communicate with each other within the server, and how they interface with the client components to allow users to work in discrete environments, without being involved in the overall simulation model and its database services.
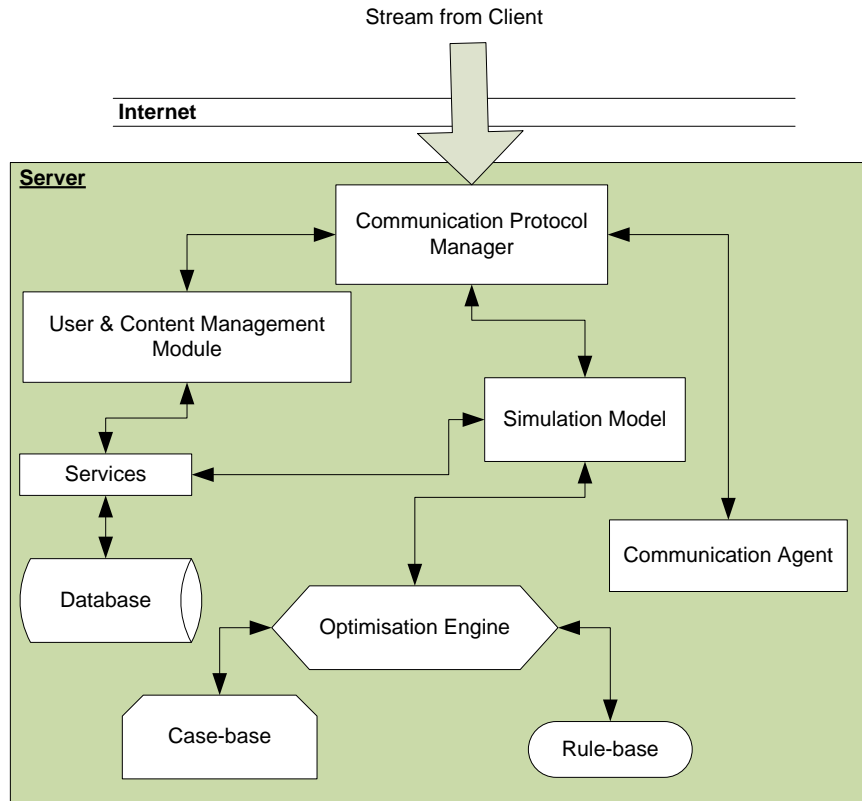

Figure 5: Server Structure

Communication Protocol Manager - Synchronises client/server communication, receiving and decoding messages from the client (via the internet) to extract identity information (describing the user, their status and security level) and operational information concerning the services the client wants to execute on the server.

User and Content Management Module - The identity information is passed on to the user and content management module to guarantee the appropriate user security levels and establish and handle the user communication channels.

Simulation Model – The engine of the system is a full supply chain simulation model, with three main streams - information, material and capital - which allow it to function as a base for the main supply chain roles (Supplier, Manufacturer, Distribution Centre, and Retailer). Changes in variables and events made by the users (or introduced by the system administrator) are sent to the simulation model on the server.

Database Management System – This component records and updates user identity information and security levels to enable the management module to set up user's environments according to their security levels, and supports the simulation model by retaining users' statistics and status while they are offline.

Optimisation Agent - A genetic algorithm–based optimisation engine has been embedded in the simulation system to handle and support users' decisions. Their status and the simulation variables they choose are converted to genes to feed data to the genetic algorithm which then calculates and suggests suitable solutions according to the likely risks distributed in the network, etc, and the scenarios that would follow for the supply chain network.

Case-Based Reasoning and Rule Base - The optimisation engine uses different rules (which are stored in its rule base) to generate suitable solutions to solve supply the chain problems that might result from users' choices

Communication Agent - creates a two-way messaging environment to enable users to communicate (either publically or privately between each other) so they can make deals amongst themselves, exchange experiences either about the field or their use of the game, and communicate with the administrator to get advice or flag up problems.

3   CONCLUSION

The current global economic recession, pressures for cost reductions, the drive for lean operations, and the increased frequency of natural disasters and terrorist attacks have increased the potential for risk in supply chain operations, and so the emphasis on managing such risks. The high levels of complexity and uncertainty affecting supply chain networks, and the variety in the sources of risk, create challenges for supply chain managers in achieving satisfactory performance for their partners and customers. To reduce the impact of high risk processes, successful collaboration and supply chain knowledge transfer between partners is essential, and it has been acknowledged that these elements need to be integrated into third-level education learning processes to optimise the probability of such success. Collaborative Learning and interactive learning processes - such as problem based and active learning - fuelled by the use of modern technology – have enabled advances in education which have promoted knowledge transfer and retention: the use of serious games in learning processes is at the forefront of such developments.

Their use in education settings has not only increased the levels of interaction between students and made learning more fun, but has also emphasised the notion of peer-to-peer teaching, collaboration and knowledge transfer. Serious multi-agent web-based games have become an alternative decision making support tool for SC collaboration, especially in the area of supply chain risk management, allowing agents to interact, cooperate with and learn from each other to solve problems beyond their own individual knowledge or experience. This paper presents the conceptual framework for the design of a multi-agent simulation system for such a learning decision support system that can facilitate the collaborative management of SC risk.

The system's web-based environment leverages learners' ability to learn, while its gaming aspects improve their engagement with the process and increase their interest in using the tool. Users play and work as single-role actors in a supply chain network in a game that emphases the goal of collaborative learning. Using encouraging elements - like awarding points and ranking users' performance - increases the competition between players and thus their chances of learning more knowledge.

Choosing discrete event simulation as the engine of the game to build a full supply chain environment helps students become more deeply immersed, eliminates their fear of change and increases their decision making experience. An optimisation agent is embedded in the game design to help enhance the quality of players decisions by recommending actions and variable values according to the current network situation.

The game administrator - who could be the instructor where it is used to teach students - has a range of capabilities to control the game, by changing the rates of demand and supply, increasing shipping obstacles and delays in the network, getting statistics for users and the whole network and tracking and communicating with them. More details and controls could be added to the game in future versions, and the multi-agent design we propose gives more flexibility in changing components and communication methods between users, which could improve its applicability to other fields of knowledge.

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