Automatic Conditions Monitoring of Perishable Products in Warehouses

César Stoll Q.
Pontificia Universidad Católica del Perú, Lima, Perú, cstoll@pucp.pe

ABSTRACT

The natural decay of fresh products is an unavoidable process and generates great loss a long the fresh food supply chain. The FEFO heuristic – First Expire First Out – improves the management of perishable products during its storage; nevertheless, there are strong technical limitations. This paper proposes the use of automatic conditions monitoring of fresh products in order to overcome current limitations. The proposal is based on simulation scenarios. Information and comunication technologies (ITC) support the implementation of automatic conditions monitoring of perishable products to guide the optimal inventory rotation.

Keywords: Fresh Food Warehouse, Automatic Conditions Monitoring, Information and Communications Technology, Simulation, First Expire First Out

RESUMEN

La descomposición natural de productos frescos es inevitable, esto genera grandes pérdidas a largo de la cadena de suministro. El método FEFO – Primero en Expirar Primero en Salir – mejora la gestión de productos perecederos durante su almacenamiento, sin embargo existen grandes limitaciones técnicas. Este artículo propone el uso de condiciones de monitoreo automático de productos frescos a fin de superar actuales limitaciones. La propuesta se basa en escenarios de simulación, donde tecnologias de información y comunicación (ITC) soportan la implementación de las condiciones de monitoreo automáticas de productos perecederos para guiar la rotación de inventarios óptima.

Palabras claves: Almacén de Alimentos Fresco, Control Automático de Condiciones, Tecnología de Comunicación e Información, Simulación, FEFO

1. INTRODUCTION

The Rising life expectancy, the increasing presence of double family income, and consumers' wishes for a larger variety of products have been changing food demand in terms of quantity, variety, quality and service. Consequently, this new socio-economic trend enhances the importance of customer orientation in the food supply chain, i.e. there is an increasing *market dynamics*. Thus, planning and control of logistic processes in the food supply chain becomes a challenging task. On the other hand, the current globalisation of markets plays an important role. It removes barriers between countries, which makes it possible for consumers to obtain new products from new suppliers situated in new production networks, and therefore, there is an increasing *market complexity*.

In such a dynamic and complex environment, it is difficult to provide all the necessary information for a central control in hierarchical organisations. Therefore, it may be attractive to apply the concept of *automatic conditions monitoring in logistics* to this context. With automatic conditions monitoring, the response of the logistic system becomes more reliable, due to the use of modern information and communication technologies such as radio frequency identification (RFID), global position system (GPS), visual sensors, software agents, etc. Considering the use of these technologies, the decentralised coordination of logistic objects in a heterarchical structure becomes feasible.

2. A NEED FOR AN APPROACH OF AUTOMATIC CONDITIONS MONITORING TO LOGISTIC SYSTEMS

Both the logistic systems and the consumers' demand in a global scenario represent a starting point in order to study the supply chain reaction, which usually must be quick and agile to satisfy the different and unpredictable consumers' desires.

The Collaborative Research Centre 'Autonomous Cooperating Logistic Processes – A Paradigm Shift and its Limitations', CRC 637, University of Bremen, uses a system concept by Ropohl (1979), which divides a logistic system into execution, information and decision system. The outcomes are three task layers of the CRC 637 (Scholz-Reiter et al., 2004), see Figure 1. This concept is an attempt to transcend the problems of separate functions or sub-systems through the identification of interfaces between them and devising means whereby they may relate to each other in the most effective way, thus ensuring that internal contradictions in the corporate activity are minimized.

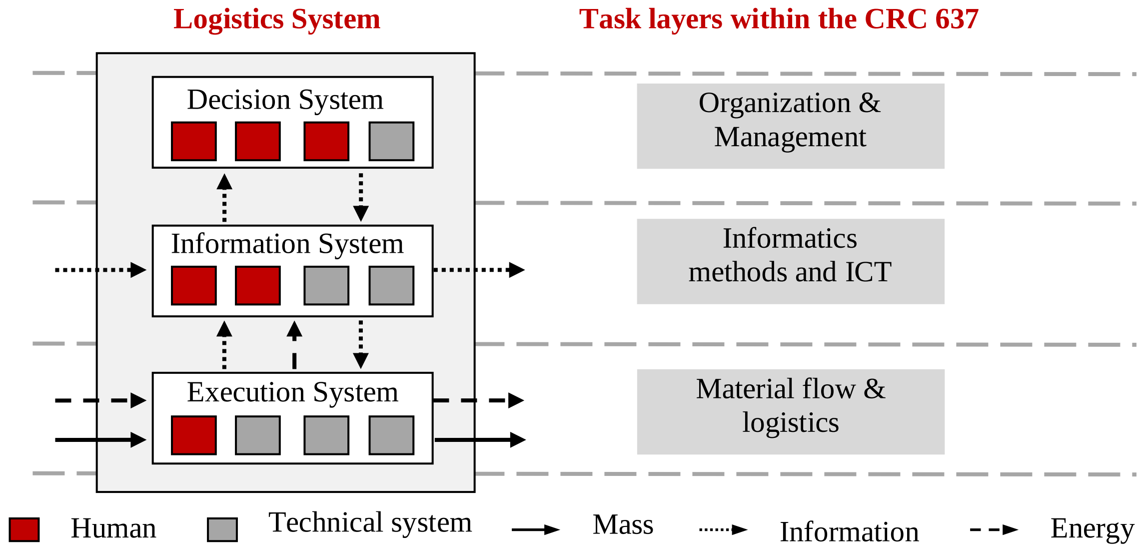

Figure 1: Holistic Perspective on Logistic System and Resulting Task Layers within the CRC 637

2.1 CURRRENT SITUATION OF LOGISTIC SYSTEMS

Business companies experts and executives are currently focusing their attention on logistic systems, due to the great influence that they have on the number of company employees needed for the company. For example, when a company considers outsourcing some functions such as distribution or storage, the number of employees is reduced, whereas it is increased in the external associated company.

Nowadays logistic systems receive transverse enterprise information, which allows coordinating and managing activities in every area. However, they must also deal with the increasing complexity and dynamic of decision, information and execution systems. Specifically, a growing number of companies and their interactions increase market complexity and the increasing importance of customer orientation increases market dynamic (Scholz-Reiter et al. 2004). There are many reasons that explain the increasing market complexity and dynamic, but most of them are based on the globalization stream, e.g. short product life cycles as well as a decreasing number of lots with a simultaneously rising number of product variants and higher product complexity (Scherer 1998).

The current logistic systems need an organisational structure where the coordination mechanisms make easier the internal/external operations of both predictable and unpredictable events. Conventional production systems are characterized by central planning and controlling processes, which do not allow fast and flexible adaptation to changing environmental influences (Windt et al. 2006). The food supply chain, for example, uses conventional central control to operate logistic processes. This implies a relatively long lapse of time between information reception, information processing, decision making and decision execution. The system requirements demand changes in the hierarchical structures, a change of paradigm. There is an ongoing paradigm shift from centralised control of ‘non-intelligent’ items in hierarchical structures towards decentralised control of ‘intelligent’ items in heterarchical structures in logistic processes (Scholz-Reiter et al. 2004), i.e. flat organisational structures.

Figure 2 shows the relationship between control mode and type of organisational structure. Flat structures demand more self-control of their elements. Organisational structures could be represented by systems, according to the system theory there is a shift of capabilities from the total system to its system elements (Krallmann 2007). Each system-element represents a decision unit, which is equipped with decision-making competence according to the current task (Frese et al. 1996)

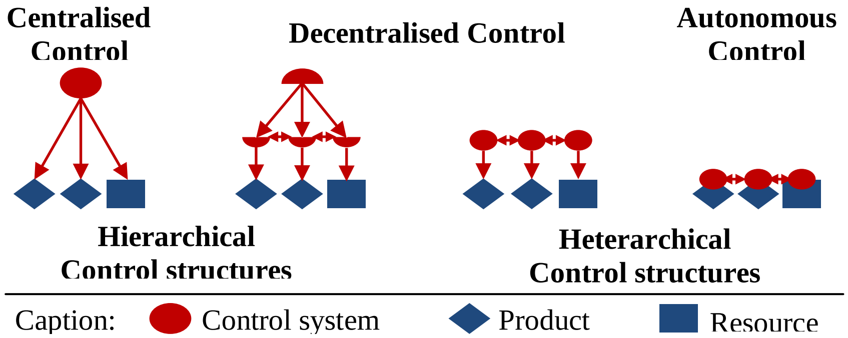

Figure 2: Organisational Structures (Scholz-Reiter and Freitag, 2007)

2.2 Technology Requirements in Logistic Systems

The automatic conditions monitoring is presented as a solution to face up to the logistics systems trends, i.e. the increase of complexity and dynamics in the current logistics scenarios. The available technologies to make real this concept could be divided into five types, Figure 3:

- *Identification*, e.g. RFID Tagging (Radio Frequency Identification). A RFID plays the main role in automatic conditions monitoring. It consists of a chip containing an integrated processor with memory and an antenna. The RFID Tagging makes possible the object identification when it is linked to the RFID.
- *Localization*, e.g. Global Position System (GPS), Galileo, Glonass, WiFi, RFID reader/writer.
- *Communication*, e.g. WiFi is the common name of a popular wireless technology.
- *Decentralised data processing*, e.g. software agents. This kind of software is able to communicate and interact with its environment in order to pursue goals or fulfil orders.
- *Sensors networks*, e.g. visual sensors.

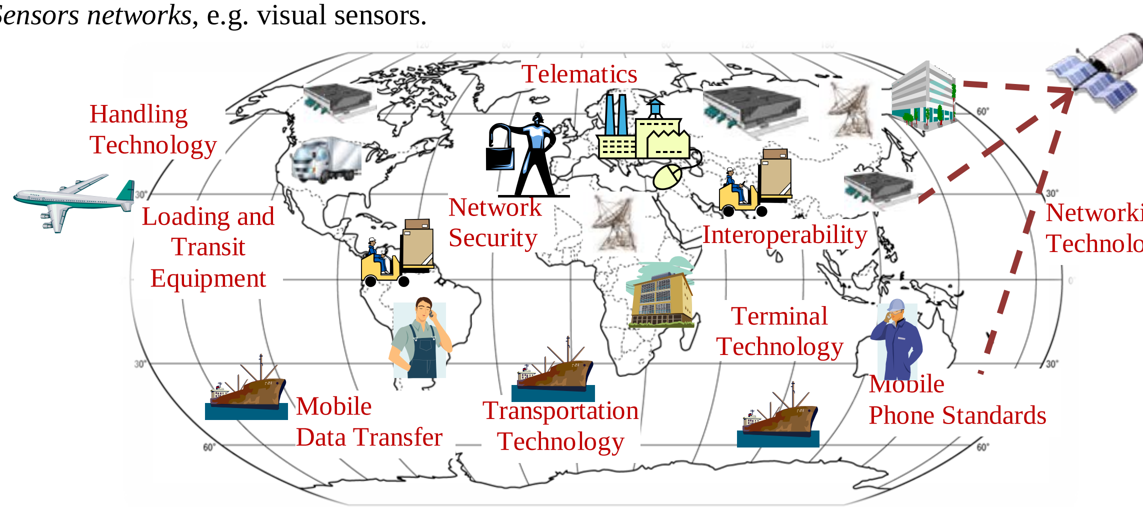

Figure 3: New Technologies and their Application to Logistics

Mobile internet applications have to adapt the display format automatically to the particular terminal, which, for example, is essential in off board communication (Zahariadis 2003). In other words, the wide range and growing number of required technology need parts compatibility in order to achieve a proper interoperability among the logistic systems.

3. APPROACH OF AUTOMATIC CONDITIONS MONITORING TO FRESH FOOD SUPPLY CHAIN

The idea of autonomous control has been developed in the CRC 637 since January 2004. The general idea consists of designing processes of decentralized decision-making in heterarchical structures. It requires the ability and possibility of interacting system elements to autonomously make goal-oriented decisions (Scholz-Reiter et al. 2006). The automatic conditions monitoring propose a similar idea to the autonomous control but main decision-making processes remain inside the human control.

3.1 CRC 637: THE INTELLIGENT CONTAINER

The intelligent container project has been developed as an autonomous transport monitoring system for perishable goods by the Microsystems Center Bremen (MCB). The project is considered a core element inside the CRC 637 'Autonomous cooperating logistics processes', Figure 4.

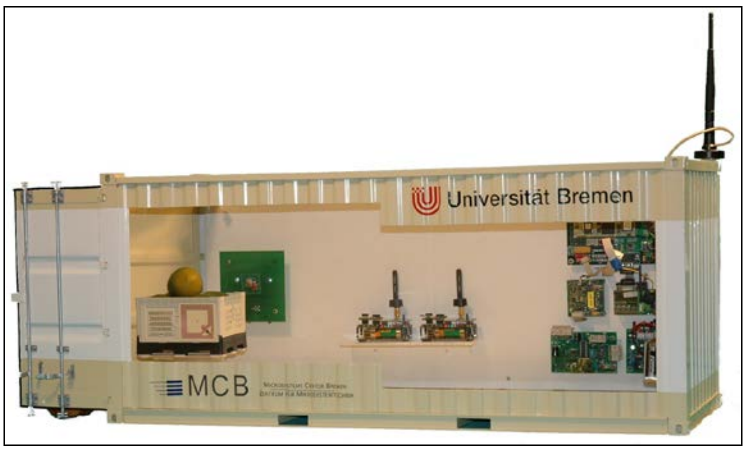

Figure 4: Intelligent Container Demonstrator as a 1:8 Scale Model

An intelligent container can be described as a container that is equipped with advanced tools for tracking and tracing. The tracking property allows the container's localization in every point of the supply chain and is also used in case of product recall. On the other hand, the tracing property allows the identification of origin and characteristics of the contained products along the supply chain and it is also used to find the source of a quality problem. Thus, temperature, humidity and gases inside the container could be monitored and used for both prediction of changes in freight quality and as additional information to optimize transport processes and warehouse keeping. These advanced tools in the context of intelligent containers need to be linked to RFID technologies, sensors networks and *software agents* to provide a permanent and freight-specific supervision of each transported container along the supply chain. The main role of software agents is to replace human decision-making; therefore, the Intelligent Container is an example of autonomous control.

3.2 FROM THE INTELLIGENT CONTAINER TOWARDS THE FRESH FOOD SUPPLY CHAIN

The intelligent-container is designed as intermodal freight transport inside the supply chain, i.e. the container and its freight are transported in international environments using several modes of transportation (rail, ship and truck). According to Kaushik (2000), the trend the world over has been towards the containerisation. Many advantages support this trend, e.g. Owen (1962) affirms that:

- Containers reduce the need for berth capacity by speeding port operations, and they stretch the supply of shipping space by shortening turn-around time for cargo vessels.

- Containerization is particularly advantageous in underdeveloped areas because of frequent transhipment where the transport system is incomplete.
- Containers may be the catalyst that integrates the various components of the transport sector.
- Rail equipment can be utilized more effectively when containers rather than rail cars are used for storage.

The main role of the container consists of products storage while they are been transported through the different firms that make up the supply chain. Figure 5 shows an agri-food supply chain, where the container's role is represented as 'transport'. Containers act as means of connection between several firms.

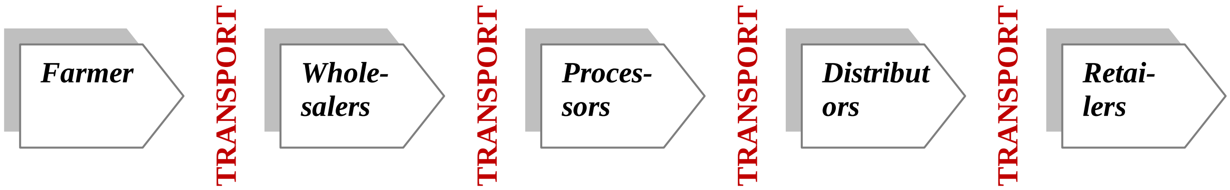

Figure 5: Example of Supply Chain: Agri-Food Supply Chain

Storage activities play an important role in the supply chain: each link of the supply chain basically stores incoming products, which keep stored until their processing, if necessary, and finally the processed products must be stored again and wait until sale opportunity. In this context, the storage function of the containers is permanently needed along the supply chain. Consequently, the technology of intelligent-container, based on autonomous control, may be applied into every link of the fresh food supply chain so that the storage function could be optimized.

3.3 Fresh Food Warehouse Replenishment Policies

Most conventional inventory models assume that material items can be stored for an indefinite period of time without loss of utility (Chiu, 1995). However, fresh food warehouses store perishable products and the effect of perishables is a factor that can not be disregarded in many inventory systems (Shiue, 1990). Nahmias (1982) considers two ways of classifying perishability:

- *Fixed lifetime:* the lifetime is known *a priori* to be a specified number of periods or a length of time independent of all other parameters of the system.
- *Random lifetime:* the product lifetime is a random variable with a specified probability distribution. Exponential decay is also included as a special case.

Fresh products are a typical example of products with *random lifetime*, i.e. products are discarded when they spoil and the time to spoilage may be uncertain (Nahmias, 1982). Furthermore, there has been considerable interest in developing mathematical inventory models for describing optimal policies for items with a stochastic perishing time, i.e. random lifetime, e.g. Shiue (1990), Chiu (1995), Goh et al. (1993). However, a mathematical inventory model for perishable fruits is a great challenge due to the high complexity of the problem. According to Nahmias (1982), when products demand is unknown and the product lifetime either exceeds one period, or is random, determining optimal ordering policies is extremely difficult. Since it is no longer possible to obtain an order policy so that there is no perishing, the state vector must include the stock level of each possible age category.

Nowadays, technology advancement, especially in computer capacity, offers new alternatives to manage warehouse inventories removing old barriers. Nevertheless, perishable products inventories do not have remarkable improvements so that conventional inventory policies and demand forecasting continue to be the main support for replenishment activities in the warehouse.

3.4 Products Picking Heuristics in a Fresh food warehouse

First-In First-Out, ***FIFO***, is a scheduling rule whereby the oldest item in line gets processed first (Van der Vorst, 2000). FIFO is the current heuristic for food distribution (Koutsoumanis et al., 2005). The FIFO heuristics favours the selection of the oldest products stored in the fresh food warehouse so that the delivery orders may be fulfilled.

Product freshness is one of the most important factors that influence consumers, so that in many cases outweighs the price of products. A successful application of the FIFO heuristics into fresh food distribution is not always possible. It strongly depends on correct labelling to avoid products wrongly dispatched. Furthermore, correct labelling must consider products freshness, which is not always associated to the date of the products reception in the warehouse. In summary, the FIFO heuristics is not only simple and easy to use, but also provides a standard criterion for fresh products distribution along current supply chains. Nevertheless, these heuristics are very susceptible to mistakes.

*First Expire First Out, **FEFO***, is a scheduling rule whereby the item with lowest admissible quality level in line gets processed first. Fresh Food distribution in warehouses would be much more efficient if it is organised based on keeping quality instead of the principle of 'First-In First-Out' (Jedermann et al., 2006). The main problem of the FEFO heuristics is the identification of the quality levels in fresh products, i.e. the measure of freshness decay. Koutsoumanis et al. (2005) face the FEFO problem through the development of a novel chill chain management policy, coded *'Safety Monitoring and Assurance System'* or ***SMAS***. The SMAS is based on actual risk evaluation at important points of the chill chain that is used to promote products to the next stage of distribution. Basically, the SMAS builds predictive models that have the ability to determine the growth of food pathogens and allow to give priority to products in such a way that risk at consumption time is minimized. SMAS supports decision-making regarding either to distribution or stock rotation of products, at designated points. Koutsoumanis et al. (2005) has evaluated the effectiveness of SMAS against the FIFO approach. A case study of cooked ham in their experimental work provide results that show that the SMAS approach has reduced the number of products with zero shelf life from 12% to 4% in the warehouse, i.e. comparative results with the FIFO heuristics.

On the other hand, Radio Frequency Identification (RFID) technology can support the SMAS providing accurate data for their predictive models. Jedermann et al. (2009) propose miniaturized RFID temperature loggers to analyze the amount of local deviations and detect temperature gradients. The temperature is the most important factor when prolonging the practical shelf life of produce, i.e. it has a great influence on the growth of food pathogens.

In summary, the FEFO approach is more suitable for the inventory rotation of fresh products than the FIFO approach. Nevertheless, technology limitations and complexity of the FEFO approach hinder its extended use.

3.5 IDENTIFICATION TECHNOLOGY FOR NATURAL DECAY OF FRESH PRODUCTS

According to Abbott (1999), quality of fresh products encompasses sensory properties, nutritive values, chemical constituents, mechanical properties, functional properties and lack of defects. People base their quality evaluation of fruit on combined sensory inputs from several of their senses and since human judgments are, in general, subjective, these evaluations are liable to be inconsistent and can lead to erroneous quality determination of the fruit. Thus, there is an increased need for better quality monitoring (Mizrach, 2008). Furthermore, all actors in the fresh food supply chain: producers, packing houses, warehousemen, wholesaler, retailer, etc., are potential users of instrument and equipment for measuring fruit and vegetable quality properties (Barreiro et al., 2004).

Over the years many methods and associated instrumentation have been developed, based on mimicking human sensory characteristics, to measure quality and quality-related attributes; they have been accompanied by a large number of instrumental sensors for real-time and non-destructive testing (Upchurch et al., 1994; Abbott, 1999). 'Non-destructive' or 'non-invasive' tests mean that the examined products remain at all times physically and chemically unaltered.

Butz et al. (2005) have used an internet search engine to find items for the key words 'non-destructive' or 'non-invasive' in the context of 'food'. Figure 6 shows the distribution of these entries in different techniques of non-destructive analysis of food:

- *Vision based methods (50%):* They include many different applications, from traditional manual evaluation by trained inspectors to computer vision using modern image acquisition apparatus like multispectral cameras, and so forth, and highly sophisticated image-processing software for object measurement and classification utilizing for example, fuzzy logic and neural network methods (Butz et al., 2005).

- *Acoustic methods (20%):* They use ultrasonic energy propagated through a material until the sound wave encounters an impedance change, which means that there are some changes in the material density or/and the velocity of the sound wave (Kuttruff, 1991).
- *Spectroscopic methods (20%):* They use interactions between atoms or molecules and electromagnetic radiation to supply qualitative and quantitative chemical and physical information. Photons from certain wavelength of frequency ranges of the spectrum are absorbed or emitted according to their energy content (Butz et al., 2005).

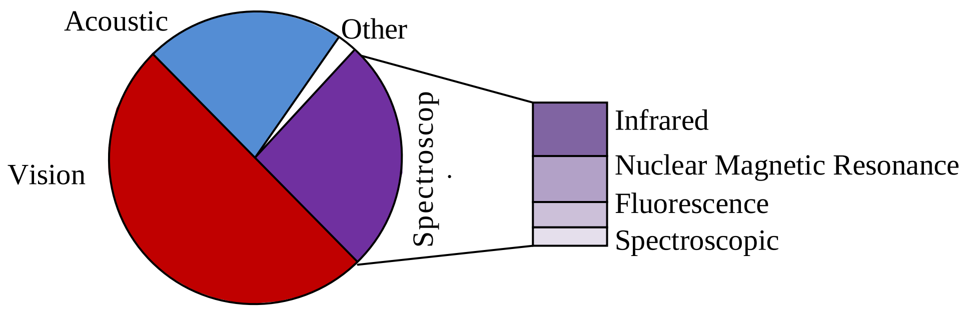

Figure 6: Distribution of Non-Destructive Techniques to Measure Fresh Food Quality

4. APPLICATION OF AUTOMATIC CONDITIONS MONITORING OF PERISHABLE PRODUCTS IN FRESH FOOD WAREHOUSES

4.1 MODEL OF A FRESH FOOD WAREHOUSE

Two models has been developed, the first one represents a scenario where automatic conditions monitoring is applied into the logistic processes of a fresh food warehouse. The second model shows the same logistic processes, this time without the technology related to the automatic conditions monitoring; i.e. an up to date optimal fresh food warehouse. The models basically measure the impact that the quality changes in fresh products have on the sale process; i.e. when fresh products change their quality, the corresponding inventories must be updated, otherwise the warehouse data will be inexact and the risks of incorrectly supplying customers' – and therefore, sales losses – increase. The general process includes three stages: the first one is the reception process, where the pallets containing fresh food come into the warehouse. The second stage is the storage process. The products are observed in order to detect any changes in their quality. These changes could appear as a consequence of natural decay or exposure to an inappropriate atmosphere that could accelerate their perishability. The final stage is the distribution process, when the fresh products are selected for customer delivery.

In the particular case of the fresh food warehouse, both decentralised data processing and coordination interaction ability could be achieved through the use of RFID systems. E.g. a network of RFID readers is situated around the warehouse and ready to detect the passive RFID's attached to fresh food pallets. In this case, the passive RFID's register information about products characteristics – kind of products, required temperature, etc. – which is recognised by the readers and sent to a storage coordinator. In this example, the data processing is decentralised, because each pallet has its own passive RFID with particular information, and the interaction ability between RFID readers and passive RFID's supports the coordination functions.

Each sector of the store must have sensors to measure temperature, humidity and atmospheric composition and especially to measure the level of the gaseous hormone ethylene, which has an important impact on the ripening processes in fresh food. This information allows classifying the store ambient conditions, selecting the best storage atmosphere according to the incoming fresh product pallet atmosphere.

The simulation model based on automatic conditions monitoring considers the following activities:

- Inspections: There are many types of inspection and all of them depend on the type of product, and also on when the inspection will be carried out, e.g. during the reception, storage or delivery.
- Store: the approved products after the inspection should be stored.

- Return: if the received product is not approved after the inspection, it should be returned to the supplier or stored under special conditions and monitored.
- Delivery: when the customer is already waiting for the product it should not be stored, but directly sent to the delivery area.
- Rearrangement: when the stored products lose their quality and threaten the storage atmosphere, and also when they are put on sale. In these cases they should be moved to another place.
- Local position of mobile elements: each forklift may be localized inside the warehouse as well identifying its work state.

4.2 MESURABLE PARAMETERS FOR EVALUATION OF THE MODELS

The proposed models of fresh food warehouse can reproduce in detail the different situations that happen in the warehouse. The simulation models provide a lot of information related to the behavior of the logistic processes in the warehouse. In order to favour a comparison of both models, some parameters have to be defined to make the data evaluation easier. The evaluation data collected from the models is classified into the following parameters:

- *Lost Sales due to Quality Changes*: This parameter measures the sales that the warehouse loses when the products are no longer fresh due to a change in their quality and when the warehouse does not have enough products in order to supply the customers' demand. Inventory data continuously change because of fresh food perishability.
- *Lost Products due to their Perishability*: This parameter measures the amount of products that must be eliminated per simulated period because they are no longer fresh. Grouping products with the same quality grade avoids a speeded up decay of fresh products, optimizing the storage conditions.
- *Potential Extra Income due to Quality Changes*: This parameter provides qualitative data that are useful in order to search for secondary markets for those products that are no longer fresh.
- *Use of Warehouse Space*: This parameter measures the average use of spaces in the warehouse. During the simulation time the distribution of the products for storage within the warehouse is taken into account. Each simulation model arrange the fresh products in different ways and as a consequence, quality loss of products and processes such as rearrangements and sales, influence differently the use of warehouse spaces during the simulation of both models.

4.3 SOME SIMULATIONS RESULTS

The automatic condition monitoring model can timely detect quality changes, updating inventory data. This information is useful in order to meet the requirements of the sales orders, i.e. this model may send, if necessary, new purchase orders for timely replenishment of products so that sales lost and delivery of incomplete orders may be avoided.

Measuring quality changes may improve the storage process in the fresh food warehouse. The data inform about the quality changes that occur, so that the appropriate steps related to the purchase orders can be taken, e.g. purchasing more products or sending more purchase orders during the simulation periods. Figure 7 shows that 0.14 percent of first quality products of the automatic condition monitoring model turn into second quality products. This percentage may be really useful for the purchase process.

Due to rearrangement processes the automatic conditions monitoring model needs more storage spaces, keeping empty subsectors if necessary, in order not to mix products with different quality grades. On the contrary, the reference model cannot avoid storing all kinds of products, making better use of the warehouse spaces, although the natural decay is speeded up, i.e. sacrificing spaces favours foods quality preservation.

The potential saving costs of the automatic conditions monitoring model are estimated for the lost sales due to quality changes, Table 1. This table applies the simulation results to the average annual import of organic farming carrots, citruses, green bananas and fresh asparagus in Germany (AMI 2011; FAO 2011; CCI et al 2011). As a consequence, the average percentage of products that cannot be sold due to quality changes can be estimated in terms of Ton and Euros for each models.

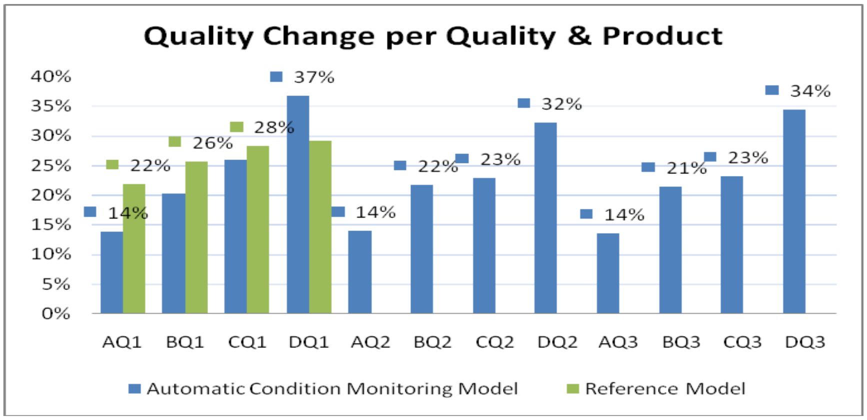

Figure 7: Percentage of total outgoing products that must be removed from their storage place due to quality changes per quality grade and product

Table 1: Annual Saving Costs With the Automatic Condition Monitoring Model

Imported Product in Germany	Lost Sales due to Quality Changes						Saving Costs with the Automatic Condition Monitoring Model	
	Automatic Condition Monitoring Model			Reference Model				
	%	Ton	Euros	%	Ton	Euros	Ton	Euros
A: Carrots	25%	1.750	1.702.750	29%	2.030	1.975.190	**280**	**272.440**
B: Citruses	27%	4.050	4.228.200	31%	4.650	4.854.600	**600**	**626.400**
C: Bananas, green	20%	2.000	2.312.000	30%	3.000	3.468.000	**1.000**	**1.156.000**
D: Asparagus, fresh	23%	8.740	45.185.800	35%	13.300	68.761.000	**4.560**	**23.575.200**
Total		16.540	53.428.750		22.980	79.058.790	**6.440**	**25.630.040**

REFERENCES

Abbott, J. (1999). "Quality Measurements of Fruits and Vegetables". *Postharvest Biological Technology*, Vol. 15, pp. 207-225

AMI (2010). Marktservice Großhandelsabgabe preise, http://www.marktundpreis.de/gartenbau/produktlinie/leseprobe/Leseprobe-Marktservice_Grosshandelsabgabepreise.pdf, 19.11.2011

Barreiro, P., Ruiz-Altisent, M., Valero, C., García-Ramos, J. (2004). "Fruit Postharvest Technoloy – Instrumental Measurement of Ripeness and Quality". In: Ramdame, Shri Mohan, J. (eds) *Production Practices and Quality Assessment of Food Crop*, Kluwer Academic Publishers, EEUU, Vol 3, pp. 321-340

Butz, P., Hofmann C., Tauscher, B. (2005). "Recent Developments in Noninvasive Techniques for Fresh Fruit and Vegetable Internal Quality Analysis". In: *Journal of Food Science*, Vol. 70, Issue 9, pp. 131-141

CCI (2011). Alemania. In: Agronet, Ministerio de Agricultura y Desarrollo Rural, Colombia, http://201.234.78.28:8080/dspace/handle/123456789/888, 19.11.2011

Chiu, H. (1995). "An Approximation to the Continuous Review Inventory Model with Perishable Items and Lead Times". In: *European Journal of Operational Research*, Vol. 87, pp. 93-108

FAO (2011). World Markets for Organic Fruit & Vegetables – Opportunities for Developing Countries in the Production and Exports of Organic Horticultural Products. In:FAO Corporate Document Repository, Roma, http://www.fao.org/DOCREP/004/Y1669E/Y1669E00.HTM. 19.11.2011

Frese, E., Schmidt, G., Hahn, D. and Horváth, P. (1996). “Organisationsstrukturen und Management”. In: Eversheim, W. & Schuh, G. (Hrsg.): *Betriebshütte, Produktion und Management*. 7. völlig neu bearbeitete Auflage, Springer-Verlag, Berlin, New York

Goh, Ch., Greenberg, B., Matsuo, H. (1993). “Two-Stage Perishable Inventory Models”. In: *Management Science*, Vol. 39, Issue 5, pp. 633-649

Jedermann, R., Schouten, R., Sklorz, A., Lang, W., Kooten, O. (2006). “Linking Keeping Quality Models and Sensor Systems to an Autonomous Transport Supervision System”. In: *Proceedings of the 2nd International Workshop Cold Chain Management*, Bonn, pp. 3-18

Jedermann, R., Ruiz-Garcia, L., Lang, W. (2009). “Spatial Temperature Profiling by Semi-Passive RFID Loggers for Perishable Food Transportation”. In: *Computers and Electronics in Agriculture*, Vol. 65, pp. 145-154

Kaushik, D. (2000). “Private Investment and Policy Developments in Transport Sector”. In: *Economics and Political Weekly*, Vol. 35, Issue 15, pp. 1277-1282

Krallmann, H. (2007). “Systemanalyse in Unternehmen: Partizipative Vorgehensmodelle, objekt- und prozessorientierte Analysen, flexible Organisationsarchitekturen”. 3er ed. München, Wien: Oldenburg

Koutsoumanis, K., Taoukis, P., Nychas, G. (2005). “Development of a Safety Monitoring and Assurance System for chilled Food Products”. In: *International Journal of Food Microbiology*, Vol. 100, pp. 253-260

MCB and CRC 637, (2009). “The Intelligent Container – Application of RFID and Sensor Technology for Autonomous Transport Monitoring”. In: *University of Bremen, Microsystems Center Bremen and Collaborative Research Center 637* - http://www.intelligentcontainer.com, 25.05.2009

Mizrach, A., Galili, N., Rosenhouse, G. (1994). “A Method and a System for Non-destructive determination of Quality Parameters in Fresh Produce”. Israel Patent No. 109406

Nahmias, S. (1982). “Perishable Inventory Theory: A Review”. *Operations Research*, Vol. 30, No. 4, pp. 680-708

Owen, W. (1962). “Transportation and Technology”. *The American Economic Review, Papers and Proceedings of the 74 Annual Meeting of the American Economic Association*, Vol. 52, Issue 2, pp. 405-413

Ropohl, G. (1979). “Eine Systemtheorie der Technik – Grundlegung der Allgemeinen Theorie”, Carl Hanser Verlag, München

Scholz-Reiter, B.; Windt, K.; Freitag, M. (2004). “Autonomous Logistics Processes – New Demands and First Approaches”. *Proceedings of the 37th CIRP-International Seminar on Manufacturing Systems*, pp. 357-362

Scholz-Reiter, B., Hilderbrandt, T., Kolditz, J. (2006). “A Modelling Methodology for Control Processes of Autonomous Production Systems”. In: Monostori, L.; Ilie-Zudor, E. (Hrsg.): *Proceedings of MITIP 2006. 8th International Conference on The Modern Information Technology in the Innovation Processes of the Industrial Enterprises*. Budapest, Hungary, pp 317-322

Scholz-Reiter, B; Freitag, M. (2007). “Autonomous Processes in Assembly Systems”. In: *CIRP Annals*, Vol. 56, Issue 2, pp. 712-729

Shiue, Y. (1990). “An Inventory Model for Perishable Items in a Lot-Size System with quantity discounts”. In: *European Journal of Operational Research*, North-Holland, Vol. 45, pp. 260-264

Upchurch, B., Affeldt, H., Aneshansley, D., Birth, G., Cavelieri, R., Chen, P., Miller, W., Sarig, W., Schmilovitch, Z., Throop, J., Tollner, B. (1994). “Detection of Internal disorders”. In: *Proceedings of the International Workshop on Nondestructive Technologies for Quality Evaluation of Fruits and Vegetable*, ASAE Publication. Washington-USA, No. 4-94, pp. 80-85

Van der Vorst, J. (2000). “Effective Food Supply Chains - Generating, Modelling and Evaluating Supply Chain Scenarios”. *Dissertation Wageningen University, Neatherlands*, pp. 1-36, 91-110, 141-165, 273-276

Windt, K., Böse, F., Phillip, T. (2006). “Evaluation of Autonomously Controlled Logistics Processes”. In: *Proceedings of 5th CIRP International Seminar on Intelligent Computation in Manufacturing engineering*, Ischia, Italy, pp. 347-352

Zahariadis, Th. (2003). “Evolution of the Wireless PAN and LAN standards”. In: Schumy, H. (Eds.), *Computer Standards & Interfaces*, Vol. 26, Issue 3, pp. 175-185

Authorization and Disclaimer