Information Technology and Management Science doi: 10.1515/itms-2015-0014

2015 / 18

Case Study on Inventory Management Improvement

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Abstract – **Inventory management is a challenging problem area in supply chain management. Companies need to have inventories in warehouses in order to fulfil customer demand, meanwhile these inventories have holding costs and this is frozen fund that can be lost. Therefore, the task of inventory management is to find the quantity of inventories that will fulfil the demand, avoiding overstocks. This paper presents a case study for the assembling company on inventory management. It is proposed to use inventory management in order to decrease stock levels and to apply an agent system for automation of inventory management processes.**

Keywords – **ABC classification, demand forecasting methods, inventory management, replenishment policies.**

I. Introduction

Inventory is the stock of any item or resource used in an organisation [1]. There are three types of manufacturing inventories: raw materials, work in progress and finished goods (Fig. 1).

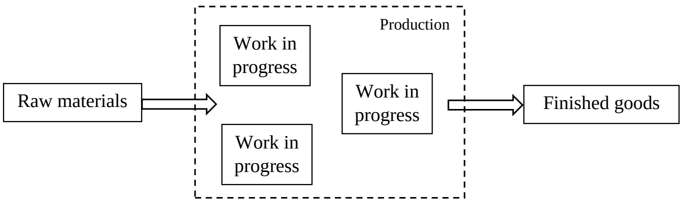

Fig. 1. Types of manufacturing inventories.

The author [2] mentions several reasons why it is needed to have inventories:

- To meet anticipated demand;
- To smooth production requirements;
- To protect against stock-outs;
- To take advantage of order cycles;
- To hedge against price increases or to take advantage of quantity discounts;
- To permit operations;
- To decouple components of the production-distribution system.

Otherwise, it will lead to production delays, shortages and/or dissatisfied customers [3]. The paradox of inventory management is that having inventory is needed, but it is not desirable to have inventory due to inventory keeping costs. This situation makes inventory management a challenging problem area in supply chain management. This paper presents a continuation of the research [3], [4] adding new experiments and forecasting algorithms on the same analysing data.

This paper is organised as follows: at first, the task is presented, after that the existing situation is analysed, then the solution is proposed, after that the experiments are shown and, finally, conclusions are presented.

II. Task Definition

Inventory management is not the novelty, but still not every company uses it in order to reduce inventory costs. The inventory management task is to find out how much and when to order:

- Objective: To keep enough inventory to meet customer demand,
- Purpose: To determine the amount of inventory to keep in stock – how much to order and when to order.

The task of the research takes place within the company, which deals with assembling of microchips from raw materials and selling them to customers. Therefore, there are raw materials and finished goods warehouses with inventories (Fig. 2).

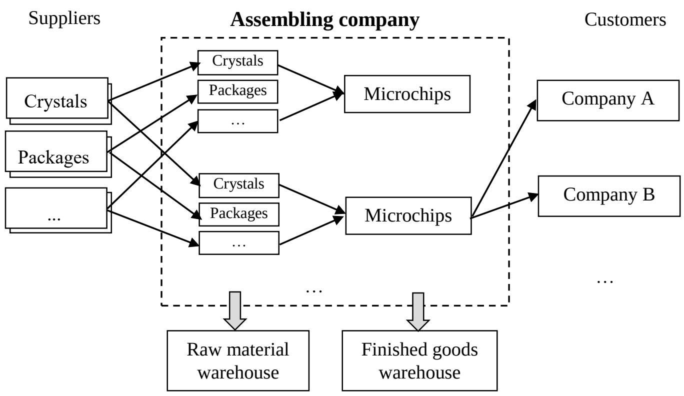

Fig. 2. Assembling company's inventories.

The authors [5] state that only 8 % of the companies have the trained personnel for inventory management. Companies are used to have big safety stock in order to fulfil the demand [3].

The task of this research is to analyse existing inventory management situation for finished goods inventories, to propose the improvement on it and to compare the proposed results with real demand data.

III. Data Analysis

The company's data on sales, inventories in warehouses were analysed for the period of 2014. The data analysis of previous year's microchip quantity fluctuation revealed that there were items in stock with no sale in 2014. The results for these items were the following: 16.69 % of total inventories (at the end of 2014) in warehouse did not have any movement that year, 3.95 % of total inventories reduced their quantity due to expiration of time, 5.13 % of total inventories having no sale for the year of 2014 increased their quantity due to production of new ones.

In addition, there were some items, whose assembled quantity was higher than the sold one, meanwhile having big amount of inventory in stock (Fig. 3). There were also items, whose inventory level was high, meanwhile company assembled new ones, therefore inventory level was higher than the quantity of annual sales at the end of 2014 (Fig. 3).

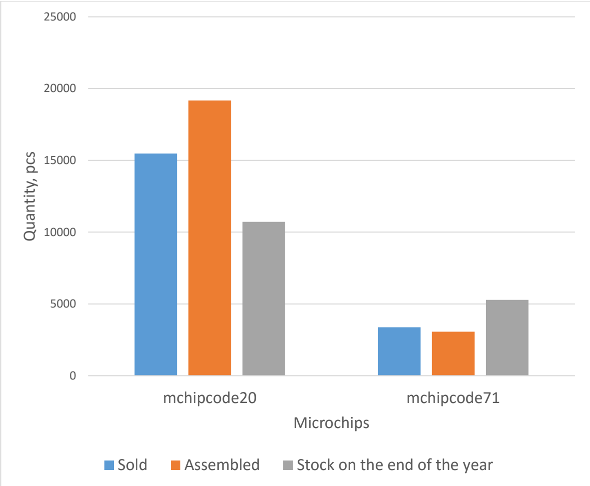

Fig. 3. Annual operations of two microchips.

It was also detected that an inventory level was too high for items, whose quantity on monthly sales was less than their safety stock (Fig. 4).

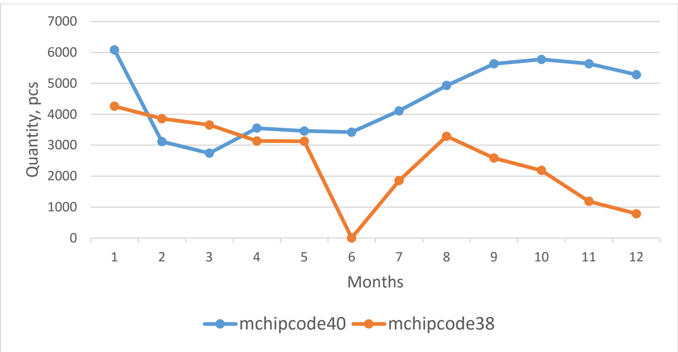

Fig. 4. Inventory levels of two microchips.

In addition, it was noticed that an inventory level for one item fell down to zero, which indicated out-of-stock situation (Fig. 4). Therefore, inventory management was highly recommended for this company.

IV. The Proposed Solution

In order to improve the existing situation of company's inventory control, it was proposed, firstly, to use inventory management for inventory control, and secondly, to apply agent system for inventory management [3], [4].

Effective inventory management consists of ABC classification, demand forecasting algorithms and replenishment policies [3]. Meanwhile, an agent system can provide automatization of inventory management and timely react to demand deviation from the forecasted demand, by making corrections on replenishment policies.

The proposed system can be used in two modes: completely autonomous mode, when an agent performs all of the inventory management operations: ABC classification, future demand forecasting, replenishment policy definition and assembling order making, or it works as a decision support system for a human inventory manager performing all the mentioned activities except ordering by providing the achieved results to an inventory manager and he decides whether to accept or not these recommendations.

A. ABC Classification

ABC classification (or ABC analysis) is a basic supply chain technique, often carried out by inventory controllers/materials managers, and the starting point in inventory control. This classification allows assigning priorities to management time and financial resources. The ABC analysis is based on the Pareto analysis, which says that 20 % of the items contribute to 80 % of sales [6]. It implies that a small portion of items in inventory contribute to maximum sales (Table I). Typically less than 20 % of items classified as *class A* contribute to as much as 80 % of the revenue. *Class B* items do the next 15 % (80 %–95 %) contribution to revenue. Items classified as *class C* generate the last 5 % revenue.

TABLE I

ABC Classification

	Number of items	**Number of annual sales revenue**
Class A items	About 20 %	About 80 %
Class B items	About 30 %	About 15 %
Class C items	About 50 %	About 5 %

ABC classification usually categorises company's products into three classes in order to assign priorities in inventory control [7]:

- *Class A* items are the most critical ones. These items require tight inventory controls, frequent review of demand forecasts and usage rates, highly accurate part data and frequent cycle counts to verify perpetual inventory balance accuracy;
- *Class B* items are of lesser criticality. These items require nominal inventory controls, occasional reviews of demand forecasts and usage rates, reasonably accurate part data and less frequent but regular cycle counting;
- *Class C* items have the least impact in terms of warehouse activity and financials and therefore require minimum inventory controls.

The inventory management starting point is the definition of *class A* items – microchips that represent the top 80 % of total annual revenue; *class B* items are the next 15 % and *class C* items are the last 5 %. Please, refer to [8], [9], [10] in order to better understand calculations of ABC classification.

The results of ABC classification for the analysed company by total annual revenue is presented in Table II.

TABLE II

FRAGMENT OF COMPANY'S MICROCHIP CLASSIFICATION

	Microchips	ABC classification
1	mchipcode56	B
2	mchipcode71	A
3	mchipcode139	C
4	mchipcode49	C
5	mchipcode133	C
6	mchipcode33	A
7	mchipcode264	C
8	mchipcode471	C
9	mchipcode473	C
10	mchipcode38	C
11	mchipcode39	C
12	mchipcode40	A
13	mchipcode96	C
14	mchipcode620	B
15	mchipcode674	C

For *class C* items with low (or zero) demand volume it is proposed to use make-to-order production strategy [11].

B. Demand Forecasting Methods

Demand forecasting is used to determine the quantity of goods or services that will be purchased by customers in the near future. Demand forecasting methods fall under these categories:

- Qualitative forecasting;
- Quantitative forecasting.

Qualitative forecasting methods are typically used when historical data are limited, unavailable, or not currently relevant to perform a quantitative method for forecasting. Forecast depends on skills and experience of forecaster(s) and available information. This is a subjective method used and is based upon how customers and experts think or feel a product will sell [12], [13]. Many new businesses use this method when writing business plans and projecting first year sales [13]. Four qualitative models are as follows [12]:

- Jury of executive opinion;
- Sales force composite;
- Delphi method;
- Consumer market survey.

Quantitative forecasting methods take numbers or quantities sold in the past to forecast how much will be sold in the near future. Usually this forecast provides quantities for the next sales year. Some examples of quantitative forecasting methods include last period demand, multiplicative seasonal indices, and simple and weighted moving averages. Each of these methods use past data in different types of mathematical formulas to determine how many products or services will be sold at the same times in the future that is being predicted [13].

Here, the following quantitative forecasting methods are used in order to predict future demand using historical data on demand for the period of 2014:

- Naïve forecasting method;
- Simple moving average forecast;
- Weighted moving average forecast;
- Exponential smoothing method;
- Single moving average.

The forecasting accuracy can be measured using forecasting errors defined as the difference between actual demand quantity and the forecasted demand. Several measures of forecasting accuracy are as follows: Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE), Running Sum of Forecast Errors (RSFE) – indicates bias in the forecasts or the tendency of a forecast to be consistently higher or lower than actual demand. Tracking signal – determines if forecast is within acceptable control limits. If the tracking signal falls outside the pre-set control limits, there is a bias problem with the forecasting method and an evaluation of the way forecasts are generated is warranted [12]. More detailed explanation of forecasting methods and accuracy measures is presented in [3], [12].

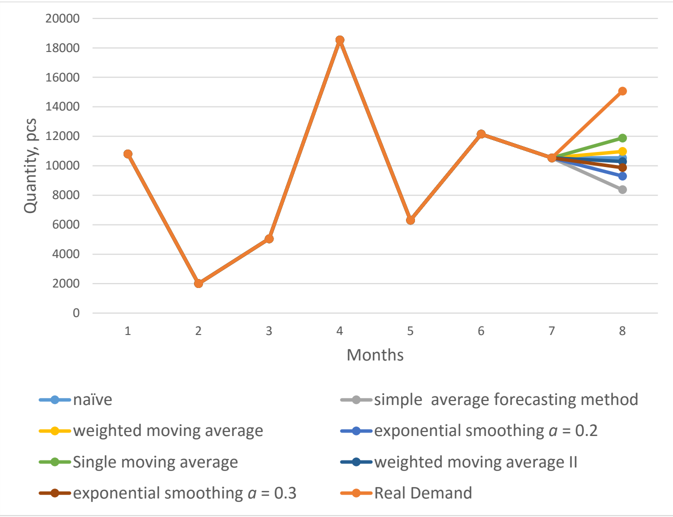

Fig. 5. The real demand and forecasted demand for one microchip.

The inventory level graph with forecasting results for one *class A* microchip is shown in Fig. 5. The calculations of forecasting accuracy measures have given the appropriate forecasting algorithm for this kind of microchip. The above-mentioned forecasting methods have been applied to all company's microchips.

C. Replenishment Policies

An inventory system provides the organisational structure and the operating policies for maintaining and controlling goods to be stocked. The system is responsible for ordering and receiving of goods: timing the order placement and keeping track of what has been ordered, how much, and from whom [14].

There are a single-period and multi-period inventory systems [15]:

- In a single-period inventory system, the items unsold at the end of the period are not carried over to the next period (for example, newspapers). The unsold items, however, may have some salvage values.
- In a multi-period inventory system, all the items unsold at the end of one period are available in the next period.

Here, the talk is about a multi-period inventory system. There are two types of multi-period inventory systems: *fixed-order quantity models* and *fixed-time period models* [14]. A fixed-order quantity model initiates an order when the specified reorder level is reached. This model requires continual monitoring of inventories. In contrast, in the fixed-time period model placing orders is available only at the end of a predetermined time period [14].

Fixed-order quantity models attempt to determine the reorder point, R, at which an order, Q, will be placed and the quantity of Q. An order Q is placed when the inventory level (currently in stock and on order) reaches the reorder point R. Inventory position is defined as follows: on-hand plus on-order minus backordered quantities [14].

In a *fixed-time period model*, inventory is counted only at particular times, such as every week or every month. Counting inventory and placing orders periodically are desirable in situations such as when buyers want to combine orders to save transportation costs. Fixed-time period models generate order quantities that vary from period to period depending on the usage rates. These generally require a higher level of safety stock than a fixed-order quantity system [14]. Safety stock can be defined as the amount of inventory carried in addition to the expected demand. Safety stock must protect against stock-outs during the review period and also during the lead time from order placement to order receipt.

Some concluding remarks are the following:

- If demand is constant, reorder point is the same as the demand during the lead time.
- If demand is uncertain, reorder point is usually set above the expected demand during the lead time.
- Reorder point = Expected demand + Safety stock [15].

Having forecasted demand, it is possible to calculate safety stock and reorder points for every microchip (see Table III). Please, refer to [14], [15] for more details in calculations of safety stock and reorder points.

TABLE III

Fragment of Results of Forecasts, Safety Stock and Reorder Points for Microchips

Microchips	Forecasted Demand	Safety Stock	Reorder Point
mchipcode33	1688	2081	3769
mchipcode40	12249	9096	21345
mchipcode20	1508	1603	3111
mchipcode102	537	5927	6464
mchipcode465	3625	6363	9988

V. Experiment 1

Having calculations on future demand and replenishment policies, the proposed inventory management result check on real data is of interest. The real data is the demand data on first 5 months of 2015.

The idea of this experiment is that the proposed quantities of inventories with replenishment policy results are compared with real demand, and the quantities of inventories are compared with company's inventories (Fig. 6).

The experiment has shown the following results: inventory level has decreased (Fig. 6), real data average inventory level is 20860 pcs, the proposed inventory management system's average inventory level is 11705. It was not an out-of-stock situation in both cases.

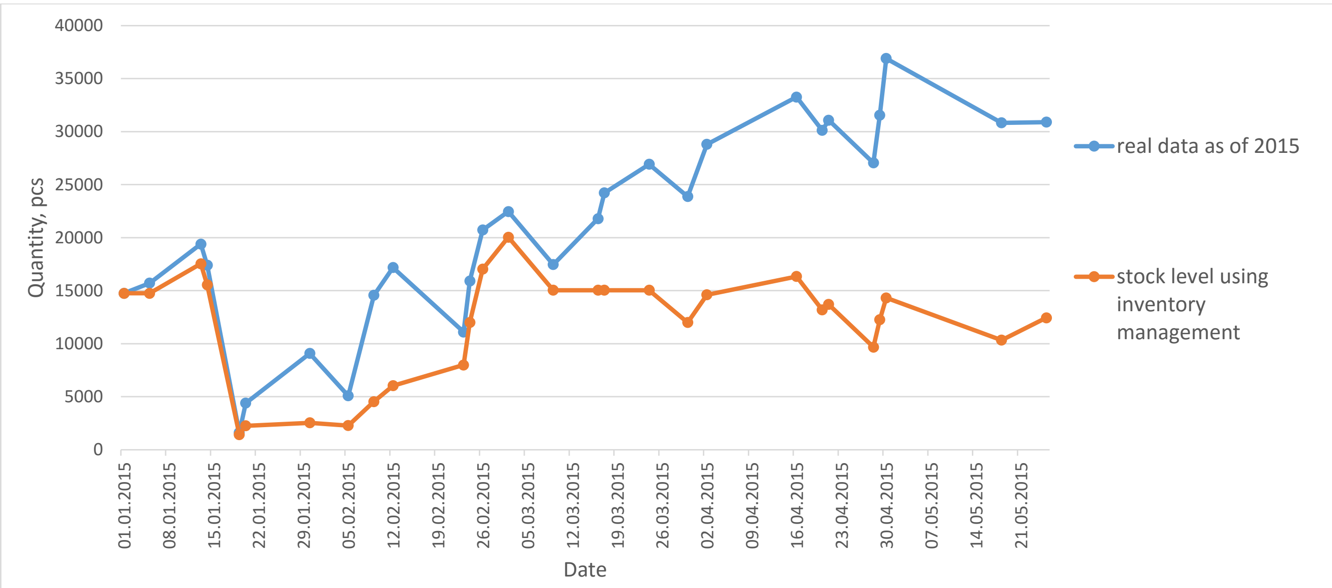

Fig. 6. Comparison of the inventory management system with real data.

The experiment for another microchip has shown that safety stock has been used during the lead time because of unpredictably high demand – having average monthly demand of 9800 pcs, that month demand is 17789 pcs. This demand will be taken into account in further safety stock calculations. Company's average inventory level based on real data is 6964 pcs, average inventory level of the proposed inventory management system is 5955 pcs.

VI. Experiment 2

An improvement of company's inventory management situation is twofold: inventory management process application and agent system realisation [3], [4]. Agent system can provide the following benefits to the proposed system:

- It can learn from the past inventory, forecasting and replenishment histories;
- It can change demand forecasting techniques, inventory control constants and replenishment policies if needed;
- It can ensure monitoring and control of large amount of SKUs;
- It can provide autonomy and pro-activeness.

This paper presents part of the ongoing research on *AEMAS* (Assembling Enterprise Multi-Agent System); therefore, it is related to the inventory management agent [3], [4]. One of the functions of inventory management agent is to make decisions on when and how many microchips to assemble. It has the information of the possible minimum reserves – safety stock, the future demand forecasting algorithm and the production capacity. Inventory management agent has the following behaviours: ABC classification algorithm, future demand forecasting algorithms and replenishment policies in order to avoid out-of-stock situations, meanwhile decreasing the inventory levels and their holding costs.

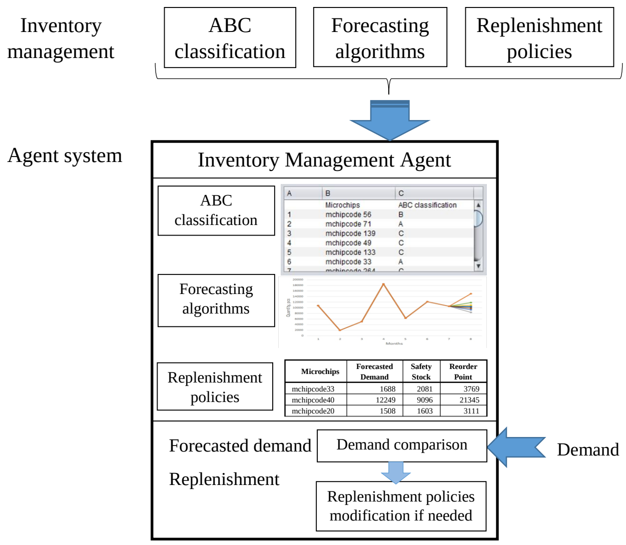

Fig. 7. The idea of agent system application for inventory management.

Excel file is provided as input data for agent system's ABC classification algorithm, then the forecasting methods are applied to microchips and forecasting errors are calculated, according to achieved results the best forecasting method is chosen for every microchip that is intended to be used subsequently. Replenishment algorithm uses forecasting results, calculates safety stock and reorder points. Meeting real demand, the agent-based inventory management system compares it with the forecasted demand and makes modifications in future orders to assemble if needed. This inventory management system can be fully automated or work as a decision support system for an inventory manager [3]. The output of a fully automated system is an agent decision, alternatively, if the system works as a decision support system, then a manager decides whether to agree or not with the proposed system recommendations.

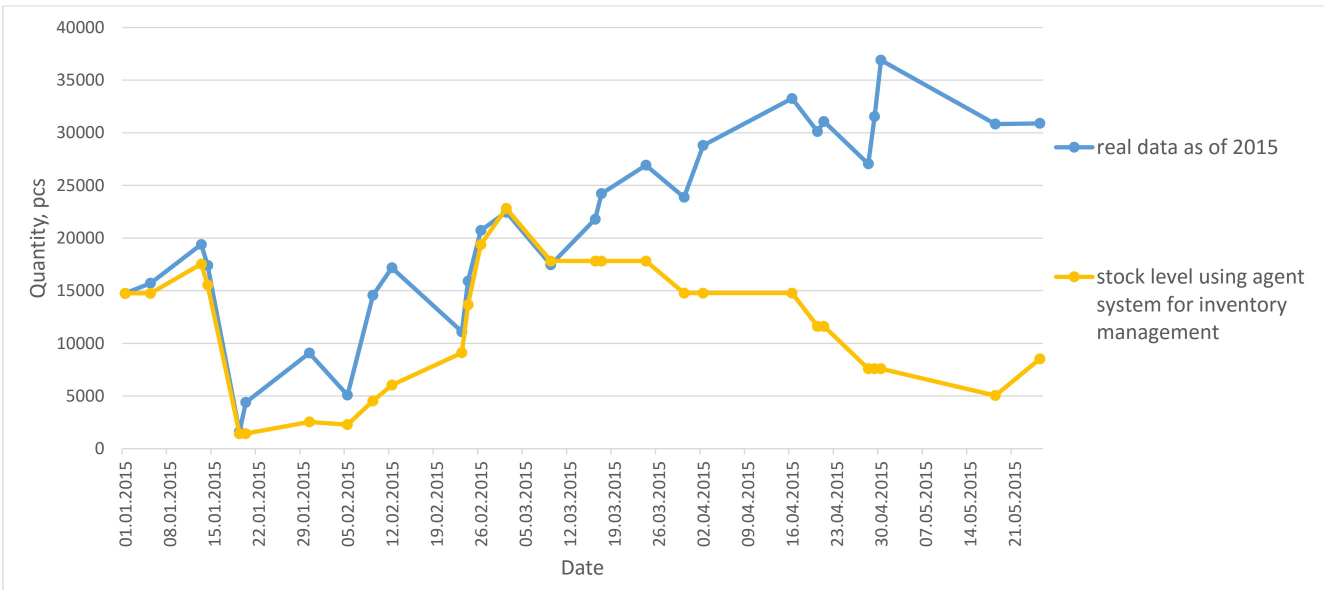

Fig. 8. Comparison of the inventory management agent system with real data.

The idea of the second experiment is that meeting the real demand it is possible to change replenishment policies (Fig. 7). Again, the comparison of inventory levels' quantities is presented (Fig. 8).

The experiment has shown the following results: for the first type of microchips the inventory level has decreased compared with company's real inventory level. Company's average inventory level is 20860 pcs; the average inventory level proposed by the agent system is 11461 pcs.

Another microchip type has the following results: company's average inventory level is 6964 pcs; the average inventory level proposed by the agent system is 5405 pcs.

At the end of May 2015, inventory levels had the following results: the lowest inventory level was typical of the agent-based inventory management system (due to timely reaction to demand comparison), the highest one was shown by company's data. Agent-based inventory management system showed the best results in comparison with simple inventory management application and real data. The difference between the results provided by the agent system and that of the inventory management (Fig. 6, Fig. 8) was not so considerable, as it was between real data and agent-based inventory management system. This could be explained by the following: at the end of 2014 the demand had an increasing trend, but in February it started to decrease; therefore, the agent system took into account this demand shift.

VII. Conclusion and Future Work

Inventory management is essential to every company, having inventories. Companies need to have stock, but in such amount to avoid out-of-stock and overstock situations.

Inventory management can improve company's inventory control existing situation and decrease costs of the company.

Agent system, in turn, proposes the automation of this process, it can support several forecasting methods and it reacts to changes in the environment.

In this paper, the existing inventory management situation is analysed, twofold improvement is proposed – to use inventory management with the aim to decrease company's inventory level and holding costs by avoiding overstocks and to apply the agent system in order to automate the inventory management processes and to timely react to demand deviations from the forecasted demand by making corrections in replenishment policies.

According to experiments, it can be concluded that timely reaction to changes in the environment can propose better results. This can be done by a human or decision support system comparing the forecasted demand with real and making corrections in orders, or this can be done by an agent as it is proposed here.

The next step of the present research will be the application of achieved results of demand forecasts, safety stock and reorder points into simulation software in order to achieve more accurate results.

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