DEVELOPMENT OF AN AGENT BASED SIMULATION FOR THE CELLULAR TRANSPORT SYSTEM AND SCENARIO BASED PERFORMANCE ANALYSIS

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Abstract- Intralogistics Systems, in the rapidly increasing global business environment, are becoming more complex to analyze and more challenging to manage. In order to achieve the highest possible performance of warehouse operations, demanded by today's modern businesses, intralogistics systems should be agile and flexible. With this objective in mind, the Cellular Transport System (CTS) was developed as an alternative intralogistics system by Fraunhofer Institute for Material Flow and Logistics. This study investigates novel intralogistics system, the CTS, and proposes an integrated simulation tool in order to systematically anticipate change drivers and take optimum measures for the CTS.

Keywords- Intralogistics System, Agent Based Modelling, Cellular Transport System.

I. INTRODUCTION

In recent years, research activities in decentralized control systems by means of the Internet of Things architecture in intralogistics systems have been growing (Günthner & ten Hompel, 2010). The CTS is accepted as an example of a decentralized intralogistics system as well in the vision for the 'Internet of Things' in logistics. The concept of the Internet of Things, which has a vision of creating a link between digital and physical entities through efficient information and communication technologies, enables a new class of applications and services. For instance, RFID technology, one of the technological mainstays of the Internet of Things allows original solutions for intralogistics systems. Hence, it is possible to change conventional central material flow systems by a decentral material control system. The CTS is based on autonomous transportation entities (ten Hompel & Heidenblut, 2011) which are able to pick, pack and ship movable storage shelves.The research on robotics and on multi-agent systems was combined in order to provide a new type of autonomous vehicle for intralogistics applications which is called a Multi-Shuttle Move (MSM).

II. PROBLEM DEFINITION

Recent developments in the field of intralogistics have led to fully automated warehouses. Thus, many industries automate warehouse facilities in order to obtain high throughput levels and improve accuracy. However, intralogistics systems are currently lack sufficient flexibility due to bulk conveyor systems and huge sorters which are unable to react fast enough when needed. Also, their equipment and installation costs are very high. Besides, although warehouses are the essential contact point between manufacturer-customer and supplier-manufacturer, they add no value to the product itself. Because of this trade off, it would be expedient to reduce operating costs.

On the other hand, the simulation models of warehouse systems designed based on agent architecture are limited, even though Agent-Based Simulation has become more popular in a broad range of areas and disciplines. Besides this fact, there are no studies available in the literature concerned with CTS simulation due to its novelty. Hereby, the essential question to be examined in this study is how to simulate the structural design of Multishuttle Move thinking together with conventional warehouse activities.

III. THE PROPOSED INTRALOGISTICS SYSTEMS; THE CELLULAR TRANSPORT SYSTEM

Although the term intralogistics has become more commonly used, it has not been defined sufficiently in literature as yet. The term intralogistics is generally used in English literature as a warehousing system, material handling system or material flow. It is necessary here to clarify exactly what 'intralogistics' means by giving Arnold's comprehensive definition; "intralogistics comprises organization, controlling, execution and optimization of the in-house material flow, information flow as well as handling in industry and trade companies as well as public facilities" (Arnold, 2006).

Short production cycles and just-in-time inventory management require flexible intralogistics systems in terms of material flow, with the usage of small autonomous transport vehicles which perform as a swarm of mobile robots (Röhrig, Lategahn, Müller, & Telle, 2012). However, current autonomous vehicle applications such as AVS/RS are relatively inflexible (Ekren & Heragu, 2010). In other words, autonomous vehicles are neither self-controlled nor fully autonomous. For instance, they are not able to communicate with each other in order to find the shortest way, nor negotiate to fulfil the customer requirements in a minimum time. Up to the present, several autonomous vehicle applications have been implemented in the practical intralogistics environment. Subsequently, the most popular applications by groups of autonomous vehicles are the KIVA Mobile Fulfilment System,the KARIS Kleinskaliges (Small-scale) Autonomes Redundantes Intralogistics System, ADAMTM (Autonomous Delivery and Manipulation), and the Multi-Shuttle Move (MSM).In contrast to previous studies, the proposed MSMs will have the following technical features: 1) they will be autonomously intelligent and self-oriented. 2) They will be able to move, not only on the floor, but also inside the rack storage. 3) They will have the ability to communicate with other vehicles and their surrounding environment. 4) They will have a decentralized architecture with an autonomous and a swarm intelligent system.

The main principle behind the CTS concept is that decisions are made by the self- governing MSM units which depend on some gathered information or probabilistic calculation. A currently experimental hall containing the CTS was built on an area of 1000 m2 with a 65 meter long test area in Dortmund Fraunhofer IML to analysis its exact performance (Kirks, et al., 2012). The entire system, including fifty Multishuttle Move® units, five order picking stations and storage racks with elevators located at two sides of the storage racks, was implemented to examine the performance of the CTS by comparing it to other conventional intralogistics systems.

IV. AGENT BASED SIMULATION APPROACH FOR CTS

Growing competition in many industries has resulted in a greater emphasis on developing and using automated manufacturing systems in order to improve productivity and to reduce cost. The motivation behind designing the simulation model is for it to become one of the most popular methods to model and analyze these automated systems, due to their complexities and their dynamic domains. That is why; the CTSis modelled and analyzed by simulating Agent Based Modelling. Because of its novelty, it is not known which operations should be included in the CTS. Also, the CTS design totally differs from other alternative systems in terms of conveying items and storage rack structure, but still there exists basic operations which are contained within all kinds of intralogistics systems such as, order picking, storage, receiving shipping products etc.

Simulation methodology is generally based on one kind of paradigm, such as: Discrete-Event, Continuous-Event and Agent-Based Simulation. In contrast to the conventional simulation tools, AnyLogic is a single tool that gives freedom to users to utilize the all too common simulation paradigms within the same visual environment. In the current study, a hybrid model, which is combination of discrete event and agent based simulation, is used. For the purpose of further explanation, both simulation paradigms with an example are explained as follows. The main principal behind discrete- event simulation thinking is that the modellers investigate the system from the aspect of a process structure. In this methodology, the flow between entities plays a key role. In many cases, this kind of structure starts with a source entity which produces input into the system i.e. orders, finishes product etc., and ends with a sink entity in which the input variables are eliminated from the system. In the following Figure 1, a discrete event structure obtained from the CTS simulation is given as an example.

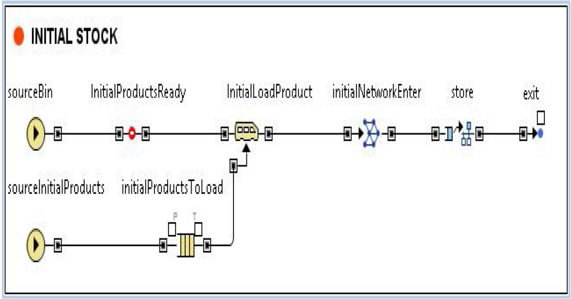

Figure 1: Discrete event structure screenshot from a CTS simulation.

Agent-Based modelling is established based on autonomous and decentralized thinking. The agent-based model is composed of some active objects which are referred to as an agent. In the CTS simulation, customers, shuttle vehicles, charge machines, left/ right lifts, enter/ exit points and workstations are created as an agent. In this modelling technique, each single agent has several specific behaviors that are embedded into agents by using state charts. A state chart or state diagram is a graphical approach which can be used instead of writing programming code. Such a diagram facilitates the expression of events and the behavior of agents efficiently and accurately. In order to provide a better understanding of state charts and their components, a Customer Behavior State Chart is used below in Figure 2 as an illustrative example.

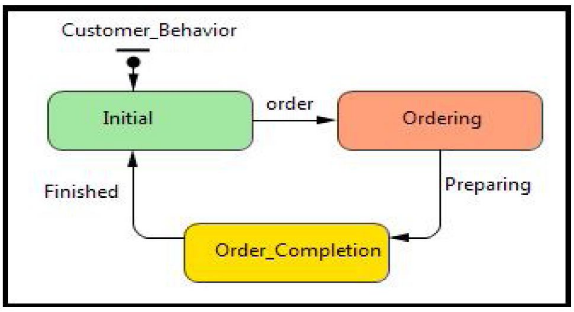

Figure 2: Customer Behavior State chart

V. EVALUATION OF CTS EFFICIENCY

In an attempt to prove the efficiency of the CTS simulation, validation and verification of the recommended framework is provided by using the scenario planning technique.In the following scenario, local and global promotions are made only for the blue products to increase demand twice as many and the related graphs are represented as follows in Figure 3. In short, demand goes up approximately 50-60 % for a blue product and an unbalance between order lines is observed.

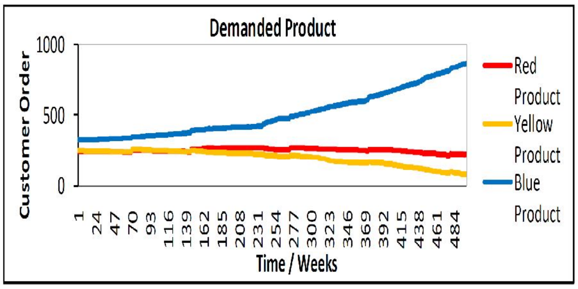

Figure 3: Increased demand about 50 % for a key product

After the abovementioned change is applied, the storage analyses and products fluctuations are given below in Figure 4.

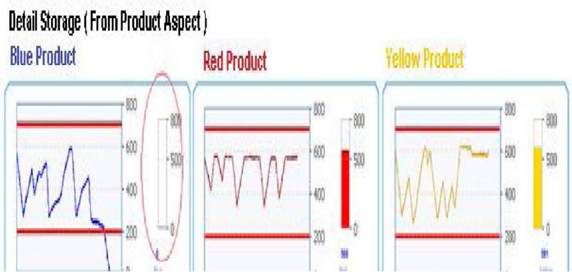

Figure 4: Storage behaviors for three products before measure implementation.

As demonstrated in the above, each three diagrams which present a detailed storage analysis, the blue product has run out. In order to strengthen understanding, the bar charts are attached next to the time plot and they show the total product amount in the storage for each product types. To put it simply, unbalanced demand between order lines can lead to huge fluctuations for some order lines; the blue product being one example. In order to overcome this challenge, three measures are chosen which are explained comprehensively as follows:

5.1 Increase the Maximum Stock Level

At the beginning of the CTS simulation, a specific amount is assigned for each product type. This amount, also called the maximum stock level, is determined as 600 bins for every type of product. However, the maximum stock level goes up by 33%, and the new amount of product varies from 600 bins to 800 bins. The graphs concerning storage behaviors after increasing the maximum stock levels are represented below in Figure 5.

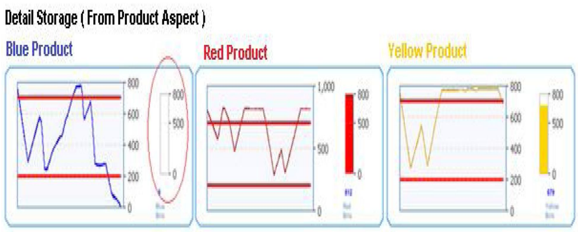

Figure 5: Storage behavior for three products after increasing the maximum stock levels.

What is remarkable is that 'run out of blue product problems' has emerged again. Thus, it can be concluded that increasing maximum stock levels is not viable for solving the encountered problems.

5.2 The Adding Safety Stock Policy

Another measure is selected from the most important part of anticipatory change planning, in which control rules and warehouse strategies are modified by removal or insertion. Safety stock policy is an example under the headings of the planning control rules step. Normally, Re-order point rules are carried out in order to avoid stock deficiency. However, Re-order point rules remain incapable in the case of this scenario. At this point, 100 bins are kept in reserve as safety stock.

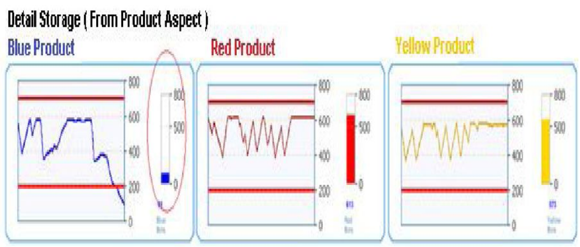

Figure 6: Storage behaviors for three products after adding safety stock

It can be seen from the above stock graphs Figure 6, that even though the simulation is completed without a non-available situation, an enormous wave can be observed on the blue product. Hence, inserting the safety stock measure cannot be accepted as an exact solution for this case study.

5.3 The Alter Supply Strategy

Within the concept of CTS simulation, the purchasing process is performed under three strategies. The first is based on forecast strategy that obtains the purchasing amount by calculating different forecasting techniques. The second strategy is carried out according to maximum levels, and aims initially for full storage. The third strategy is based on the fix value strategy, in which users are able to arrange the purchase amount for each product group. The default value of CTS simulation is the maximum level method. However, other supply techniques will be applied to understand which strategy is the most suitable when an unbalanced case is realized between demanded products.

The Forecast Option

The graphs below in Figure 7 illustrate that the forecast options are not capable of handling out of stock problems. On the other hand, waving on the blue product has also appeared.

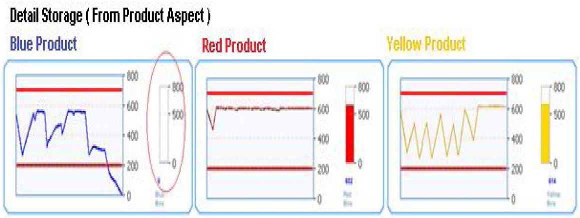

Figure 7: Scenario 2 Storage behavior after applying forecast option

The Fixed Order Quantity Option

The Fixed Order Quantity method is used when demand for the product is invariable and the required quantity are not quite known. As can be understood from the demanded product Figure 3, blue products should be supplied two times more than red and yellow products. According to this logic, the amounts of products that will be purchased for each product type are given below in Figure 8.

Fix order quantity for the blue product = 400

Fix order quantity for the red product = 200

Fix order quantity for the yellow product = 100

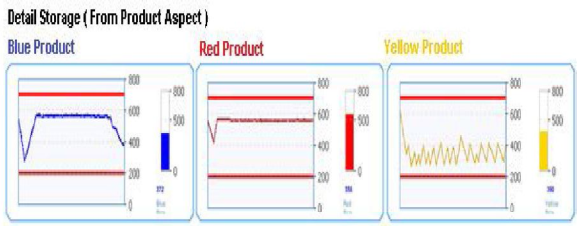

Figure 8: Storage behavior after applying the fixed value option.

Ultimately, the huge fluctuations and the non-available situation for the supplied blue product can be prevented by using the fixed order quantity supply strategy.

VI. SUMMARY

Cellular Transport System simulation composed of autonomous multi shuttles was simulated on the basis of Agent-Based simulation. Regardless of the lack of knowledge and research about the CTS, the all warehouse activities and inventory rules were inserted into the CTS simulation. In order to enlarge the specification of the CTS simulation, agent based simulation, discrete event simulation and statistical analyses parts are generated by writing Java programming language. As a second step, the study seeks to anticipate any occurrence, which could be any type of expected and unexpected event, to proactively find its effect on the intralogistics system and if required, how could the optimum measure be chosen methodically.

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