C-Track

Inventory management and control using SMART Business Processes at C-Track

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Executive summary

This project entails the use of SMART business processes in inventory management and control. The SMART business processes assist in creating new ordering policies.

The business involved in this project is C-Track. C-Track is a business from Digicore Holdings Group Ltd. They specialise in advance vehicle and personal tracking by using the latest GPS (Global Positioning System) and GSM (Global Systems for Mobile communications) technologies. C-Track sells and installs their devices in a network of Branches country wide.

C-Track recently decided to distribute stock to their various branches, using a centralised warehouse. The Inventory Management and control of this warehouse is under investigation.

A new optimal order policy needs to be initiated of the stock of this warehouse. A PID (Proportional-, Integral-, and Derivative Control) Control Process will be created as an adaptive control process and will be in an alignment with other techniques. Collected it will form the SMART business processes. The SMART processes are a new intriguing engineering approach for inventory management.

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1. Introduction

1.1 Background

Inventory is a very important aspect and plays an important role in any company. Whether the inventory is raw materials, finished goods or work-in-progress is irrelevant. Inventory is described as the stock of any item or resource used in an organisation (Jacobs et al, 2009). Inventory levels is driven and managed according to an inventory system. The aim of an inventory system is to satisfy all the demand of the inventory system at a minimum cost (Eksteen, 2009). Inventory (as the whole inventory system) has to be management and control correctly in order to create customer satisfaction and also to increase process flow of goods. As seen in the figure below, the relationship between inventory and the customer service level (Langely et al., 2009).

Inventory management involves the following frequently asked questions; how much inventory to keep, how much to reorder and when to reorder, with the intention of delivering the right product, at the right time, in the right place, in the right quantities at the right price to the customers.

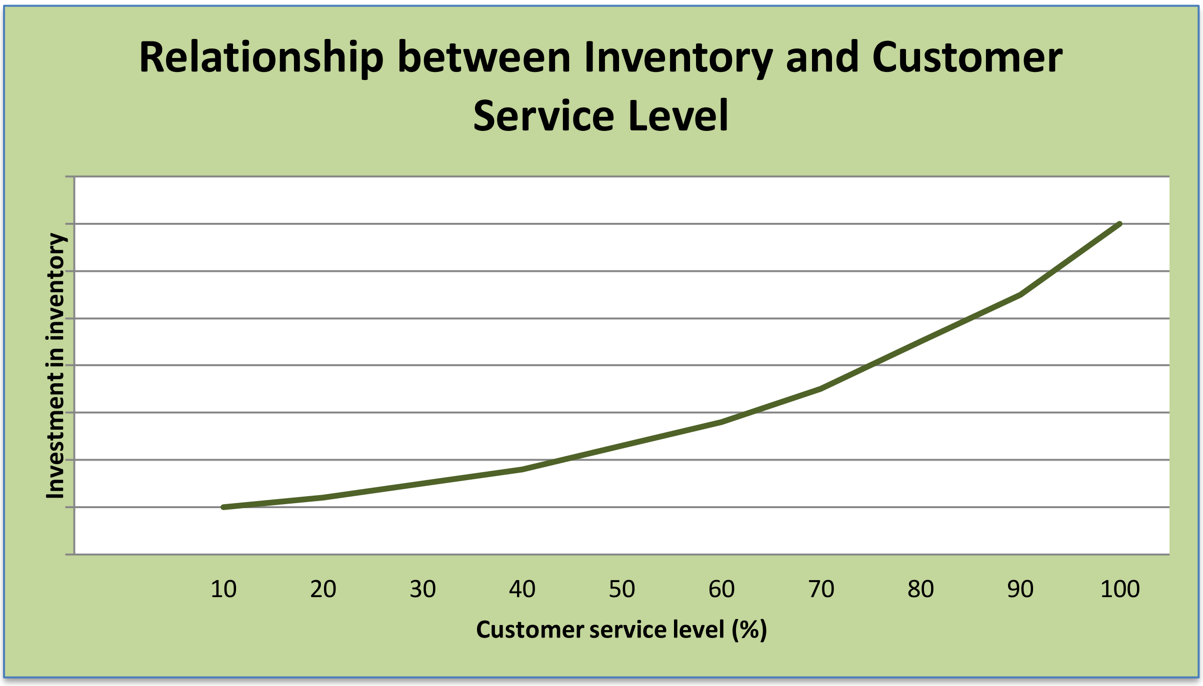


Figure 1: Relationship between the inventory and customer service levels

The following company was under investigation concerning its inventory.

1.2 Organisation background

C-Track is a business of DigiCore Holdings Group Ltd. C-Track specialises in advance vehicle tracking whether it is a private vehicle or fleet management, they also offer personal tracking solutions by using the latest Global Positioning Systems (GPS) or Global Systems for Mobile Communications (GSM) technologies. Clients enter a contract with C-Track, for after sales services, after the organisation sold and installed their products. They offer highly controllable and visible solutions through their services for the functionality, reliability and flexibility of mobile assets and mobile workforces.

Clients can track their vehicles at any given point in time and recall its location, performance and condition or reveal the circumstance or situation. Depending on the product chosen different benefits are enhanced and value added services can be added for further assistances for personal solutions.

1.3 Problem background

C-Track operates in a business industry which is regularly subjected to technology changes and improvements. C-Track is subjected to continuously improve and created processes in order to stay ahead of their competitors.

C-Track does not manufacture their devices, (but sell and install the devices) therefore their focus is more on customer services and customer support services. C-Track install's their devices in located branches. A centralised warehouse is being used to distribute the stock to several of these Branches.

Investigations within C-Track's operating businesses revealed that inventory management is an aspect of interest for improvements. The current processes being used to assign inventory levels require continuously high stock levels. Excessive and unnecessary stock kept on hand is a very large expenditure in any company. C-Track would like to lower their inventory levels but still keep their customers satisfied or even improve their customer service levels. A new ordering policy needs to be created in order to satisfy these requirements.

C-Track has four main products which they sell and install namely Product A, Product AX, Product B and Product BX. In this report the products will be referred to as Product A and Product B. Only the two main groups of the products are used because the “X subgroup” only illustrates that additional services such as collusion alert, ER24 notification and security assistance are added to the main product which is the Product A and Product B types. In other words the Product A will include Product A and Product AX, along with Product B will include the Product B and Product BX products.

C-Track does not manufacture their products but buy and order it directly from Digicore Holdings Group Ltd. C-Track has a fairly new centralised warehouse in Area A which also functions as a Branch. Here stock is kept and distributed to other Branches namely Branch B, Branch C, and other third party Branches such as Branch D, Branch E as well as the recently added Branch F.

1.4 Project aim

The aim of this project is to develop a more optimal stock policy and a more optimal order policy for C-Track to ensure that suitable customer service levels are maintained and managed at each of their Branches at a minimal cost to ensure customer satisfaction.

The idea is to lower the current inventory levels by way of a new ordering policy, but still maintain the customer satisfaction.

C-Track should then be able to create, build and plan a schedule to determine their stock levels for each of the products for each Branch to comply with the customer demand.

1.5 Project scope

The scope of the project entails the Inventory management of C-Track, which includes the stock policy and order policy at their centralized warehouse in Area A. The project does not include Warehouse management, Sales, Planning and the Logistics and distribution to the other involved Branches. Its solely involve the creation of an ordering policy and stock policy for C-Track. In other words, how much stock will C-Track order and when should they order their stock.

2. Literature review

A study has been conducted involving the Inventory management of C-Track. The approaches and methods used to conduct this study are explained as follow;

2.1 Methodology

There are various engineering methods and approaches to address such an inventory problem. Older, more known and recognized methods include; Linear programming, Just-in-time (JIT) analysis and Material requirement planning, to mention a few. In this project SMART business processes was chosen as a way to solve the problem stated here, because it is a newly developed and intrigue engineering method or approach in dealing with engineered problems.

2.2 Literature study

The literature study includes inventory management, existing SMART business processes and adaptive control models. It is discussed and explained below.

2.2.1 Inventory management

As stated earlier, inventory management is the way to know how much stock to order and when to order the stock. In order to comprehend the way to do such calculations, some concepts need to be defined.

- Stock management – to comprehend the stock mix and demand of the stock items in a company.
- Demand management – a focused effort to estimate and manage customers' demand with the intention of using this information to shape operating decisions. Demand management allows a firm throughout the supply chain to collaborate on activities related to the flow of product, services, information and capital (Ngoma, 2011).
- Lead time – The length of time between the instant when an order is placed and the instant at which the order arrives (Winston, 2004).

- Safety stock – The amount of inventory carried in addition to the expected demand (Jacobs et al. 2009).

2.2.1.1 Inventory costs

To make any decisions regarding inventory size, some costs must be considerate;

- Holding cost – Storage cost which includes; handling, insurance, breakage, depreciation, the opportunity cost for capital, ect. High holding costs tend to favour lower inventory levels and more frequent replenishment.
- Setup cost – To make each different product involves obtaining the necessary materials, arranging specific equipment setups, filling out the required papers, appropriately charging time and materials, and moving out the previous stock of material (Jacobs et al, 2009).
- Ordering cost – Managerial and clerical cost to prepare the purchase or production order.
- Shortage cost – When the stock of an item is depleted, an order for that item must either wait until the stock is replenish or be cancelled (Jacobs et al, 2009).
- Unit purchasing cost – The variable cost associated with purchasing a single unit. Typically includes the variable labour cost, variable overhead cost, and raw material cost associated with purchasing or producing a single unit (Winston, 2004).

Inventory management research done will assist in the decision making of the ordering policies and in some instances will be variables in the model. It will not be used as the exclusive techniques to calculate the ordering policy. The problem created in this project will be addressed using SMART business processes.

The Inventory management research is divided into sub-groups and it is discussed and explained as follow;

2.2.2.1 Forecasting

Forecasting is a tool of demand management. Because the customer demand is uncertain, forecasting is used to predict the future customer demand. To use a forecasting medium in order to predict the future demand one must understand that, no demand forecast method is 100% accurate (Pantana, 2010). Forecasting are also used by production and operations personnel to make periodic decisions regarding process selection, capacity planning and facility layout and continual decisions about production planning, scheduling and inventory (Jacobs et al. 2009). According to Saeed (2009) by using forecasting models, one can pick up on trends and seasonality which is very valuable when the demand is uncertain. The use of trend forecasting in policy design has been viewed with reservation in the system dynamics community. Trend forecasts applied to the determination of ordering policies in supply chain management systems often seem to exacerbate periods of shortage and oversupply sometimes referred to as the bullwhip effect. Saeed (2009) further states that trend information has been used, on the other hand, with great reliability in engineering in controller control.

There are different forecasting types and can be classified as; qualitative, time series analysis, casual relationship and simulation. Jacobs et al. (2009) defines these forecasting types as follow:

Qualitative techniques are subjective or judgmental and are based on estimates and opinions. Time series analysis is based on the idea that data relating past demand can be used to predict future demand. Casual forecasting assumes that demand is related to some underlying factor or factors in the environment. Simulation models allow the forecaster to run through a range of assumptions about the condition of the forecast.

Time series analysis will be the main focus of the type of forecast method. Within time series analysis there are different forecasting methods. To mention a few:

- Simple moving average – When demand for a product is neither growing nor declining rapidly, and if it does not have seasonal characteristics, a moving average can be useful in removing the random fluctuations for forecasting (Jacobs et al.,2009).
- Weighted moving average – Whereas the simple moving average gives equal weight to each component of the moving average database, a weighted moving average allows any weights to be placed on each element (Jacobs et al., 2009).
- Trend projections – Fits a mathematical trend line of the data points and projects it into the future (Jacobs et al. 2009).

- Exponential smoothing – Exponential smoothing assigns exponentially decreasing weights as the observations get older. In other words, recent observations are given relatively more weight in forecasting than the older observations (Kalekar, 2004).
- Box Jenkins techniques – Very complicated but apparently the most accurate statistical technique available. Relates the class of statistical models to data and fits the model to the time series by using Bayesian posterior distributions (Jacobs et al. 2009).

The Holt-Winters Method can pick-up on trends and seasonal variations, thus make it useful in projects such as these. Holt-Winters Forecasting Method is a more sophisticated algorithm that builds upon exponential smoothing. The Holt-Winters exponential smoothing is used when the data exhibits both trend and seasonality (Kalekar, 2004). Another advantage of this method is being able to adapt to changes in trends and seasonal patterns in sales when they occur. Holt-Winters Forecasting rests on the premise that the observed time series can be decomposed into three components: a baseline, a linear trend, and a seasonal effect. The algorithm presumes each of these components evolves over time and this is accomplished by applying exponential smoothing to incrementally update the components (Brutlag, J.D).

2.2.1.2 EOQ Models

Economic order quantity model (EOQ model) also known as Fixed order quantity model, attempt to determine the specific point at which an order will be place and the size of that order. In other words it involves ordering a fixed amount of product each time reordering takes place (Langely et al., 2009). The reordering point is when the inventory level reaches a certain point and an order should be placed. According to Winston W.L. (2004) an EOQ model has some assumptions such as;

- Repetitive ordering – The ordering decision is repetitive, in the sense that it is repeated in a regular fashion.
- Constant demand – Demand is assumed to occur at a known, constant rate. This implies, for example, that if demand occurs at a rate of 1000 units per year, the demand during any t-month period will be 1000t/12.
- Constant lead time – The lead time for each order is constant.

- Continuous ordering – An order may be placed at any time. Inventory models that allow this are called continuous review models. These models are described in the next section.

For a basic EOQ model to hold, certain assumptions are required;

- Demand is deterministic and occurs at a constant rate
- Lead time for each order is constant
- No shortages are allowed
- Price per unit is constant
- Ordering and setup costs are constant

Given these assumptions the EOQ model equations determines an ordering policy that minimizes the yearly sum of ordering cost, purchasing cost and holding cost (Winston, 2004).

Deviations of the EOQ models exist creating different types of EOQ models. The different models are basic EOQ model as described above, basic EOQ model when price-breaks are allowed, which means there are certain discounts when certain order sizes are ordered which depends on the supplier to be used. Basic EOQ when back orders are allowed. In other words the demand is not met on time and shortages occur. There is also an EOQ model with uncertain demand. It is used when lead time is nonzero and the demand during each lead time is random.

To use an EOQ model certain inputs need to be known, then by using these inputs parameters are calculated. These inputs, parameters and the equations used for calculating them are listed in the following tables.

Table 1: Input variables

Input Symbol	Input description
AVG	Average demand of the customer
STD	Standard deviation of the demand
L	Lead time
H	Holding cost
α	Service level

K	Ordering cost	
Parameter symbol	**Parameter description**	**Formula**
Z	Service factor	
SS	Safety stock	$SS = z*STD*\sqrt{L}$
R	Reorder level	$R = L*AVG + z*STD*\sqrt{L}$
Q	Order quantity	$Q = \sqrt{(2K*AVG)/h}$

Table 2: EOQ Symbols and Formulas

EOQ model will be used as inputs and variables such as the safety stock levels in the process to be used in this paper and not as the exclusive techniques to calculate the ordering policy.

2.2.2 Inventory policies

As mentioned before, there are different inventory policies. These policies describe how one should react when certain inventory levels are reached. Three inventory policies are described by WL Winston (2004).

2.2.2.1 Continuous Review (r, q) Policies

If q units are ordered when inventory level r is reached, an (r,q) policy is followed. This policy is also called a two-bin policy, since it can easily be implemented by using two bins. One order q units when the first bin is empty. The second bin will have r units to ensure no shortages. Thus when bin one is empty the reorder point r is reached. This model is applied in inventory systems where the level of inventory is reviewed on a continuous basis thus the instantaneous inventory levels can be determined at any given time. This type of review system typically provides a more responsive inventory management system than a periodic review system where inventory levels are only checked at discrete time intervals such as once a week when stock taking is being done (Croeser, 2011).

2.2.2.2 Continuous Review (s, S) Policies

This policy differs from the (r, q) policy since it allows inventory levels to drop below the reorder point, r. This is typical in situations where inventory items are not depleted singly. The policy implies that the company order units to fill inventory levels up to S, whenever inventory is equal or below s. For example if a (10, 45) policy is used and the inventory level suddenly drops from 13 to 7, an order will then be place for 45 – 7 = 38 units. Optimal computations of the (s, S) policy are difficult, and can be approximate as follows. Set S – s = q (economic order quantity). S is obtained from r and q, thus S = r + q.

2.2.2.3 Periodic Review(R, S) Policy

The periodic review policy as described by WL Winston (2004) follows a predetermined time schedule to replenish inventory. A review period R is determined and all stock is adjusted up to S (maximum stock level) when that period occurs.

2.2.3 Existing SMART Business processes

SMART business processes are relatively new concept thus existing applications are few. Some of the existing applications include intelligent maintenance, dominant innovation and service oriented architecture (Croeser, 2011).

Examples of the applications of existing SMART business processes are discussed below. The examples are used to describe the idea of the SMART business processes.

2.2.3.1 Intelligent maintenance

According to Croeser (2011) an Intelligent maintenance system is a product service system that can predict the failure of a product in advance. Organisations can therefore use this process to develop proactive instead of reactive maintenance strategies to guarantee product performance and ultimately eliminate unnecessary system breakdowns. Intelligent maintenance offers manufacturing companies the opportunity to extend their customer relationship by offering smart services through e-maintenance and consequently ensuring customer loyalty.

2.2.3.2 Dominant innovation

Dominated innovation offers companies an approach to developing new product-service offerings, by capturing ”invisible” areas of value and creating sustainable and enduring relationships with individual customers worldwide (Croeser, 2011). Lee (2010) describes Dominated innovation as a system and a set of tools designed to help create new products and services that can succeed in a changing competitive global market. "*It helps formulated gaps between a product and a customer's invisible needs, using an innovation matrix and application space mapping tools. Ultimately it may help both world-class companies and small to midsize enterprises transform themselves into innovative leaders*." Dominate innovation approach can be used to find the current gaps existing between product requirements and customer needs, and this must be done by implementing a systematic methodology to generate, develop and implement new concepts (Croeser, 2011)

2.2.3.3 Service orientated Architecture

According to Croeser (2011) Service orientated Architecture is concerned with the ability of a process (architecture) to adapt itself when applied in a different environment. In this paper this dynamic is applicable in the sense that we will take an Adaptive control model and implement it in an inventory management system as a SMART business process.

2.2.4 Adaptive control models

Control theory is applied to reduce inventory variation, reduce demand amplification and optimize ordering rules, thus proving adaptive control theory an appropriate tool in determining an ordering policy (Ortega and Lin, 2007).

Adaptive control models provide a set of techniques for automatic adjustment of the controllers in real time in order to achieve or to maintain a desired level of control system performance, when the parameters of the plant model are unknown and/or change in time (Landau et al., 2011).

By adaptive, we mean that the control parameters of inventory-control models are dynamically adjusted toward satisfying a target service level with the consideration of the non-stationary of customer demand. By non-stationary demand, we mean that the mean and variance of the demand distribution changes with time (Kim et al. 2005).

The PID Control process is used as the tool for the application of the Control theory and the SMART business processes in determining the ordering policy of this inventory problem.

2.2.4.1 PID control process

PID Control is concerned with adaptive control that comprises of Proportional control, Integral control and Derivative control, therefore PID control.

A PID Controller is a type of a control loop feedback process or mechanism and is a commonly used controller.

According to Saeed (2009) the analogy PID Control process can be expressed in the following simplified form:

$M(t) = P[e(t)] + I[\int e(t)dt] + D[d(e(t))/dt]$ **Equation 1: Analogy PID Control processes**

Where M is the total correction applied, P (proportion control) is the part of total correction that is proportional to the instantaneous error e, I (integral control) is the part of the total correction that is proportional to the integration of the instantaneous error e, and D (derivative control) is the part of the total correction that is proportional to the trend or derivative of the instantaneous error e. Instantaneous error e is invariably the discrepancy between the tracking quantity and a reference point which is either fixed or tied to the tracked quantity.

The role of each control term is further explained by Ortega and Lin (2007) as follows; the proportional control improves performance but leaves an offset from the target and the integral term eliminates this offset. The integral term has a destabilizing influence so the derivative term is introduced to restore the necessary stability margin.

According to Saeed (2009) PID control together with the use of trend information can be used with reliability for the determination of ordering policies in supply chain management. In application to the context of this problem, the PID Controller will comprise of;

The proportional control will be the inventory discrepancy, which is the difference between the desired inventory level and the instantaneous inventory level. Thus an increase in the error caused by a decrease in the instantaneous inventory level which in turn will cause an increase in the delivery rate thus the system will be adapting itself continuously to ensure that the desired inventory and the instantaneous inventory levels are nearing one another.

The derivative control term is a function of the trend in delivery to customers as well as an estimated demand of customers. This portion comprises the forecast in deliveries. Thus as the trend in customer demand increases, the orders will also increase.

The integral control term comprises the cumulative delivery orders for inventory. Delivery orders for inventory are those orders that are placed to minimize the inventory discrepancy. Thus this term is the accumulation of all these orders.

For the inventory management problem in the context of this paper the approaches and methods used was the PID Controller as the adaptive control model. iThink software was used to simulate this model in order to create a basis to test and validate alternatives. Also an EOQ model will be used to calculate the safety stock levels. An ordering policy will be generated from this process.

The process as a whole is seen as the SMART business process as the essence of the approach to the inventory management problem in this paper.

3. Model formulation

3.1 Data gathering

Sales data of C-Track was collected. The sales data contained the sales of the Branch A of C-Track which also acts as a warehouse. The period of the revealed data was from January 2008 to April 2012. The Branch A' sales data comprise of the sales data of the other Branches and the Third party Branches of which their stock is kept and then distributed form this warehouse. These Branches are; Branch B, Branch C, Branch D, Branch E. Within each Branch's data, the data is divided into each of the main products that C-Track sells namely Product A and Product B, as stated in the introduction chapter. The figure below shows the breakdown of the sales data collected from C-Track. The sales data is then sorted and filtered before it is imported in the PID Control model within the various Branches within the model.

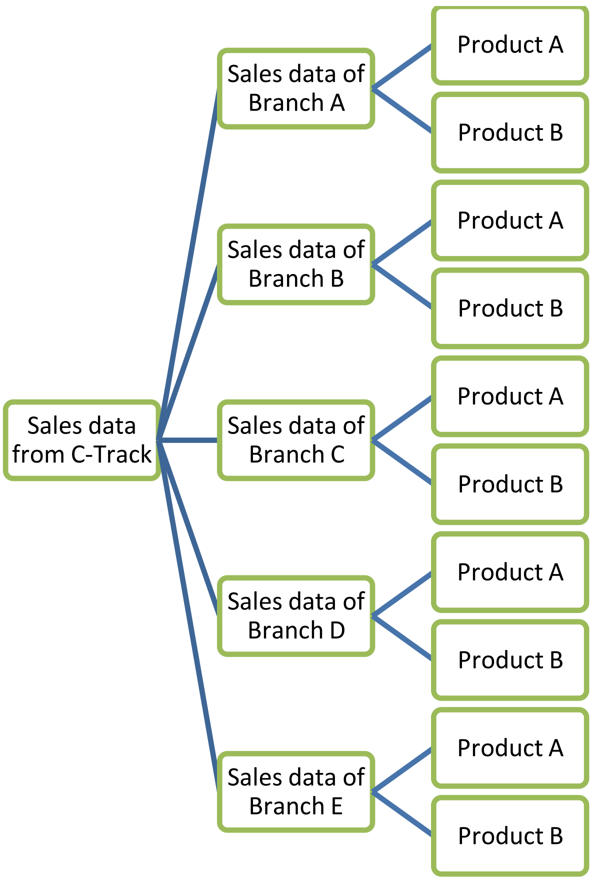


Figure 2: Breakdown of collected data

3.2 EOQ calculations

To perform the EOQ calculations some additional information other than the sales data need to be known. The kind of business industry C-Track operates can help to narrow these assumptions and according to the problem addressed in this paper, some conclusions can be made.

From the information collected it was clear that no backlog is allowed in any orders. Backlog is when a customer demands a product and the demand is not met on time, a stock-out, or shortage, is said to occur. If the customer will accept delivery at later date, we say that demands may be back-ordered (Winston, 2004). In the terms regarding C-Track, if a customer should arrive and the stock regarding the client is not available the chances are very likely that the customers will simply walk away, given that the market in this kind of business is very competitive.

The lead time of the orders is constant. When an order is placed an assumption was made that it will take 1 month before arrival at the warehouse.

EOQ calculation is used to calculate the safety stock levels. The safety stock levels are an input variable to the controller model. The table below shows the results obtained. The symbols are explained in the Literature review chapter.

Symbol	Branch A	Branch B	Branch C	Branch D	Branch E
Z	1.65	1.65	1.65	1.65	1.65
STD	46.9	77.3	23.3	22.5	14.7
$\sqrt{L}$	1	1	1	1	1
SS	77.40	127.51	38.44	37.19	24.24

Table 3: EOQ results obtained

The safety stock levels will be imported into the PID Control Model.

3.3 Forecasting of the customer demand

The future customer demand is necessary in order to establish an idea of the need of the customers in order to create an ordering policy. If the demand is not known an order can not be place before it is actually required. The lead time of an order is about a month, so the order needs to be place a month prior for it to be on time.

3.4 PID Controller model

As explained in the Literature review chapter, the PID Controller comprise of the proportional control, the derivative control and the integral control. In the context of this problem the controller is explained as follows;

3.4.1 Proportional control

The proportional control is the portion that is proportional to the error which is the inventory discrepancy. The inventory discrepancy is the difference between the instantaneous inventory and the desired inventory levels. The instantaneous inventory level is the inventory level at the specific point in time. The desired inventory level is the level of the inventory which would be the most likely to be maintained at that point in time. It is calculated by the forecasted demand added with the fixed safety stock level. The forecast within the process is generated through continual tracking of the trend in the demand.

The inventory discrepancy is the trigger in the control. If the discrepancy should increase the production for deliver will also increase. The difference will thus continually be kept at a minimum. The figure below is an illustration of the proportional control of the model.

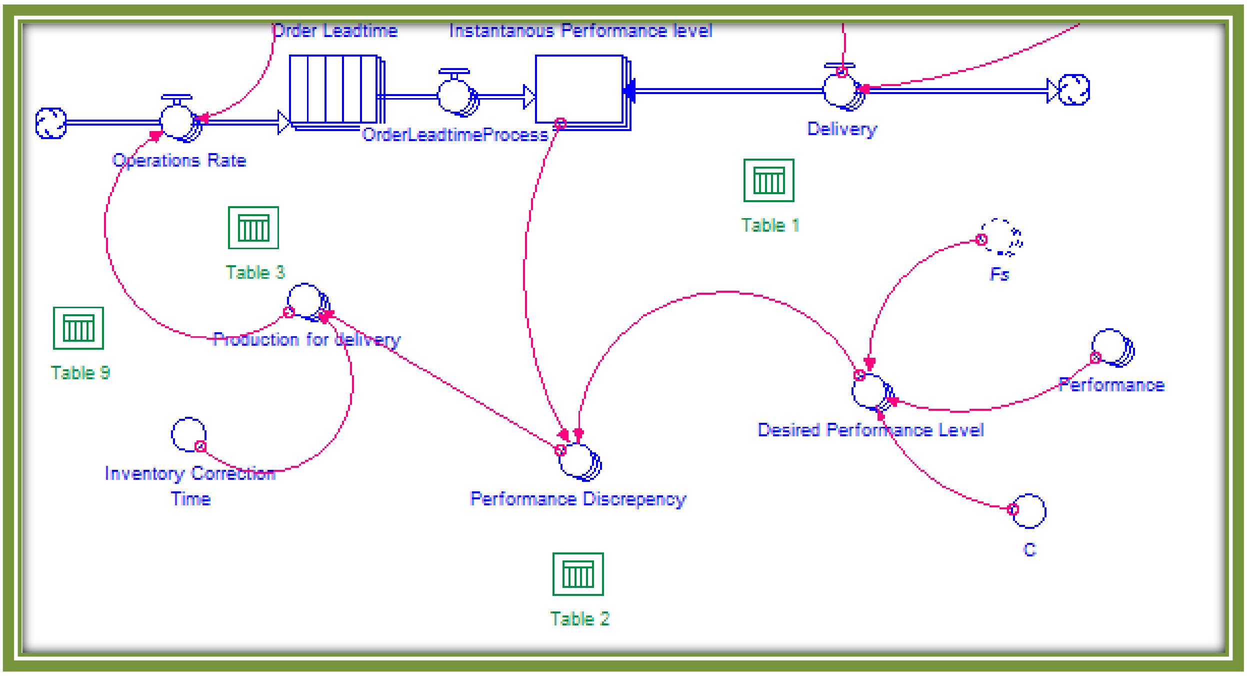


Figure 3: Illustration of the proportional portion of the PID model

3.4.2 Derivative control

The derivative control portion of the control comprise of the estimated demand and the trend in delivery. The control is activated by the imported sales data which indicates the demand of the customers. The trend in delivery and the estimated demand forms the forecast of the process which then influence the inventory levels. The figure below is a portion of the derivative controller of the model.

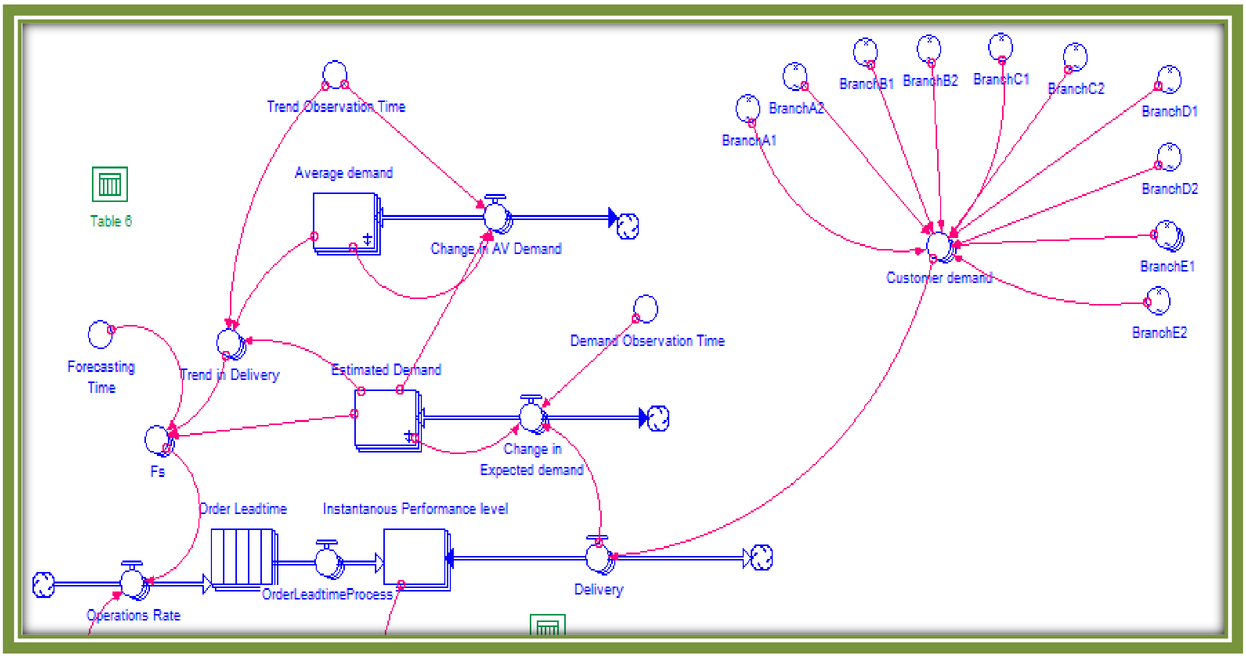


Figure 4: Illustration of the derivative portion of the PID model

3.4.3 Integral control

The integral portion of the model is the accumulation of all the inventory discrepancies. The accumulation of these discrepancies is the operations rate which drives the instantaneous inventory levels. The figure below is a view of the whole PID Controller process.

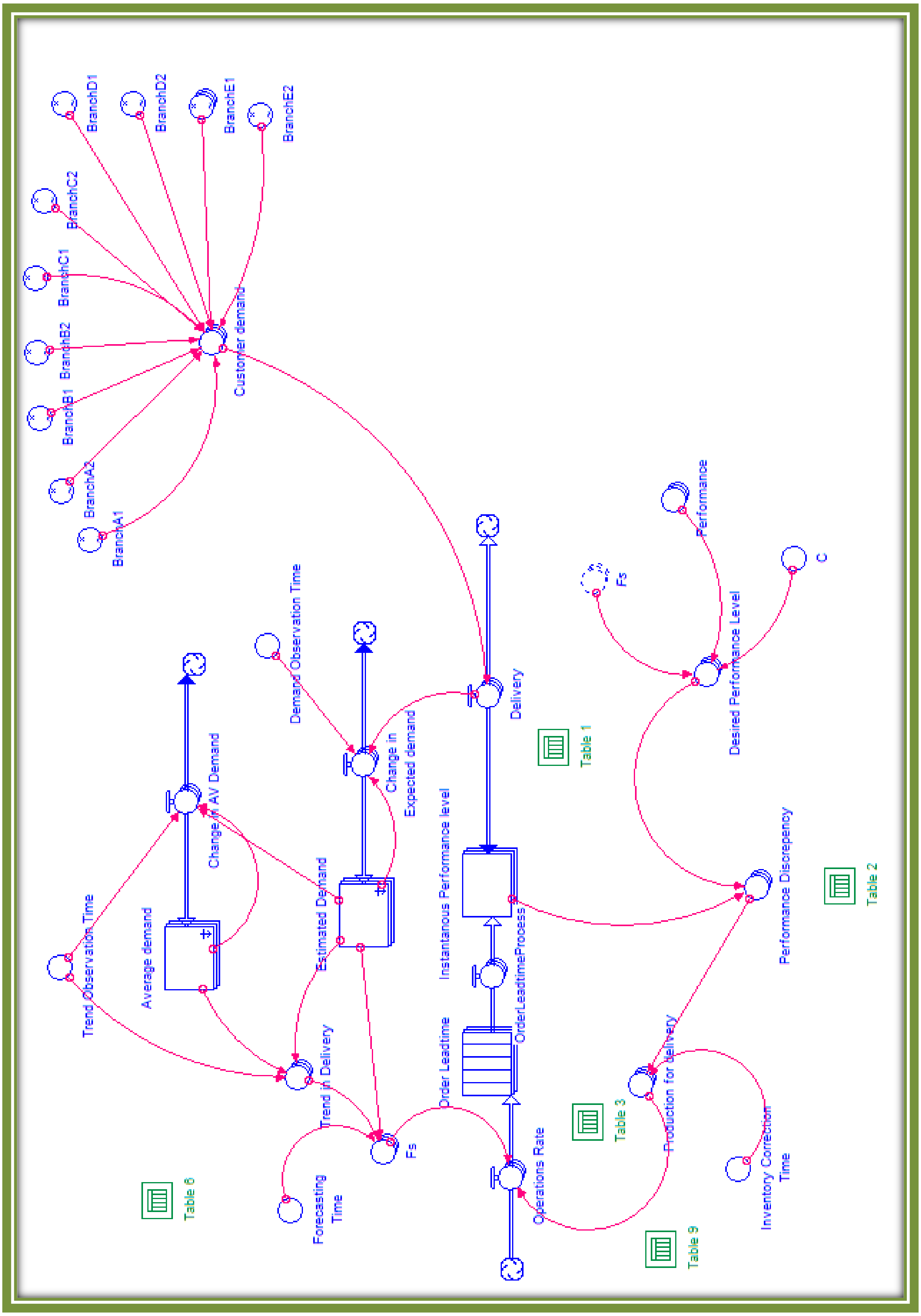


Figure 5: A view of the whole PID control model

4. Data analysis

After the data gathering and all necessary information were obtained, the PID Control model was built. The model formed the SMART business processes, with all its inserts and outputs from the PID Controller.

4.1 The PID Control model

4.1.1 The data of the model

Actual sales data were imported from January 2008 until April 2012. Forecasted demand data were imported from May 2012 until April 2013, making the forecasted range 1 year. The imported data of the sales and forecast forms the variable Customer demand in the PID Controller process.

The safety stock levels that were calculated for each Branch were used as the variable Performance in the PID Control process.

To show the output of the model, the Branch A and the Product A is used to illustrate some components. The full table can be seen in appendix.

Months	Delivery[BranchA,ProductA]	Instantanous Performance level[Branch A,ProductA]	Operations Rate[Branch A,ProductA]	Desired Performance Level[Branch A,ProductA]	Customer demand[BranchA,ProductA]
48	81.38	190.21	31.49	156.59	97
49	85.38	136.32	73.24	152.73	66
50	77.63	131.94	86.63	155.93	97
51	90.63	127.95	120.84	165.03	80
52	81.79	166.99	105.27	159.66	84.77
53	84.77	187.49	65.35	161.83	84.77
54	84.09	168.75	64.21	161.15	82.95
55	86.13	146.83	85.79	165.03	91.43
56	93.47	139.15	116.96	173.07	96.88
57	92.79	163.32	124.69	169.89	85.98
58	90.97	197.03	79.61	170.73	99.3
59	83.4	193.23	66.33	153.38	56.91
60	65.99	193.57	12.36	143.09	81.13

61	86.58	119.35	55.73	165.47	95.66
62	97.7	77.37	171.09	179.08	101.11
63	92.48	155.98	180.96	168.63	78.1
64	78.1	258.85	46.04	154.04	78.1

Table 4: Portion of the Branch A policy of the Product A

In column 1, Months, the initial month represents January 2008 up to month 64 which is April 2013.

Column 6, Customer demand, represents the sales and the forecasted demand, as stated before, of the Branch A's Product A.

Column 5, Desired Performance Level, is the level of the inventory in the warehouse which is the desired level to be maintained. It is calculated by adding the forecasting of the demand done within PID Control process and the safety stock level. The safety stock level was calculated through the EOQ calculations as seen in chapter 3. The forecast in the PID Control model is generated as part of the PID Control process and is determined by adding the variables of Estimated demand and the Trend in delivery multiplied by the forecasting time.

Column 3, Instantaneous Performance level, is the level of the inventory in the warehouse at a specific point in time, the beginning of each month. It is calculated by using the following equation;

Instantaneous Performance levelt + Operations ratet – Deliveryt+1 = Instantaneous Performance levelt+1 Equation 2: Instananeous performance level

where t represent the point in time, a month.

Column 4, Operations rate, represents the rate at which the products are needed but there is a lack of products, where in this case the products are then ordered from Digicore Holding Group (Ltd). The operations rate is calculated by variables within the model by adding the Production for delivery and the forecast of the demand within the model.

Column 2, the Delivery is the rate at which the products are actually delivered according to the model. In this case, by delivery we mean sold to a customer.

The same process is repeated for all of the Branches as stated earlier as well as both of the main product types that C-Track sells and installs.

The following is a graphical illustration of the table presented above.

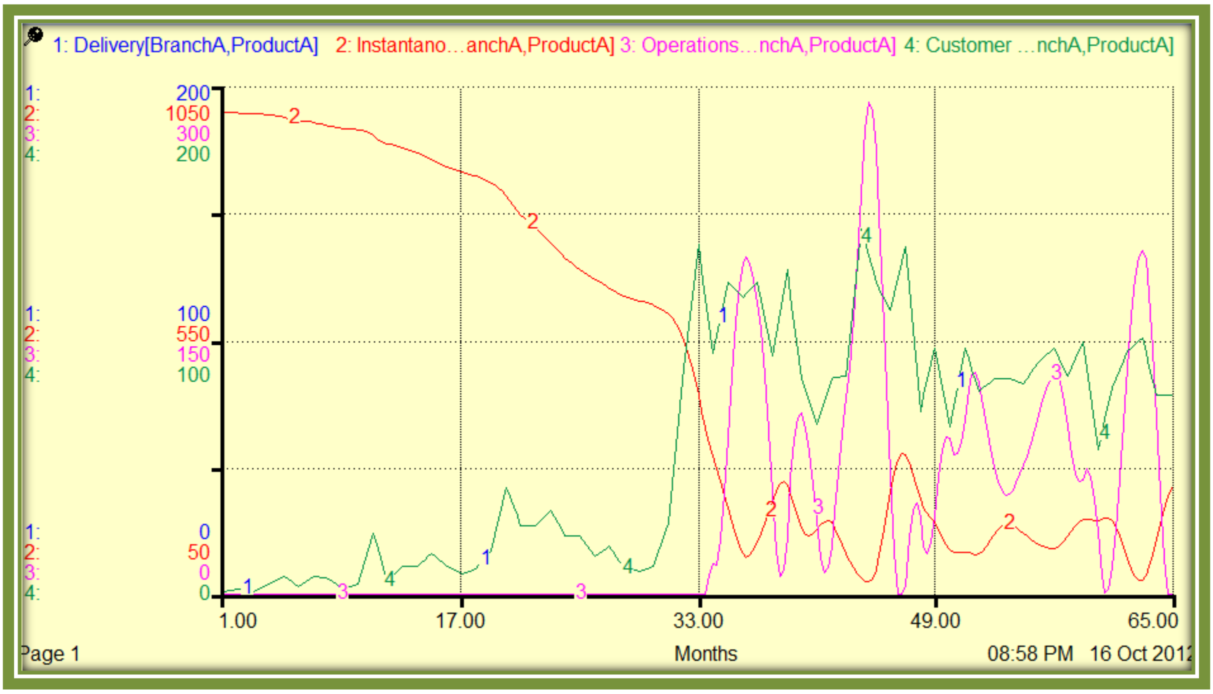


Figure 6: Illustration of the Branch A and the product A according to the table above

As seen on the graph, the Instantaneous performance level is decreasing but then reaches a level around which it fluctuates, while the Delivery and the Customer demand is kept as close as possible to one another. The Operations rate alters in between.

4.2 Ordering policy

4.2.1 Delivery rate of each product type in each Branch

Branches	Product A	Product B
Branch A	98.67%	98.64%
Branch B	99.08%	98.93%
Branch C	99.16%	99.03%
Branch D	98.97%	98.80%
Branch E	98.86%	98.68%

Table 5: Delivery rate of each product type in each branch

The table shows the rate at which the product in each Branch is delivered, or rather sold in this case, by having enough stock on hand. The delivery rate was determined by measuring the Delivery variable in the model against the Customer demand variable. By using this model, the PID Control process, one can see that this delivery margin can be quite acceptable.

The following table is an indication of the total amount of products ordered in each month of all the branches in the model combined. The full table can be seen in the appendix.

4.2.2 Operations rate of the product types

Year	Month	Product A	Product B
2012	January	169.66	175.71
	February	381.87	349.8
	March	385.11	614.35
	April	126.47	479.11
	May	275.83	76.14
	June	453.83	16.97
	July	397.56	105.07
	August	352.65	359.74
	September	401.69	499.47
	October	346.11	310.92
	November	344.44	165.92
	December	79.59	16.68
2013	January	183.23	161.64
	February	643.74	527.64
	March	731.43	566.32
	April	214	147.38
	Total	**5487.21**	**4572.86**

Table 6: Operations rate per product of all branches

The ordering policy of the model takes several of parameters in consideration when determining the policy, such as the Instantaneous level of inventory and the trend in customer demand. The ordering policy that was created by the PID Control model is truly a result of the SMART process of the self-adaption of the decisive control parameters.

The following is a graphical illustration of the Instantaneous performance levels of the product A in each branch.

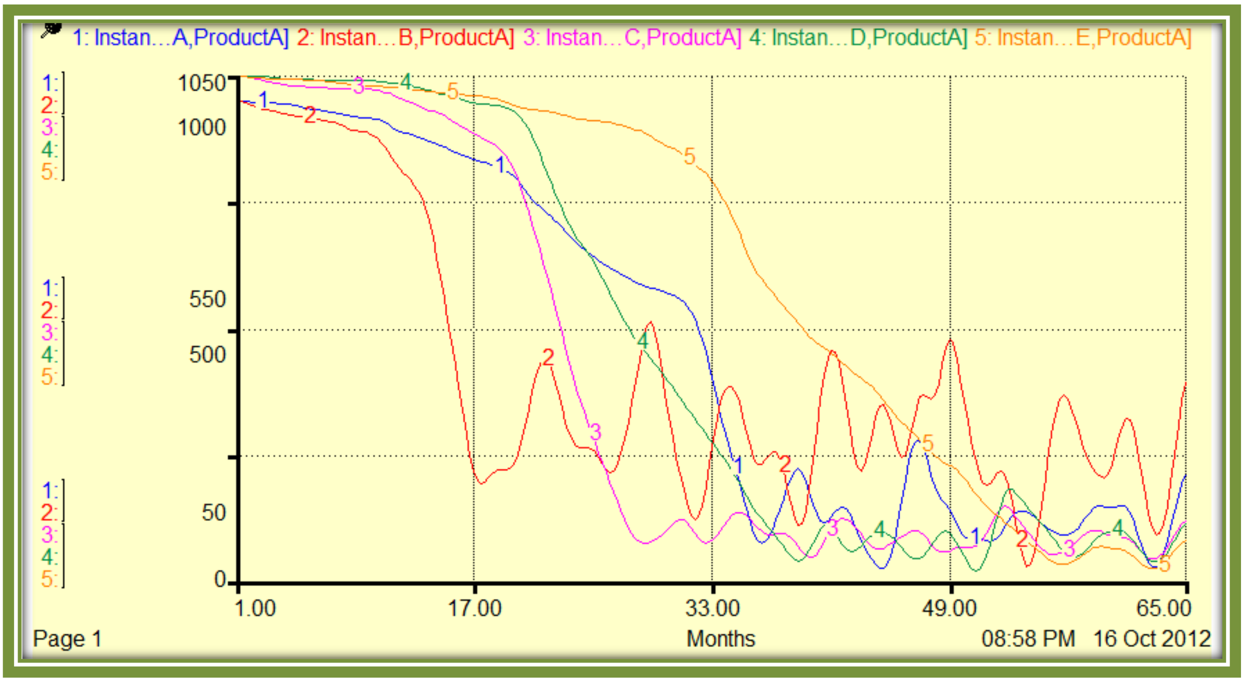


Figure 7: The Instantaneous performance level of the product A per branch

The following graph is an illustration of the Instantaneous performance level of the product B in each Branch.

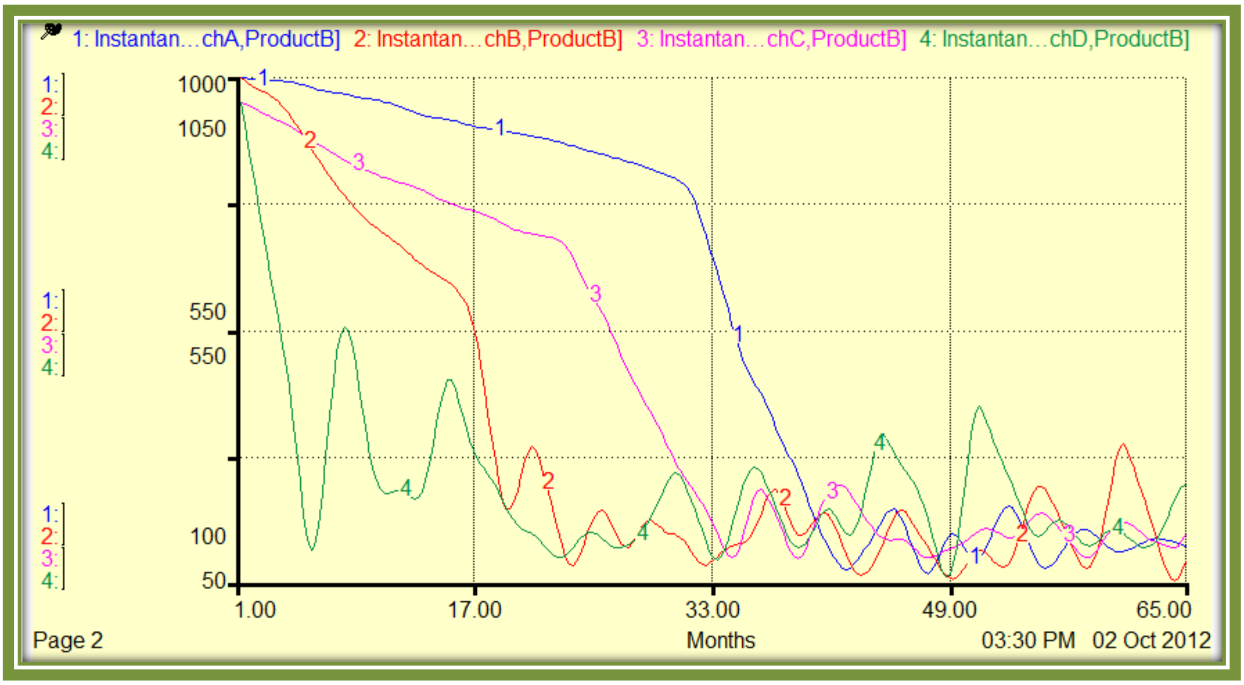


Figure 8: The Instantaneous performance level of the product B per branch

It is clear that the level of inventory has decreased according to all of the parameters measured here.

The conclusion is drawn in the next chapter.

Currently C-Track orders their stock by forecasting their targeted sales to match their budgets six months in advance. Then they order every month the necessary stock for the next month according to the forecast. A problem that can occur is that one can not reach one's target for sales each and every month in order to maintain the monthly budget. An alternative is to forecast the customer demand according to the market and then deliver the sales to reach the market's need.

It is extremely important to note that the forecasting of the customer demand has an enormous influence on the outcome of the model. If the forecasting is not done probably the demand of the products will be off scale and so will the ordering rate.

This method of implementing a SMART business process in the inventory management can be an advantage to a company. With the use of the model C-Track will be able to keep continuously track of their inventory levels. They can keep track of how their stock should be managed in order to maintain the minimum level of inventory with the maximum of deliveries.

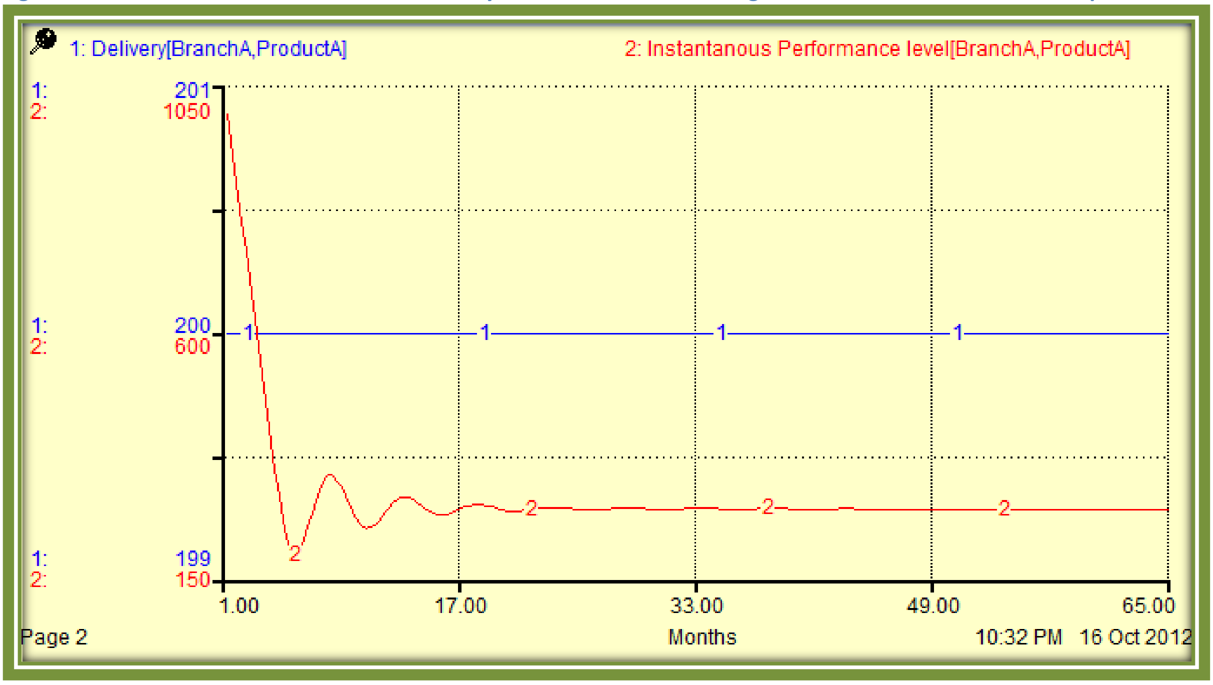
5. Model Validation

For the validation purposes of the adaptive model, the Delivery was set at a constant value. The model reached an equilibrium state when the customer demand was constant. The equilibrium state was maintained as long as possible through the continual self-adaption of the model.

When the Instantaneous performance level and the Desired performance level were the same while keeping the customer demand constant, the Performance discrepancy was constant. This implies that the only difference between the Delivery and the Instantaneous performance level is the fixed safety stock level. Therefore the only excess stock is the fixed safety stock level.

The graphs below show the validation of the model.

Figure 9: The illustration of the validity of the model using the Branch A and the product A



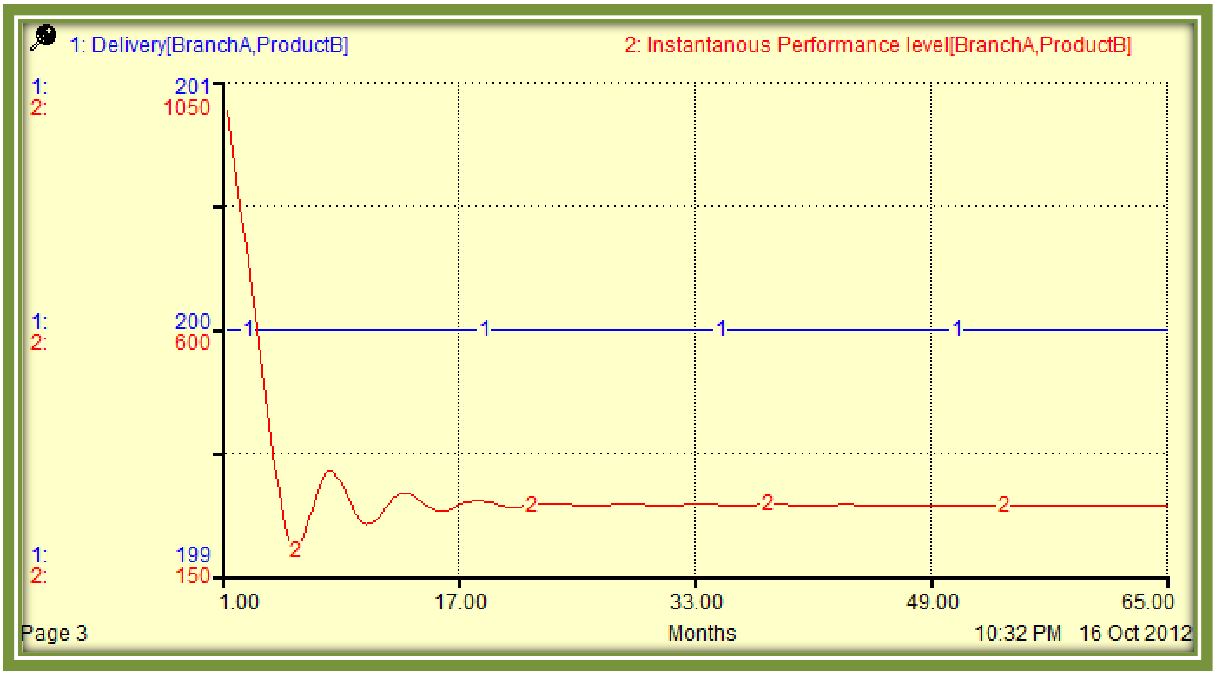


Figure 10: The illustration of the validity of the model using the Branch A and the product B

The same results were obtained for each branch with each product type.

6. Conclusion

The aim of this project was to lower the inventory level of C-Track's centralised warehouse, by developing a new ordering policy. The use of an adaptive control model as a SMART business processes was the tools used in this project.

A PID Control model which is a self-adapting process was created in the software called iThink to create a basis to test and control parameters in order to generate the best possible ordering policy.

The project can be elaborated in the future by taking more parameters in consideration for example by studying the batch sizes of the products to be ordered.

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Appendixes

Appendix A: Sales data

Customer demand

BranchA1	BranchA2	BranchB1	BranchB2	BranchC1	BranchC2	BranchD1	BranchD2	BranchE1	BranchE2
1	3	8	22	2	10	1	9	4	3
2	3	12	11	8	17	0	7	2	1
1	1	5	26	7	12	4	10	0	1
4	2	7	43	3	23	0	9	1	3
7	9	5	41	2	14	2	8	3	2
3	8	3	35	2	20	1	12	1	2
7	2	8	30	1	12	0	7	4	1
6	6	14	21	0	14	1	9	3	4
2	5	1	18	0	8	0	4	2	0
4	4	23	26	6	9	2	7	2	4
24	10	49	18	11	16	5	3	2	9
5	9	27	14	13	12	4	9	5	3
11	9	52	47	13	8	8	4	2	3
11	3	157	183	7	10	8	3	5	0
16	5	176	141	21	19	8	8	1	4
11	9	184	88	16	7	9	7	3	2
8	3	160	93	16	4	3	4	2	3
10	5	223	106	16	11	3	8	6	2
17	4	253	81	44	66	11	5	13	1
42	5	234	84	95	46	38	12	7	8
27	5	226	101	100	71	75	25	2	0
27	7	234	70	112	60	73	46	6	3
33	7	206	84	120	47	63	49	10	6
23	9	198	56	82	68	34	16	3	1
23	6	252	73	82	37	55	16	2	0
15	8	264	70	76	52	60	50	7	6
19	7	259	93	66	74	50	25	8	5
10	10	180	116	62	29	39	23	11	9
9	9	218	87	66	35	35	18	20	22
11	9	160	113	51	76	41	34	12	10
28	25	228	82	71	73	42	45	28	22
89	89	185	59	68	83	40	39	17	28
138	81	198	65	63	67	40	63	49	37
95	103	183	65	58	51	45	65	56	31
123	62	198	70	60	39	55	27	81	23

117	38	131	40	49	18	37	31	37	26
123	75	167	40	35	29	35	28	37	8
94	43	246	43	47	24	49	77	31	26
128	78	215	49	58	41	34	88	39	43
85	55	210	46	42	40	28	46	20	14
67	72	227	78	49	46	53	58	23	26
85	69	269	105	42	56	35	45	27	21
86	85	185	94	48	41	34	45	19	30
144	63	233	99	38	26	29	22	35	19
123	58	294	83	44	32	32	28	39	16
112	69	198	116	29	41	37	22	24	28
137	69	317	118	44	40	29	18	34	21
72	49	139	51	36	41	20	20	25	27
97	77	181	77	42	42	39	43	13	21
66	87	162	82	62	41	60	57	41	28
97	80	110	107	50	63	59	55	36	18
80	68	64	109	30	35	34	39	23	30
84.77	55.21	158.51	71.46	37.14	31.84	34.54	32.44	25.15	18.83
84.77	55.21	159.2	71.77	37.68	32.3	34.54	32.44	25.15	18.83
82.95	54.03	155.75	70.21	36.61	31.38	34.02	31.96	24.58	18.4
91.43	59.55	171.61	77.36	40.38	34.61	37.63	35.35	26.87	20.12
96.88	63.1	181.25	81.71	42.53	36.45	39.7	37.29	28.59	21.4
85.98	56	161.27	72.7	38.22	32.76	35.06	32.93	25.73	19.26
99.3	64.68	186.08	83.88	43.61	37.38	40.73	38.25	29.16	21.83
56.91	37.07	106.82	48.15	25.3	21.69	23.2	21.79	16.58	12.41
81.13	52.84	152.31	68.66	36.07	30.92	32.99	30.99	24.01	17.98
95.66	62.31	179.19	80.78	41.99	35.99	39.18	36.8	28.01	20.97
101.11	65.86	189.53	85.44	44.68	38.3	41.24	38.74	29.73	22.26
78.1	50.87	146.79	66.17	34.45	29.53	31.96	30.02	23.44	17.55

Table 7: Imported sales data

Aggregated customer demand per product type

		Product A	Product B
January	2008	16	47
February		24	39

March		17	50
April		15	80
May		19	74
June		10	77
July		20	52
August		24	54
September		5	35
October		37	50
November		91	56
December		54	47
January	2009	86	71
February		188	199
March		222	177
April		223	113
May		189	107
June		258	132
July		338	157
August		416	155
September		430	202
October		452	186
November		432	193
December		340	150
January	2010	414	132
February		422	186
March		402	204

April		302	187
May		348	171
June		275	242
July		397	247
August		399	298
September		488	313
October		437	315
November		517	221
December		371	153
January	2011	397	180
February		467	213
March		474	299
April		385	201
May		419	280
June		458	296
July		372	295
August		479	229
September		532	217
October		400	276
November		561	266
December		292	188
January	2012	372	260
February		391	295
March		352	323
April		231	281

May		340.11	209.78
June		341.34	210.55
July		333.91	205.98
August		367.92	226.99
September		388.95	239.95
October		346.26	213.65
November		398.88	246.02
December		228.81	141.11
January	2013	326.51	201.39
February		384.03	236.85
March		406.29	250.6
April		314.74	194.14

Table 8: Aggregated customer demand per product type

Appendix B: EOQ Model calculation

Aggregated sales data per Branch

Overall Total Branches	Branch B	Branch C	Branch A	Branch D	Branch E
	41.60%	**12.54%**	**25.26%**	**12.14%**	**7.91%**
225	94	28	57	27	18
241	100	30	61	29	19
222	92	28	56	27	18
363	151	46	92	44	29
320	133	40	81	39	25
306	127	38	77	37	24
293	122	37	74	36	23
241	100	30	61	29	19
204	85	26	52	25	16
347	144	44	88	42	27
396	165	50	100	48	31
270	112	34	68	33	21
320	133	40	81	39	25
450	187	56	114	55	36
479	199	60	121	58	38
378	157	47	95	46	30
355	148	45	90	43	28
432	180	54	109	52	34
536	223	67	135	65	42
638	265	80	161	77	50
697	290	87	176	85	55
697	290	87	176	85	55
703	292	88	178	85	56
562	234	70	142	68	44
653	272	82	165	79	52
703	292	88	178	85	56
717	298	90	181	87	57
587	244	74	148	71	46
576	240	72	145	70	46
588	245	74	149	71	47
668	278	84	169	81	53
704	293	88	178	85	56
828	344	104	209	100	66

770	320	97	194	93	61
793	330	99	200	96	63
529	220	66	134	64	42
579	241	73	146	70	46
695	289	87	176	84	55
777	323	97	196	94	61
592	246	74	150	72	47
701	292	88	177	85	55
760	316	95	192	92	60
675	281	85	170	82	53
712	296	89	180	86	56
753	313	94	190	91	60
678	282	85	171	82	54
828	344	104	209	100	66
482	201	60	122	58	38
634	264	80	160	77	50
687	286	86	174	83	54
676	281	85	171	82	53
512	213	64	129	62	41

Table 9: Aggregated sales data

Service level and Service factor

Service level	**92%**	**93%**	**94%**	**95%**	**96%**	**97%**	**98%**	**99%**	**99.9%**
z	1.41	1.48	1.56	1.65	1.75	1.88	2.05	2.33	3.8

Table 10: Service level and Service factor

Appendix C: Tables gathered from the model

Operation rate of each product in each branch

Months	Operations Rate[BranchA,Product	Operations Rate[BranchA,Product	Operations Rate[BranchB,Product	Operations Rate[BranchB,Product	Operations Rate[BranchC,Product	Operations Rate[BranchC,Product	Operations Rate[BranchD,Product	Operations Rate[BranchD,Product	Operations Rate[BranchE,Product	Operations Rate[BranchE,Product	Operations rate Product A	Operations rate Product B
Initial												
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	11.72	0	0	0	0	0	0	0	11.72
15	0	0	34.39	86.87	0	0	0	0	0	0	34.39	86.87
16	0	0	198.48	28.18	0	0	0	0	0	0	198.48	28.18
17	0	0	240.59	16.65	0	0	0	0	0	0	240.59	16.65
18	0	0	302.19	121.63	0	0	0	0	0	0	302.19	121.63
19	0	0	362.2	129.99	0	0	0	0	0	0	362.2	129.99
20	0	0	247.09	73.18	0	0	0	0	0	0	247.09	73.18
21	0	0	113.8	83.49	0	0	0	0	0	0	113.8	83.49
22	0	0	152.45	57.19	0	0	0	0	0	0	152.45	57.19
23	0	0	208.42	54.96	0	0	0	0	0	0	208.42	54.96

24	0	0	217.24	37.64	0	0	0	0	0	0	217.24	37.64
25	0	0	327.8	66.54	0	0	0	0	0	0	327.8	66.54
26	0	0	387.14	108.48	18.9	0	0	0	0	0	406.04	108.48
27	0	0	257.64	152.67	66.89	0	0	0	0	0	324.53	152.67
28	0	0	18.85	177.26	84.08	0	0	0	0	0	102.93	177.26
29	0	0	42.21	77.97	74.83	0	0	0	0	0	117.04	77.97
30	0	0	156.37	47.31	34.7	43.15	0	0	0	0	191.07	90.46
31	0	0	345.49	40.77	62.96	129.68	0	0	0	0	408.45	170.45
32	0	0	296.56	5.88	99.66	135.86	0	0	0	0	396.22	141.74
33	2.73	0	130.1	40.45	72.13	41.12	0	0	0	0	204.96	81.57
34	31.5	0	76.27	102.56	27	0	0	0	0	0	134.77	102.56
35	141.06	0	169.12	107.86	30.32	0	0	0	0	0	340.5	107.86
36	194.16	0	128.71	16.13	39.04	0	1.75	0	0	0	363.66	16.13
37	138.7	0	160.58	0	18.78	0	26.43	0	0	0	344.49	0
38	27.34	0	400.2	6.66	45.89	5.38	79.69	9.67	0	0	553.12	21.71
39	74.18	0	373.52	58.92	98.73	61.99	55.06	97.22	0	0	601.49	218.13
40	88.3	19.97	135.12	91.1	61.31	89.44	2.16	55.22	0	0	286.89	255.73
41	23.02	94.7	103.7	141.68	15.22	66.36	41.18	2.32	0	0	183.12	305.06
42	60.52	127.93	311.25	187.24	14	49.92	57.98	8.47	0	0	443.75	373.56
43	152.51	110.92	246.46	116.44	51.72	14.31	23.85	39.63	0	0	474.54	281.3
44	271.93	29.02	192.33	35.63	55.61	0	1.2	15.42	0	0	521.07	80.07
45	196.37	0	358.25	25.61	40.18	6.94	23.03	3.41	0	0	617.83	35.96
46	23.66	54.32	252.51	148.83	8.52	58.04	60.76	16.16	0	0	345.45	277.35
47	35.21	111.84	267.23	203.87	33.12	79.6	41.57	20.8	0	0	377.13	416.11

48	31.49	62.25	50.58	25.11	57.66	50.06	1.18	30.6	0	0	140.91	168.02
49	73.24	67.14	0	0	63.16	22.08	33.26	86.49	0	0	169.66	175.71
50	86.63	126.68	79.46	33.75	90.74	30.7	125.04	124.92	0	0	381.87	316.05
51	120.84	108.13	89.66	171.65	57.31	90.9	117.3	72.02	0	0	385.11	442.7
52	105.27	24.56	11.91	202.37	0	48.5	9.29	1.31	0	0	126.47	276.74
53	65.35	0	210.48	38.07	0	0	0	0	0	0	275.83	38.07
54	64.21	16.97	369.3	0	18.03	0	0	0	2.29	0	453.83	16.97
55	85.79	69.92	232.13	4.71	52.84	15.57	3.24	10.16	23.56	0	397.56	100.36
56	116.96	102.26	84.13	77.82	66.32	52.66	40.28	49.18	44.96	0	352.65	281.92
57	124.69	86.67	111.87	141.89	52.4	63.04	69.09	65.98	43.64	0	401.69	357.58
58	79.61	38.07	174.05	101.14	24.74	33.56	46.7	37.01	21.01	0	346.11	209.78
59	66.33	32.84	216.65	49.82	25.41	16.28	22.72	17.16	13.33	0	344.44	116.1
60	12.36	11.96	54.06	1.47	10.68	1.03	0.71	0.75	1.78	0	79.59	15.21
61	55.73	45.17	59.49	36.09	30.38	23.33	17.99	20.96	19.64	0	183.23	125.55
62	171.09	113.4	276.76	139.77	74.3	67.19	68.61	67.51	52.98	0	643.74	387.87
63	180.96	113.03	346.37	157.32	75.4	68.14	76.2	70.51	52.5	0	731.43	409
64	46.04	26.7	115.85	43.63	18.87	16.13	20.55	17.29	12.69	0	214	103.75

Table 11: Operations rate generated from the PID Controller

Branch A of the product A

Months	Delivery[BranchA,ProductA]	Instantanous Performance level[BranchA,ProductA]	Operations Rate[BranchA,ProductA]	Desired Performance Level[BranchA,ProductA]	Customer demand[BranchA,ProductA]
Initial		1000		77.4	1
1	1.38	998.63	0	79.08	2
2	1.63	997	0	79.14	1

3	2.13	994.88	0	80.21	4
4	5.13	989.75	0	83.58	7
5	5.5	984.25	0	82.95	3
6	4.5	979.75	0	82.72	7
7	6.63	973.13	0	84.19	6
8	4.5	968.63	0	81.33	2
9	2.75	965.88	0	80.01	4
10	11.5	954.38	0	92.74	24
11	16.88	937.5	0	93.51	5
12	7.25	930.25	0	85.75	11
13	11	919.25	0	88.14	11
14	12.88	906.38	0	91.39	16
15	14.13	892.25	0	91.37	11
16	9.88	882.38	0	86.64	8
17	8.75	873.63	0	85.78	10
18	12.63	861	0	91.14	17
19	26.38	834.63	0	109.91	42
20	36.38	798.25	0	115.59	27
21	27	771.25	0	106.11	27
22	29.25	742	0	107.83	33
23	29.25	712.75	0	105.35	23
24	23	689.75	0	99.57	23
25	20	669.75	0	94.76	15
26	16.5	653.25	0	92.91	19
27	15.63	637.63	0	90.44	10
28	9.63	628	0	85.3	9
29	9.75	618.25	0	86.13	11
30	17.38	600.88	0	97.75	28
31	50.88	550	0	143.22	89
32	107.38	442.63	0	206.56	138
33	121.88	320.75	2.73	207.94	95
34	105.5	217.98	31.5	193.82	123
35	120.75	128.73	141.06	201.02	117
36	119.25	150.55	194.16	200.19	123
37	112.13	232.58	138.7	185.37	94
38	106.75	264.53	27.34	187.68	128
39	111.88	180	74.18	182.27	85
40	78.25	175.93	88.3	148.2	67
41	73.75	190.48	23.02	147.63	85
42	85.38	128.13	60.52	160.84	86
43	107.75	80.9	152.51	197.21	144

44	136.13	97.29	271.93	218.68	123
45	118.88	250.34	196.37	199.17	112
46	121.38	325.34	23.66	203.56	137
47	112.63	236.37	35.21	179.53	72
48	81.38	190.21	31.49	156.59	97
49	85.38	136.32	73.24	152.73	66
50	77.63	131.94	86.63	155.93	97
51	90.63	127.95	120.84	165.03	80
52	81.79	166.99	105.27	159.66	84.77
53	84.77	187.49	65.35	161.83	84.77
54	84.09	168.75	64.21	161.15	82.95
55	86.13	146.83	85.79	165.03	91.43
56	93.47	139.15	116.96	173.07	96.88
57	92.79	163.32	124.69	169.89	85.98
58	90.97	197.03	79.61	170.73	99.3
59	83.4	193.23	66.33	153.38	56.91
60	65.99	193.57	12.36	143.09	81.13
61	86.58	119.35	55.73	165.47	95.66
62	97.7	77.37	171.09	179.08	101.11
63	92.48	155.98	180.96	168.63	78.1
64	78.1	258.85	46.04	154.04	78.1

Table 12: The Branch A Variables of the product A

Appendix D: Graphs gathered from model

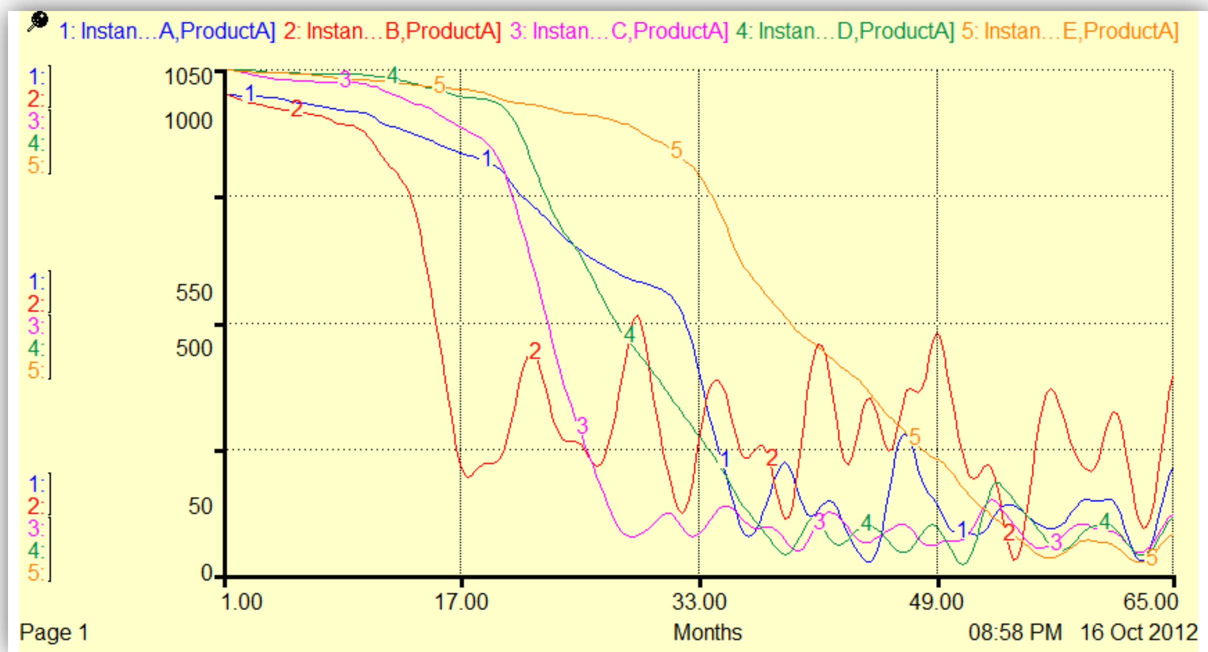

Figure 11: Instantaneous inventory of product A

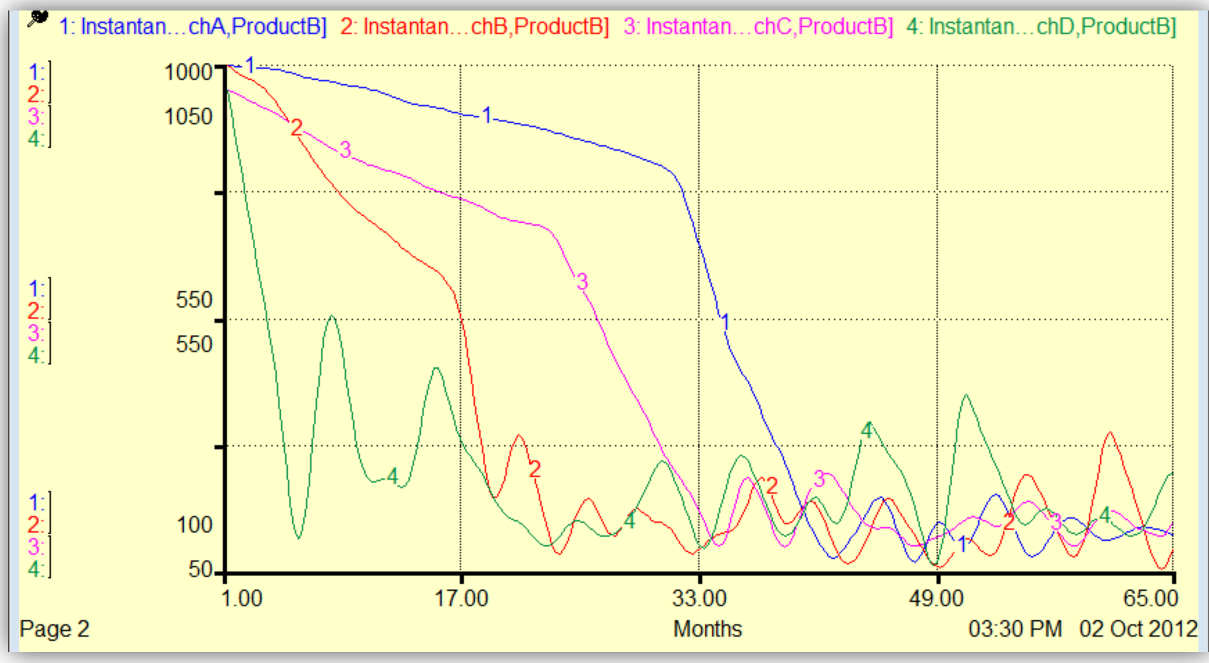

Figure 12: Instantaneous inventory of product B

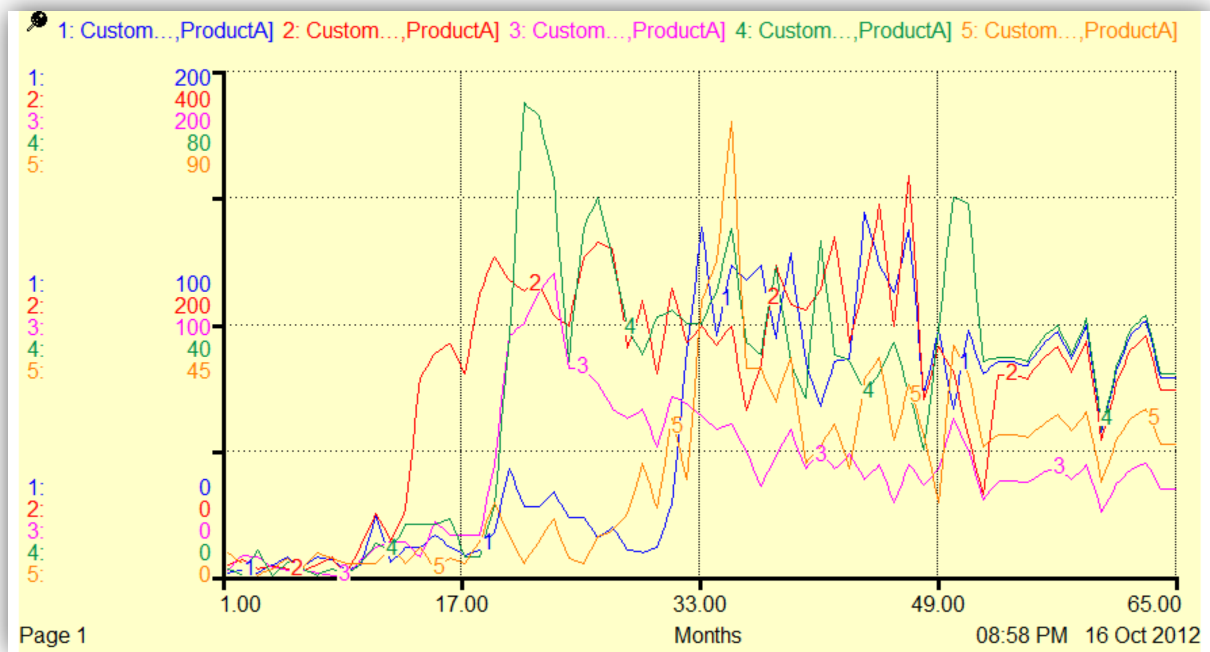

Figure 13: Customer demand of product A in all Branches

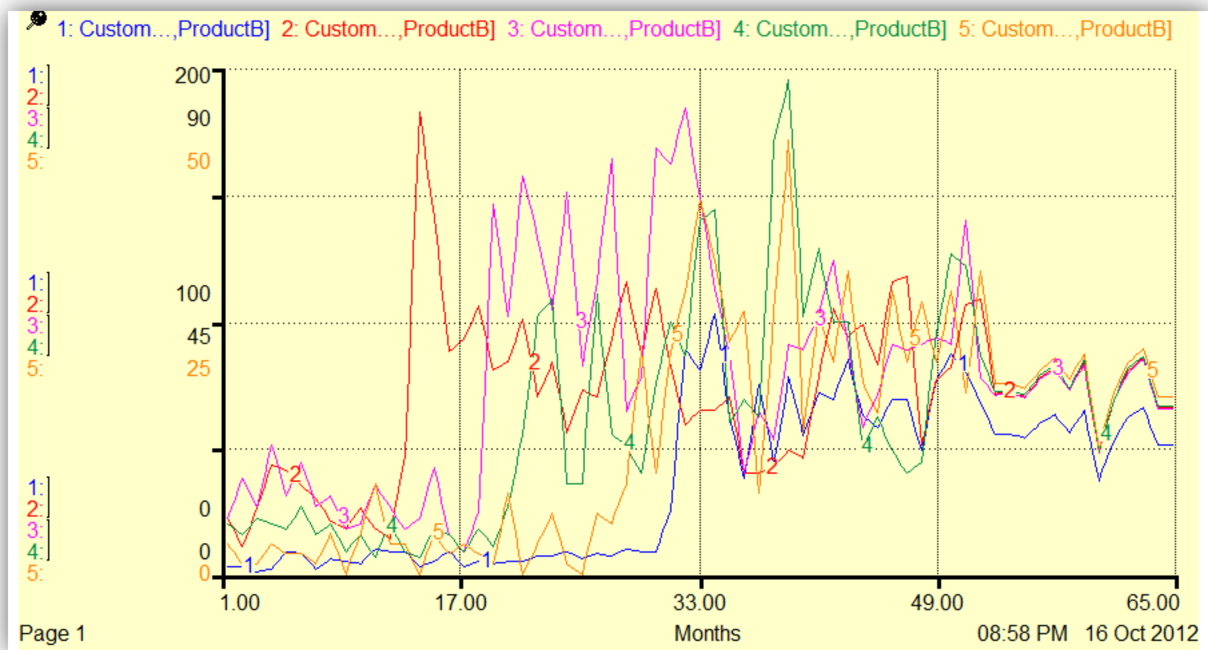

Figure 14: Customer demand of product B of Branches

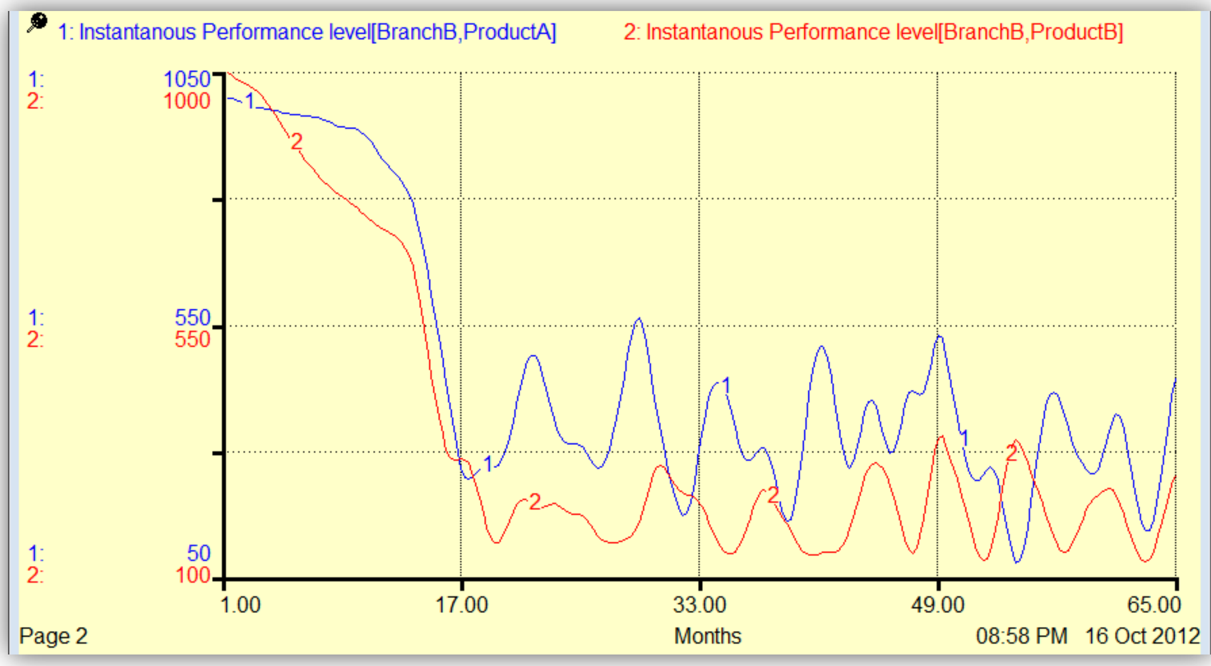

Figure 15: Instantaneous performance level of the Branch B

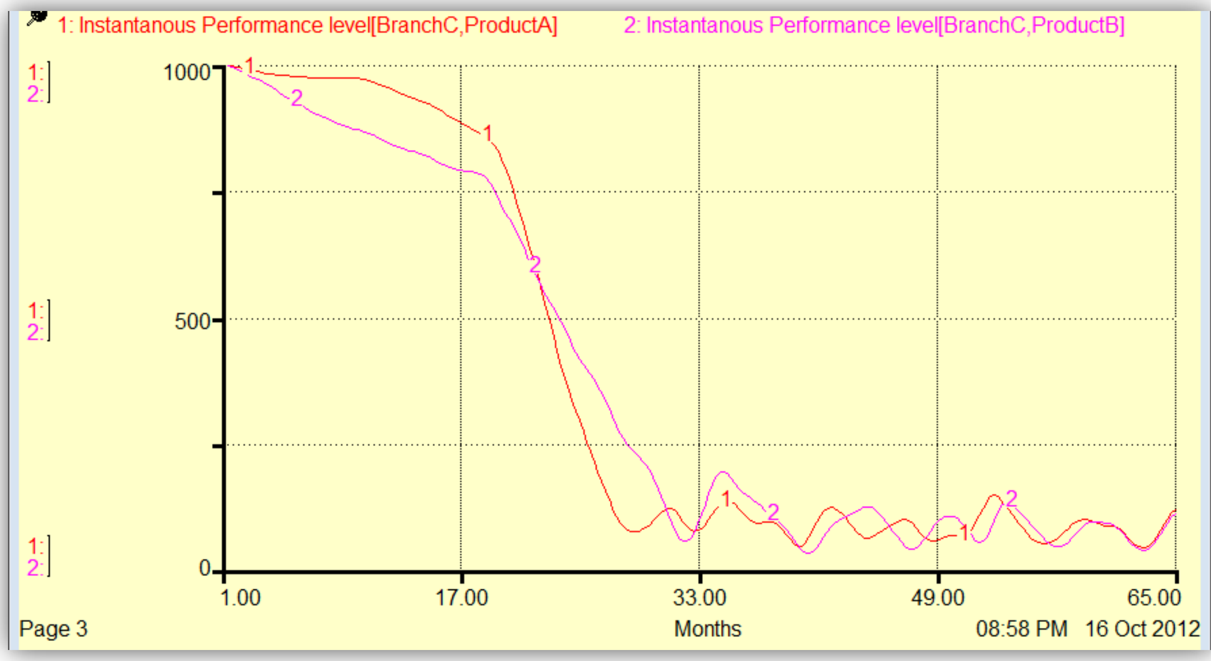

Figure 16: Instantaneous performance level of the Branch C

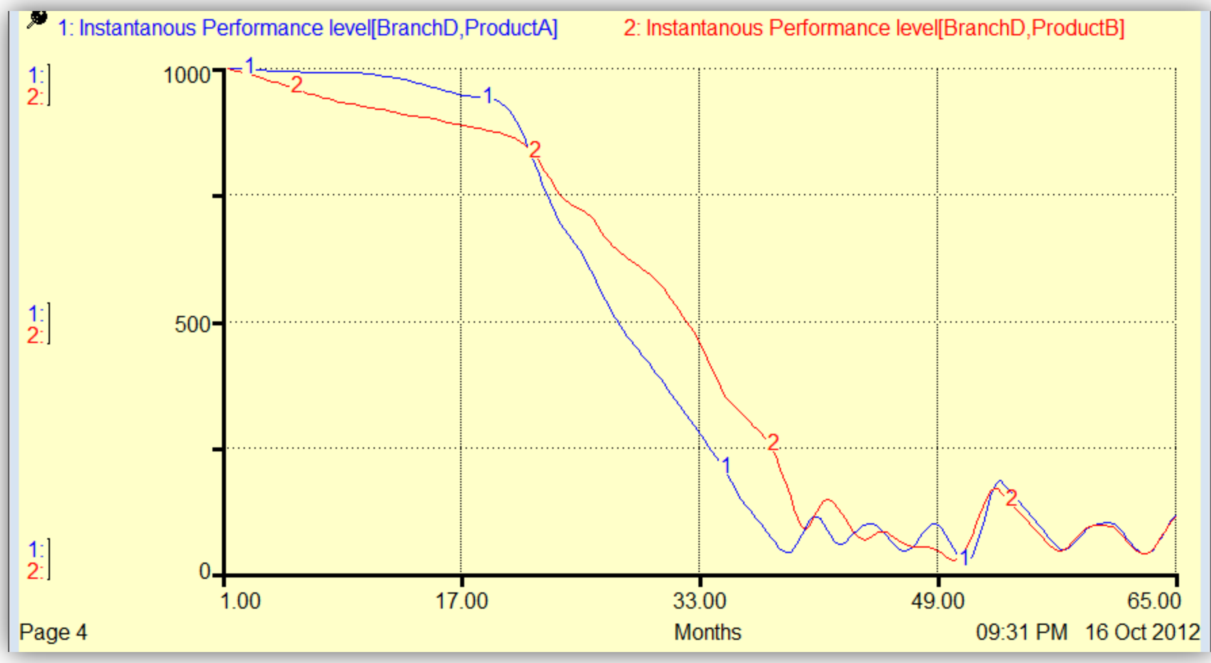

Figure 17: Instantaneous performance level of the Branch D

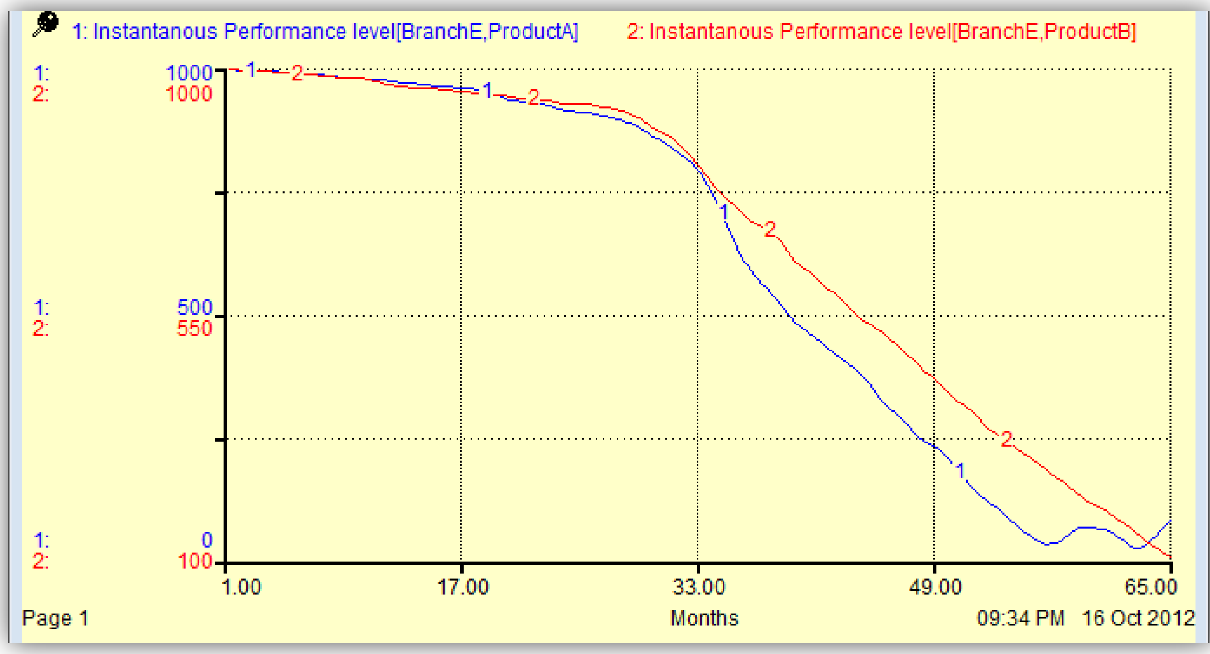

Figure 18: Instantaneous performance level of the Branch E

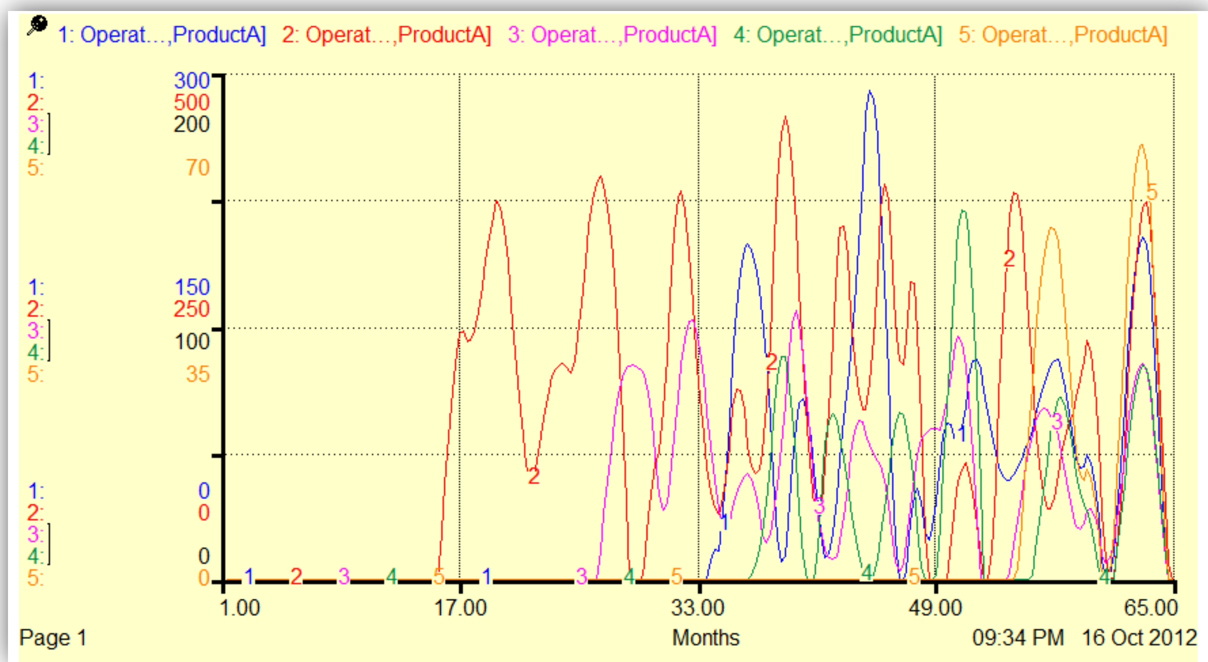

Figure 19: Operations rate of the product A

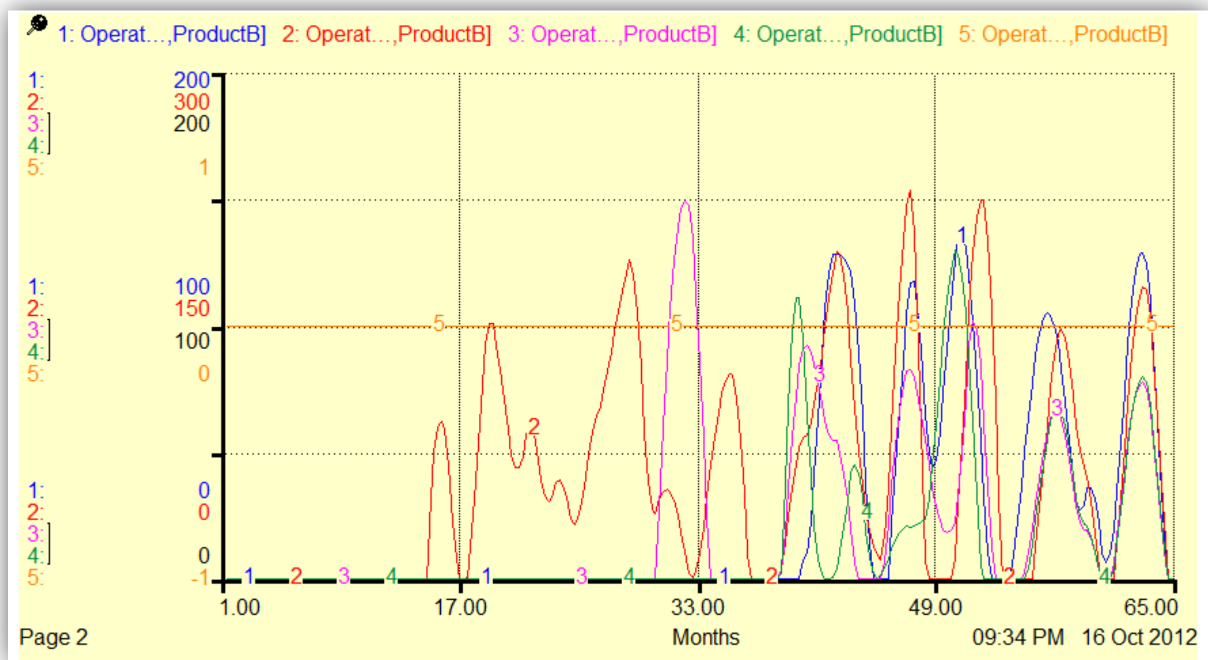

Figure 20: Operations rate of the product B