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Customer Management Analysis of Irish Plumbing & Heating Distribution System: A Simulation Study

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***Abstract*— The sudden burst of the property bubble, coupled with current global economic conditions has resulted in a huge decrease in demand for plumbing and heating fixtures in the Irish construction industry. Moreover, inefficient supply chain management policies have imposed further pressures on companies resulting in more system bottlenecks and unnecessary costs. Inventory management is seen as a functional area that can ease such bottlenecks and in turn increase supply chain efficiency, decrease costs and increase customer satisfaction. The challenge is to predict the balance of on-hand inventory and order quantity to optimise customer satisfaction and minimise inventory cost. It is also essential that managers clearly understand the cost effect stock-outs have on different groups of customer, i.e. customer segmentation policy. Traditional inventory mathematical techniques are inadequate in investigating the influence of customer segmentation policy on performance. To investigate this further, conceptual modelling using flowcharts and data flow diagrams in conjunction with simulation modelling and design of experiments have been developed to characterise the inventory management process of a plumbing and heating distribution centre. Significant process parameters where identified and examined with and without segmented customer management policies, aiming to achieve a high level of customer satisfaction rate at the lowest possible total cost.**

Keywords: Simulation Modelling; Inventory Management; Business Process Analysis; Customer Segmentation

I. INTRODUCTION

The unprecedented fall of the Irish economy into recession during the current global economic crisis has been partly caused by the dependency on an oversized domestic construction industry [8]. The sudden collapse in the property boom has led to a decrease in construction output volume of 36.9% between 2008 and 2009 [5]. As a result of this collapse, the plumbing and heating (P&H) materials distribution system has been affected greatly due to losing a considerable number of their customers and a remarkable decline in sales figures. Therefore, the application of economic management strategies for the P&H distribution industry has become crucial to survive these extraordinary circumstances. One of the biggest challenges the P&H distribution industry faces is the need to sustain a competitive advantage, by satisfying customer demands and fulfilling orders at the lowest cost. Without an efficient supply chain and strong inventory management strategies, it is becoming more difficult to achieve this target and gain a competitive advantage [6]. Improved inventory management contributes to lower costs, increased revenue and greater customer satisfaction [17].

P&H Distribution firm has about 3,000 different items that are stored in a large dedicated P&H warehouse. Many suppliers around the world (e.g. China, UK, France... etc.) are listed in the P&H supplier list. Monthly forecasts for all items based on twelve month sales historical data is the main source of input for that system. Due to the uncertainty of suppliers lead time, demand fluctuation, changeable prices and high shortage costs, the strategy of keeping safe inventory levels for fulfilling unexpected demand is currently applied. The high cost of on-hand inventory versus the cost of a stock out and late delivery drove the inventory manager to target the balance between minimizing the inventory level and keeping on time service level at an optimum point. The result of changes in this balance and its impact on customer satisfaction level has to be predicted and investigated. To model such systems that contain a large number of entities with a stochastic nature for all its processes, a simulation modelling technique is recommended [4]. This is due to its capability in modelling the dynamic nature of the systems as well as their variability. Data flow diagram (DFD) and flow charts are integrated before the development of simulation to conceptually model the system. This integration provided synergies by merging the information and object flow in one conceptual model. Finally a design of experiments has been developed to investigate the significance of process parameters and examine various customer management scenarios.

The purpose of this study is to investigate two customer management scenarios, customer equality (no segmentation) policy and customer segmentation policy. In order to identify the best policy that achieves high levels of customer satisfaction, two performance indicators will be used to represent customer satisfaction level – delivery time and total cost. The study also aims to analyse the influence of the changes in the selected scenarios and

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two process parameters (i.e. forecasted order quantity (FOQ) and safety stock level (SSL)) on system performance and get the best combination of them that achieves the best performance measures.

In this paper, a brief description of AC's inventory management process and problem definition, Section II, is followed by a detailed study of AC's business process model, Section III. Using this model, a discrete-event simulation model was developed and validated in Section IV. The results of this paper are then presented and analysed in Section V before a conclusion is made in Section VI.

II. Problem Definition

The studied company (AC) is a leading construction merchant in the Irish market. The company reported a turnover of €370 million for the 2009 fiscal year. Approximately €140 million of this figure was generated by the company's P&H distribution division. This paper will focus on the inventory management system based in the central warehouse of AC's P&H division. The central warehouse acts as a wholesale distributor to the company's retail outlets and other external customers.

The primary function of the P&H inventory management process is to satisfy customer demand through the continuous availability of stock. To achieve this, over 95% order fulfilment accuracy needs to be achieved. To determine the ultimate measure in order fulfilment, the 'perfect order' framework was created [2]. Such an order meets the customer's deadline, is delivered on time, is damage-free, and has perfect invoice accuracy [2] [11].

From this framework, it can be highlighted that the inventory management department play a crucial role in order fulfilment. For example:

- To meet a customer's deadline, sufficient inventory levels need to be available in stock.
- To deliver damage-free and good quality goods, the best products need to be sourced from the best suppliers available.
- To have perfect invoice accuracy, the previous two steps need to be clear of error.

There are various challenges that need to be addressed when trying to achieve the 'perfect order' at AC's P&H central warehouse. A balance between the cost of ordering stock, holding stock and stock-out costs is required to ensure that there are no stock-outs or over stocked items. There is a threshold between losing customer sales and losing capital investment tied up in unused stock. Forecasting demand accuracy is an issue that will affect this threshold in the inventory management process's performance. With a product range of over 3,000 products, the forecasting of sales data and stock level reviews are crucial activities within the inventory management function. FOQ and SSL are considered two important process parameters that have an impact on system performance indicators. The examination of the significance of their influence on performance indicators is a very important issue.

The inventory management process is further complicated by the need to prioritise orders within the company's 25 retail outlets. Customer segmentation has been introduced internally because the cost of stock outs is greater in the larger retail stores. Unlike traditional inventory management systems, where all customer demands are treated equally and served on a first-in-first-served basis (i.e. Customer equality policy), with customer segmentation, customers are classified into groups according to their importance (e.g. by sales volume) to the P&H department [14]. Customer segmentation is the process of dividing customers into classes for decision-making purposes such as value proposition and customer profitability [10]. In production and supply chain management, many firms are exploring when customers may be segmented into different groups based on service levels and priority. This will help to balance supply and demand and increase customer satisfaction [8].

To effectively manage the inventory flow at AC, there is a need for the development of a structured, systematic inventory management methodology that will evaluate the cost and service level for customers from different segmentations. The methodology will integrate the business process modelling techniques of flowcharts and DFD's with simulation to achieve the following objectives: (i) build a clear and effective conceptual model to understand the inventory management process at AC, (ii) develop a simulation model to examine inventory management process parameters under different scenarios, (iii) find the optimal combination of process parameters and studied scenarios in order to enhance inventory management performance.

III. Business Process Model of AC

A process can be defined as a; "*structured, measured sets of activities designed to produce a specified output for a particular customer or market*" [7]. These "structured, measured activities" are the relationship between inputs and outputs [1], and it can be suggested that every time a person performs any kind of action, a process is carried out [12]. As a result of this broad generalisation of the term, there have been many definitions published in relation to the topic.

Business process modelling (BPM) is a presentation of the sequences of system processes, procedures and resources and shows the relationship between a system's objects, such as customers and products, and their status during the systems process [15]. Many modelling methods have been developed and studied in BPM literature [16]. A classification of such models developed from the respective authors literature can be found in Figure 1 [15].

Flow charts and DFD's are two effective conceptual modelling techniques that were used individually in different publications. Flowcharts are a graphical representation of a process in which symbols are used to represent such things as operations, flow direction and

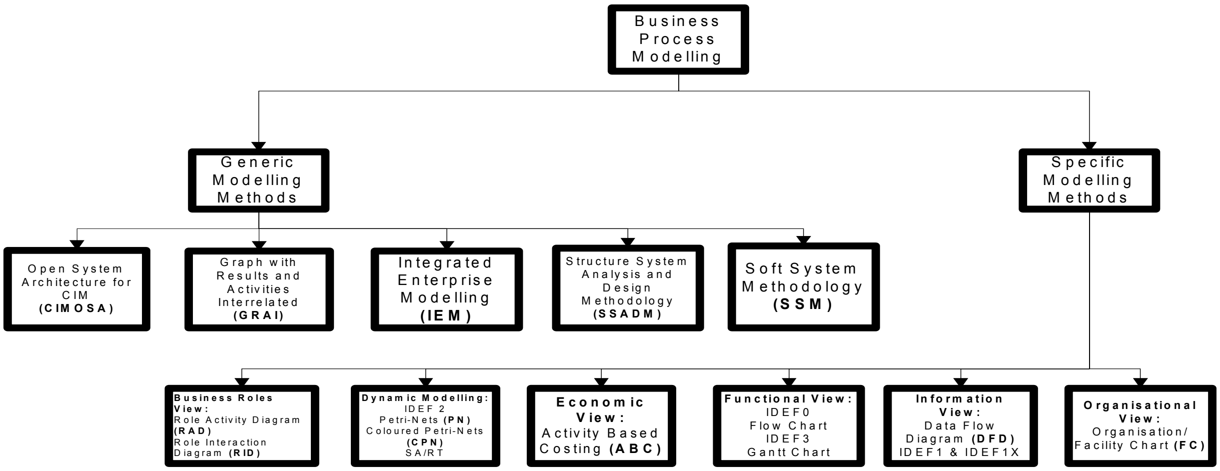

Figure 1**.** A Classification of Business Process Modelling Methods [15]

organisational charts [16]. Along with Gantt Charts, flow charts are the main method of graphically showing the sequence and duration of a process's activities. They are clear and flexible in use, but there is a risk of missing important details of the modelled process such as information flow [15]. DFD is a very effective way of modelling information and data flows within a process. DFD's are used to provide a specification of the flow of data from external entities into logical data storages, via various data processing steps [18]. Because the current model focuses on ordering processes and customer/supplier relationships, rather than the physical flow of items inside AC's warehouse, integration between items flow in the ordering process and information flow is required. Flow chart methodology and DFD is used to develop the conceptual model of AC Company. The integration will be done according to Figure 2, as each process represented in the flow chart will have a link with a DFD block which identifies the kind of data that this process may need.

A. The Conceptual Model for AC Company

Each BPM method (Fig. 1) has its own advantages and disadvantages and each individual method is limited with regard to presenting an accurate and effective view of a business [1]. Understanding business processes clearly is a key to define the required modelling techniques. In some cases, there is a need to adopt more than one modelling technique to describe a system graphically from more than one point of view [16]. For example, although DFD's provide a clear description of information flow, they lack the ability to express logical terms such as flow charts.

AC's inventory management process begins with receiving orders either by a customer or forecasted data. Customer orders are classed as one-off orders received by external customers and forecasts are orders calculated according a continuous review of historical sales data, re-order points, safety stock levels, special projects and professional knowledge. For most suppliers the inventory manager aims to keep between 1.5–2 months stock with the re-order points at approximately 1.2 months, depending on lead-times. To extend supplier credit periods and decrease the amount of capital tied up in inventory, all purchase orders are placed at the beginning of each month. Hedging foreign currencies and commodity prices are also factors that influence the

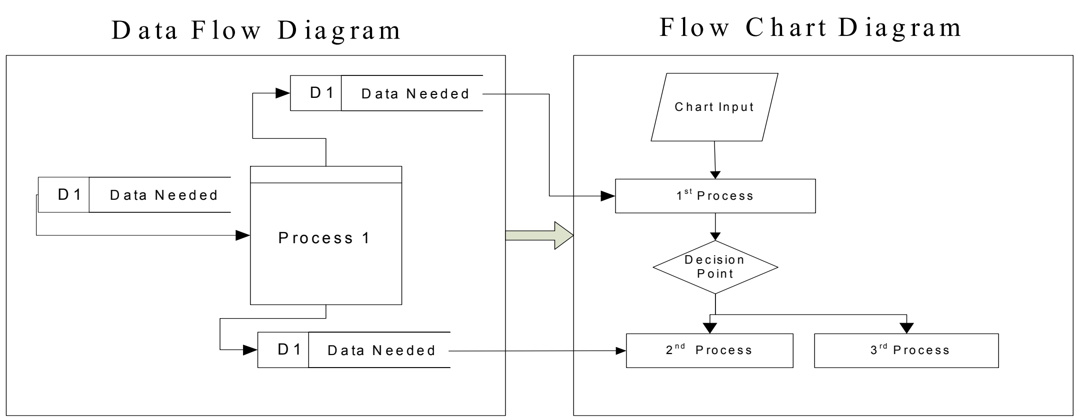

Figure 2. Conceptual Model Framework

placing of orders, especially when dealing with non-euro zone suppliers (e.g. China). For example, if the price of copper is unusually high, the ordering of bulk brass items might be delayed until the price decreases to normal levels. Two conceptual models, (Fig. 3 and 4) are developed representing ordering processes for forecasted items and customer demand respectively. When annual sales data are analysed, a forecast of what needs to be ordered to cover two months sales is calculated (Fig. 3). If current inventory levels, without safety stock, can cover the forecasted quantity, then order processing stops as there is enough stock on-hand. If it is not, the difference needs to be ordered from the selected supplier by issuing a purchase order (PO) that includes; PO number, order quantity, material codes, delivery date and address information.

Depending on supplier lead-times, the waiting period between order and delivery varies. After a quality check on receipt, if the order is correct regarding to quantity and quality, it is accepted and the inventory levels are updated accordingly. The payment process for the supplier can then proceed.

If the order is not correct, further investigation is required. At this stage there are three possible quality issues:

a) The wrong product has been received. In this case the product will be returned, or kept if it is a high turnover product. In both cases a new order is needed for

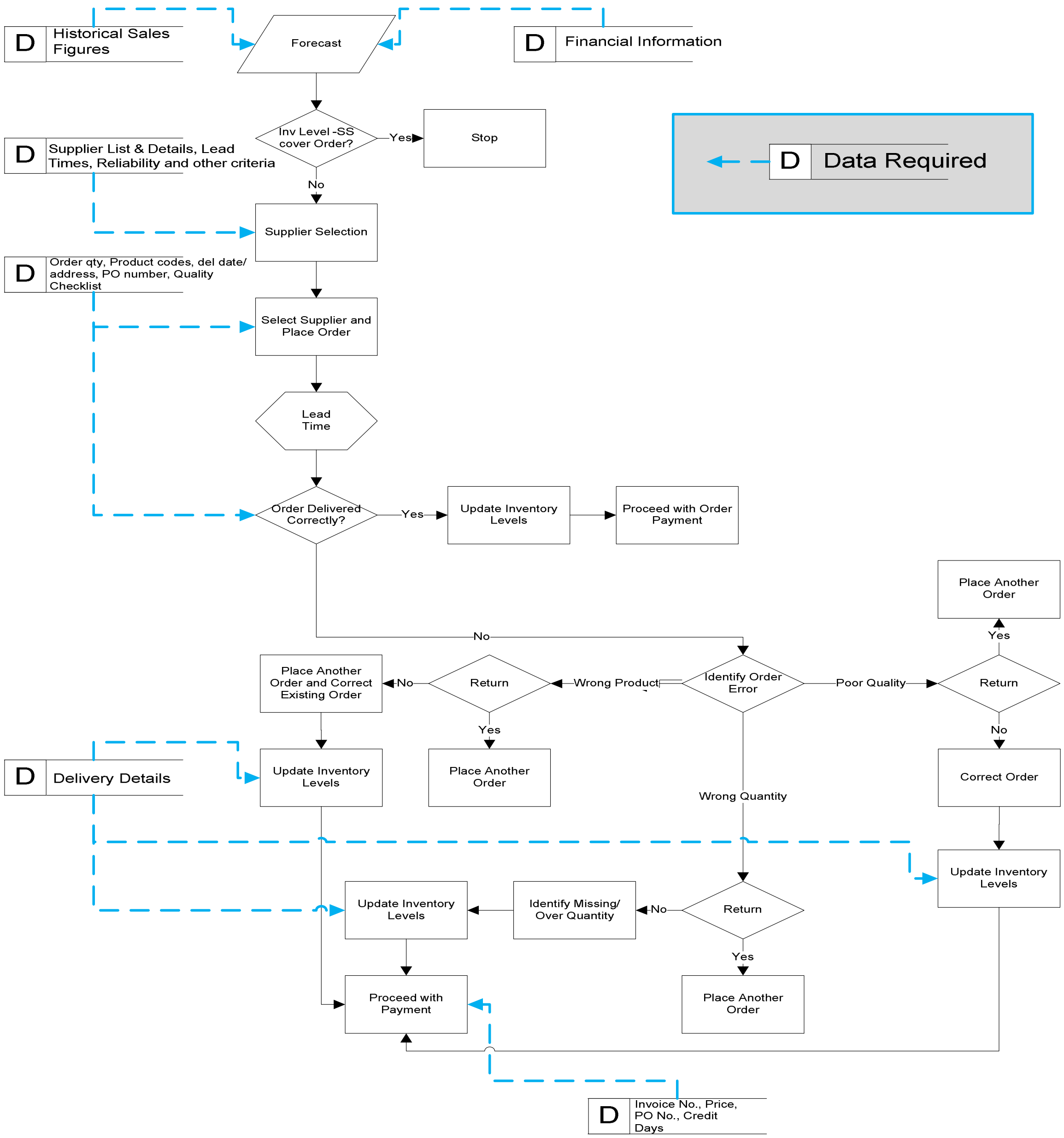

Figure 3. Forecasted Order Quantity Model using Flowchart Method

the original product.

b) The product is of poor quality. If it is within a certain tolerance set by the quality department it will be accepted, if not, the order is returned and the order process needs to be repeated.

c) The quantity is either over or under the ordered amount. If the order is returned a new PO needs to be placed. If the order is accepted with the difference, the inventory levels on the system are updated. The PO also needs to be adjusted to account for the difference and a new order for shortages is required.

The process flow of customer orders (Fig. 4) consists

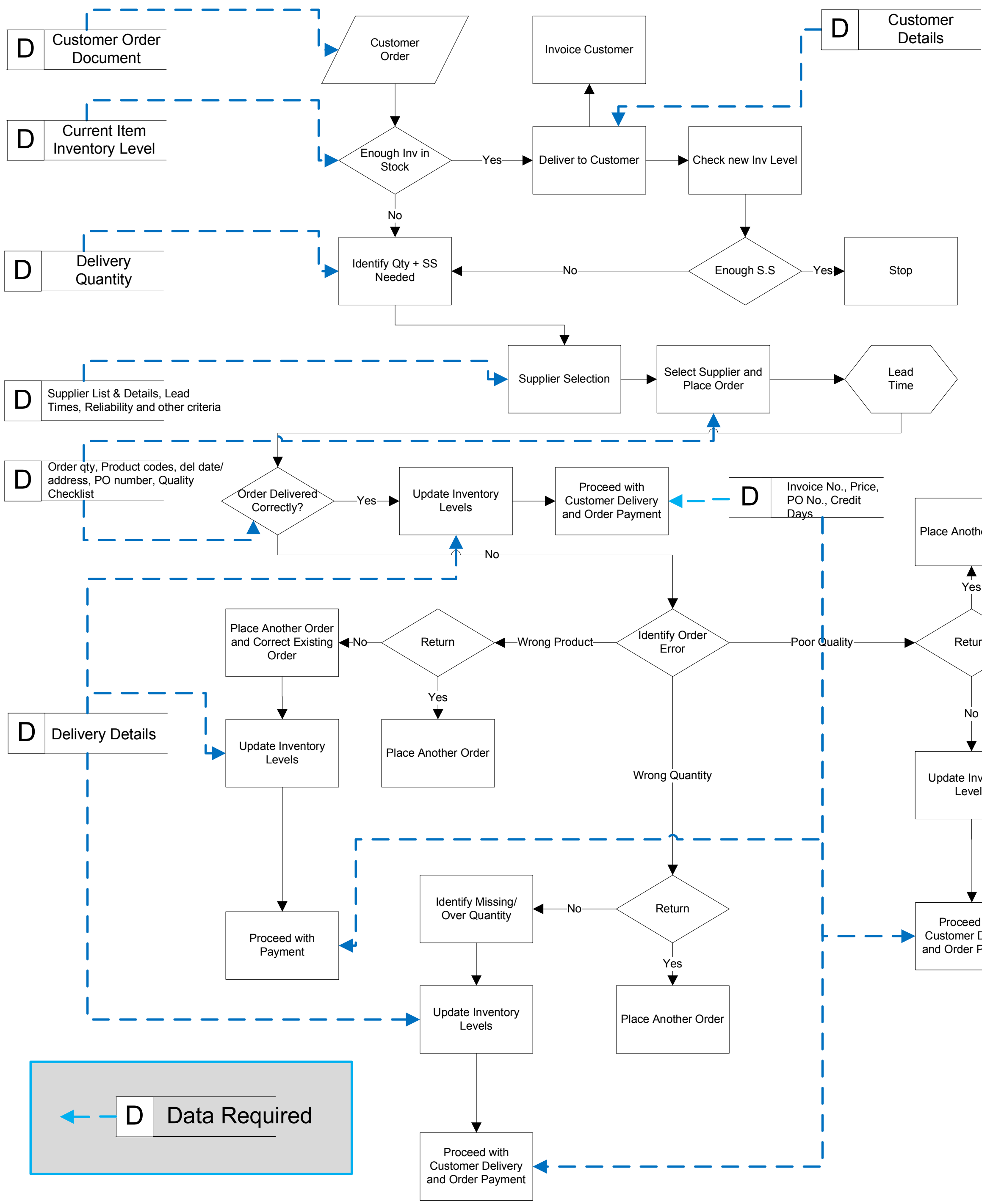

Figure 4. Customer Order Quantity Model using Flowchart Method

of the following steps. When a customer order is received, the inventory levels on-hand is checked to see if the order can be fulfilled. If there is enough stock on hand, the order is delivered to the customer and inventory levels are updated on the system. If not, the required quantity including the safety stock difference is ordered. 75% of customers accept the delay of delivery due to items being out of stock (i.e. patient customers), while the other 25% will cancel their order and go elsewhere, incurring substantial lost sales costs to AC. The process of supplier selection onwards is identical to that of the forecasting approach (Fig. 3).

IV. Simulation Model

A stochastic technique of discrete-event simulation is chosen as it is capable of powerful computation techniques for studying the variability and uncertainty of inventory systems [13] [19]. Demand quantities, sales orders arrival time, suppliers' lead time and defective rate of received items are the main uncertainty elements that need to be taken into consideration in the modelling process. A computer simulation model based on the conceptual models (Fig. 3 and 4) was developed to mimic the real life application characteristics of the inventory system. The model assumptions are (i) Forecasted item quantities are assigned based on the inventory manager's experience rather than using quantitative forecasting techniques (ii) No disruptions are expected for system suppliers (iii) Holding cost of all items in inventory is constant. Customer segmentation policy, regarding to sales volumes, was investigated against customer equality policy using delivery time and total cost as two performance indicators. For each policy, the significance of two important process parameters, FOQ and SSL were tested using Analysis of variance (ANOVA) approach.

There are two main streams in the simulation model, (Fig. 5). With each a different demand pattern was applied. The first input is the monthly forecasted quantity for each item that needs to be ordered to keep a safe inventory level that can be used to cover uncertain demands. This quantity relies totally on the inventory managers' experience and the sales' figures of the last twelve months. Customer demand, the second input stream, is randomly arrived in a form of individual sales orders that contains multiple product types with different quantities. Sales orders are dispatched to individual items and then the current inventory level of each item is checked. If inventory levels are not enough to fulfil the demand of this item, an ordering process is conducted with the required quantity. Ordering cost, shortage cost and holding cost are three cost elements that compose the total cost formula of this model. Items importance varies (i.e. must not be out of stock at any time). If these items are out of stock for any reason, the inventory manager has to place an order immediately, regardless of the supplier or the price. This action usually causes cost pressures on the manager. Once order quantities are delivered, a quality check takes place followed by updating the inventory level of received items.

A one year historical sales data record was supplied by the system manager to analyse and create statistical distributions for input data used in this model:

1. Interarrival time for customer sales orders.
2. Number of items, item types and item quantities in received customer sales orders.
3. Forecasted order quantities for each item.
4. Suppliers lead time.
5. Percentage of refused items due to quality results.

For the model to reach its steady state condition, the warm-up period is one month. Every simulation run represents a year of actual timing. Each experiment result is an average of ten independent replications.

Validation and verification are an integral part of

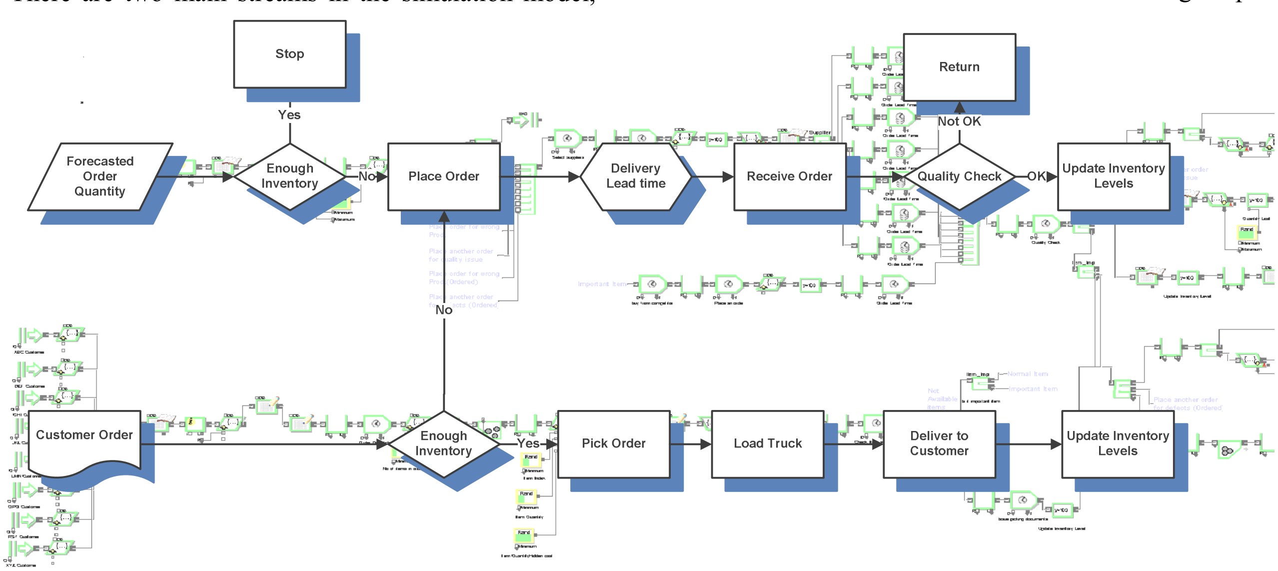

Figure 5. Simulation Model of Inventory System

TABLE I DESIGN MATRIX FOR ALL FACTORS COMBINATIONS

Customer Management Scenario (CMS)	Parameters		Response	
Customer Equality (CE) = 1 ,Customer Segmentation (CS)= 2	*FOQ*	*SSL*	*Delivery Time (DT) Days*	*Total Cost (TC) €*
1	1	1	18.56	1500
1	1	2	16.32	1843.82
1	2	1	3.32	7749.82
1	2	2	3.27	7749.5
2	1	1	15.32	647
2	1	2	18.96	1302.05
2	2	1	3.44	7542.15
2	2	2	4.73	7169.15

building a simulation model. The accuracy of the decisions made using simulation is a direct function of the validity of the output data [3]. For the verification process, a decomposition method (i.e. verify every group of blocks) and simulation software built-in debugger is used. After that the model was validated using two techniques. The first is '*Face Validation*' that was done by interviewing the system manager in order to validate simulation model results. '*Comparison Testing*' is the second approach used which was performed by comparing the model output with system output under identical input conditions. The deviation between simulated and actual results recorded 10% average percentage based on a sample of 50 sales orders.

V. RESULT ANALYSIS

The uncertain nature of customer demands and suppliers' lead time makes it difficult to select the optimal combination of system's process parameters that can achieve high levels of customer satisfaction (i.e. short delivery time) and minimum costs. The impact of FOQ and SSL (main process parameters) is one of the main aims of this study. Referring to classical inventory management models, the increase in both process parameters causes short delivery time, while on the other hand; high total cost is expected due to the increasing of holding costs. Using the simulation model, two levels of each process parameter have been examined against delivery time and total cost. The first level of process parameters represents their current values in the real case, while the second level is higher than the first level by 20%.

Using ANOVA, the main effect of the two process parameters is examined for the two customer management scenarios. The principle of ANOVA model is testing null hypothesis – change of one or more factors levels does not cause variation for response's means – against the alternative hypothesis that has at least on variant response mean. The available combinations of customer management scenarios, the two process parameters and impact on performance indicators are shown in Table I. For customer management, level 1 indicates the first scenario, customer equality, while level 2 is the customer segmentation scenario.

Changes in customer management scenarios caused no impact on delivery time indicators, according to results in Table I. On the other hand the total cost is clearly influenced by the changes in those scenarios. Table 1 shows a decline of total cost in the case of applying the customer segmentation scenario. Moreover the changes in FOQ levels result in decreasing delivery time and increasing total cost due to the increasing of holding cost; however changes in SSL level did not have this remarkable impact in both indicators.

The observations that are deduced from Table 1 were supported by ANOVA tables that analysed the main effect of the two process parameters on selected performance indicators. At both customer management scenarios, FOQ shows significant effect on delivery time and total cost indicator with a high F value and a P value less than 0.05. Looking at Table 1, it is clear that changes in FOQ levels impinge both indicators in opposite directions, decreasing delivery time with (20%) and increasing the total cost by (18%).

Whenever the 'P' value is greater than 0.05, the parameter is not significant. SSL has not shown any significant impact on delivery time and total cost indicator under the two scenarios Table II and Table III. This result is confirmed at Table I with no influence of SSL on performance indicators.

TABLE II. MAIN EFFECT OF PROCESS PARAMETERS FOR TWO CMS USING DT INDICATOR

CMS	Source	Total Cost Indicator				
		Sum of Square	*Df*	*Mean Square*	*F*	*P*
CE	FOQ	200.229	1	200.229	159.41	0.006
	SSL	1.312	1	1.312	0.13	0.92
CS	FOQ	170.366	1	170.336	45.672	0.021
	SSL	6.077	1	6.077	0.071	0.815

TABLE III. MAIN EFFECT OF PROCESS PARAMETERS FOR TWO CMS USING TOTAL CYCLE TIME

CMS	Source	Total Cost Indicator				
		Sum of Square	***Df***	***Mean Square***	***F***	***P***
CE	FOQ	51545938.2	1	51545938.2	61.72	0.016
	SSL	1622744.77	1	1622744.77	0.068	0.825
CS	FOQ	40718756.3	1	40718756.3	286.641	0.003
	SSL	19888.051	1	19888.051	0.001	0.978

According to results, to achieve the optimum delivery time, using the second level of FOQ was most effective with or without customer segmentation. Changes in SSL and CMS had no significant impact. On the other hand, customer segmentation was the most effective CMS for decreasing total costs when combined with the first level of both FOQ and SSL.

VI. CONCLUSION

The rapidly changing construction market, fluctuation in demands, along with cost and price pressure requires efficient management strategies for Plumbing & Heating inventory systems (AC Company). To balance on-hand inventory with more efficient total costs and high customer service in such a dynamic environment is a big challenge. Therefore it becomes necessary to choose an effective approach to model this complexity and to investigate different management strategies that can be used for performance enhancement.

Due to the interaction between information and object flow in the inventory system, data flow diagram and flow chart have been integrated to develop the system's conceptual model. This integration facilitates the development of a simulation model that is used to mimic the relationship and real life interdependences between the two flows. The simulation model was run under two scenarios - customer segmentation and customer equality (no segmentation). Two process parameters – forecasted order quantity and safety stock level- were investigated using the developed model. Order delivery times and total costs were the two performance indicators measured. The significance of process parameters on system performance was analysed using factorial design experiments.

Results show that for AC's inventory system, forecast order quantity parameter had a greater impact on performance indicators (i.e. delivery time and total costs) than safety stock levels, whether customers were segmented or not. Increasing the forecasted order quantity by 20% (Second Level) resulted in the most efficient delivery times. Total costs decreased most when the original forecast order quantity was used with customer segmentation.

Simulation modelling is a powerful tool in helping managers understand the affect customer segmentation has on inventory processes, order fulfilment and total costs. It has the potential to enhance customer/supplier relationship management and increase the efficiency of inventory movements along the supply chain.

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