Acquisition Policy Design; An Application of System Dynamics for a Heavy Equipment Dealer in Southeast Asia

Tooraj Moradi Pour

In partial fulfillment of

Master of Philosophy in System Dynamics

Department of Geography

University of Bergen

Spring 2012

Acknowledgement:

I sincerely appreciate the instruction that I received from Professor Pål Davidsen and Professor Kim Warren. With their wise comments and instruction, they helped me enormously to make my ideas clear.

Special thanks to Mr. Kiwi Aliwarga, for his interest in system dynamics and his support to young students like me. Without his support, it was impossible for me to finish this thesis.

In addition, I like to thank Arnanda Arfi, Ariel Nan Gani and Nyein Nyein San for helping me gathering data for the model.

My special regards goes to my parents and my dear friends, especially Mohsen who made it possible for me to travel to write this thesis. as well, I like to thank Iselin for helping me clearing my mind and focusing on my thesis.

Thanks to all the people in Myanmar who make my residence in their country unforgettable.

Table of Contents

Abstract:

In this paper, a system dynamic model is developed to design a robust policy for heavy equipment acquisition, to improve the performance of the company by preventing the company from facing low liquidity while utilizing its capacity to grow. The performance of the company depends on the resources that the company uses such as the salesmen, the customers, the inventory and the cash level. A system dynamic model is built based on these resources in order to simulate the performance of the company. By running the Simulation model of the company under various scenarios, the management of the company can prepare itself to face possible changes in government regulations. Based on the model, an interactive learning environment has been developed to enable managers to observe the consequences of their decisions on the performance of the company.

Chapter 1: Problem Definition

1-1. Introduction

Supply chain management is the study of the transition and process of a product from early stages of production until it reaches the very end user of the product. In other words, supply chain management is the management of a network of interconnected businesses involved in the provision of product and service packages required at the end customers in a supply chain (Harland, 1996). Supply chain, in its common form, starts with the factory, which manufactures the product. Later the product transfers to the whole seller, which sells the product to the retailers. In this example, retailers constitute the latest step in the supply chain who delivers the product to the customers. In some cases, the supply chain continues to the customers and the process of recycling the product to a new one. Figure 1.1 shows the structure of an example of a supply chain. The management of a supply chain addresses a variety of problems, such as choosing the network of businesses to achieve the lowest possible cost or the channels in which they can transfer and share vital information through the chain. One of the problems that supply chain management should address is Inventory management.

In a literal sense, inventory refers to stocks of any phusical material required to run a business. These stocks represent a big share of the business investment and must be managed well to secure and increase the profit. In supply chain management, inventory refers to the stock of finished product ready to be delivered to the next stage in the supply chain. Any inventory represents money tied up to the products stored in the inventory, until the product leaves the inventory as sold product. As a result, good management of the inventory will reduce the costs of the company by reducing the money locked in the inventory and thus increasing the liquidity of the company. Inventory management becomes more crucial for companies involved with the expensive products such as heavy equipment.

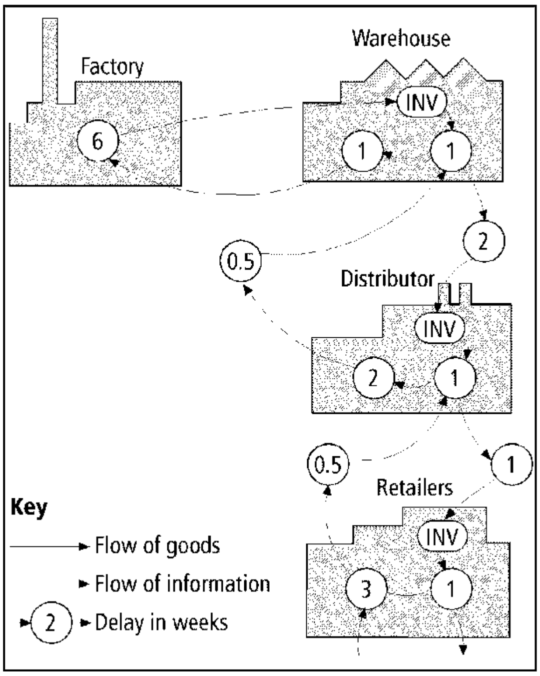


Figure 1.1: Supply chain model by Jay Forrester. Source: Forrester (1961)

Heavy equipment, also known as construction equipment or heavy machinery, refers to machines used to construct heavy-duty vehicles, usually ones involving earthwork operations. There are various types of heavy equipment with different functionalities, suitable for different tasks. Heavy equipment is needed in many industries such as construction, roads and mining. The cost of heavy equipment depends on the type of the equipment and the size of it. This thesis focuses on the inventory management for a heavy equipment dealer, ACE, in Southeast Asia.

Southeast Asia is a region in Asia, roughly consisting of the countries that are geographically south of China, east of India, west of New Guinea and north of Australia. Cambodia, Laos, Burma (Myanmar), Thailand, Vietnam, Malaysia and Indonesia are the largest countries in this region. Geologically, one of the most volcanically active regions in the world, the Malay Archipelago, is located in this region.[1] Volcanic terrain made this region one of the best regions for mining. As a result, there is a major demand for heavy equipment especially the ones designed for

[1] According to the CIA World Factbook

mining operations. Most of the countries in Southeast Asia are located very close to the equator. As a result, these countries are tropical with two seasons, a dry and a rainy seasons. The special climate of tropical countries limits the time that mining and construction companies can operate.

ACE, is a dealer of heavy equipment, which distributes, provides service and remanufactures heavy equipment in the region. Whenever the term, the company, is used in this thesis, it refers to ACE. ACE purchase heavy equipment from one of the leading brands of heavy equipment, originally located in Scandinavia. We refer to the manufacturer of the heavy equipment as the principle. The principle has many factories all over the world, and one located in Southeast Asia. The supply chain for heavy equipment in Southeast Asia starts with the manufacturer in the region, which it is referred to in this thesis as the principle. The next step in the supply chain is the dealer, ACE, and the customer is the last stage of the supply chain.

ACE, as the leading distributer of heavy equipment, in its country has lately experienced rapid growth. In less than 10 years, ACE achieved the highest market share in its country. ACE, has, as its strategy, to maintaining all of its customer, and not to lose a single customer.

1-2. Dynamic problem

While during 2010, ACE experienced an enormous growth in sales of 100%, by the end of 2011, this company faced low liquidity. In order to solve the financial problem, ACE tried to find the reason behind the low level of cash, and what solution might help the company. Managers at ACE also mentioned that the level of Inventory is rising. Figure 1.2 shows the Inventory level for ACE from 2010 to 2011. The Inventory level in figure 1.2 is based on the data of the inventory level for the most common type of excavator sold by ACE.

A high amount of inventory for ACE causes pressure on the amount of cash accessible for the company. Pressure on cash reduces the liquidity of the company, forcing the company to tighten its customers' terms of payment, which causes the rival companies to become more attractive for the customers. In extreme cases, low liquidity may delay payments to the principal company and damaging the relationship between the dealer and principal.

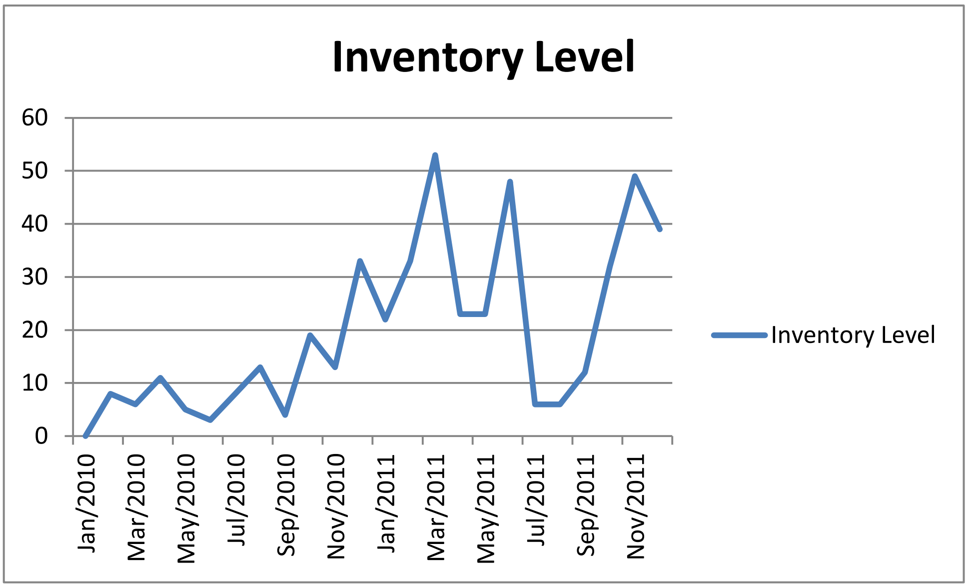


Figure 1.2: The inventory of heavy equipment 2010-2011

In this paper, we apply the resource based view. (Wenefelt 1984; Peteraf 1993). According to this view the performance of the company depends on the resources that a company acquires and the interaction between its various resources. The most important performance indicator of any business unit is generating a larger future cash flow. A policy should not increase short time performance at the cost of long-term cash flow (Forrester, 1991). Mining, construction and roads companies are the main customers of heavy equipment from ACE. Located near the equator, mining companies are able to operate only during the dry season, around half of the year. On the supply side of the heavy equipment, ACE issue purchase orders to the principal company. The orders are executed, and the merchandise arrives after 4 months. The long transition time is caused by long distance between the manufacturer and ACE. When unwilling to wait for such a long delivery time, customers of heavy equipment purchase their required equipment from rival companies. This will cause a reduction in the future cash flow of the company, - the main performance indicator of the company.

Another important factor affecting the future performance of the company is caused by external conditions, over which ACE has no control. The most important of these factors is the government regulations. In the country where ACE is operating, the government controls a large fraction of the economy and changes the regulations frequently. In order to identify a robust policy, various policies is tested under a variety of scenarios, based on possible changes in government regulation.

In order to address the problem of high inventory, we developed a system dynamics model to enable us design a robust policy for this problem. The system dynamic model has following sectors: Salesperson, Customers, Inventory and Cash. Each sector explains the dynamics of an important resource for the company. In chapter two, the big picture of the structure of the company, which shows the interaction between different resources, is presented. Then the dynamics of each sector will be discussed briefly. Subsequently, various policies are addressed by reporting on the results of running the simulation model, governed by these policies, under different scenarios. Then there is a final section is dedicated to conclusion.

1-3. Methodology

System dynamics is a computer-aided approach for analyzing and solving complex problems with a focus on policy analysis and design. The problems addressed by system dynamics are based on the premise that the structure of a system, that is, the way essential system components are connected, generates its behavior (Sterman, 2000). When a problem arises from the feedback within the system, it is important to understand the structure of the system. Understanding the system enables us to simulate the system, using computer programs, so as to reproduce the problem behavior. According to Jay Forrester, this kind of tool is necessary because, while people are good at observing the local structure of a system, they are not good at predicting how complex, interdependent systems will behave. (Forrester 1994)

'System Dynamics', initially known as industrial dynamics, was first developed by Jay Forrester at the Massachusetts Institute of Technology. Originating from control theory and engineering, the System Dynamics approach is based on the recognition of accumulation processes (delays), information feedback and non-linear relationships as the source of many of the problems we tend to face. Forrester (1961) describes Industrial dynamics as "… *the study of the information feedback characteristics of industrial activity too show how organizational structure, amplification (in policies), and time delays (in decision and actions) interact to influence the success of the enterprise. It treats the interactions between the flows of information, money, orders, materials, personnel, and capital equipment in a company, an industry, or a national economy*".

Lane (1998) summarizes Forrester's method to address management problems as "… *social systems should be modeled as flow rates and accumulations linked by information feedback loops involving delays and nonlinear relationships. Computer simulation is then the means of inferring the time evolutionary dynamics endogenously created by such system structures. The purpose is to learn about their modes of behavior and to design policies which improve performance*".

Social systems typically originate from a synergy of relationships. According to Vennix (1996), as it is not possible to identify an analytical solution to most non-linear models (differential equation systems), Forrester choose an experimental, numerical, approach based on simulation.

Human mind is usually incapable of calculating the behavior of complex systems. As a result, intuition based policies tend to fail, and the behavior of many complex systems are often deemed counter intuitive. Counter intuitive systems tend to resist intuitively designed policies. System dynamics models enable us to assess the behavior of the system resulting from policies we design under various scenarios. In this thesis we deemed system dynamics a suitable methodology precisely for the purpose of designing and assessing the effects and robustness's of policy alternatives for ACE,.

For this thesis, a System dynamic model of the supply chain is developed based on physical processes of the company and interviews with the managers of the company. The supply chain does not include decision rules for ordering of the equipment. An interactive game has been developed and presented to the managers of the company to allow them understand the effects of their decision rules (i.e. policies).

The parameters of the variables are estimated based on the data from ACE and from interviews with its managers.

1-4. Research review

A wide range of problems has been addressed using system dynamics, such as; corporate planning and policy design (Forrester 1961; Lyneis 1980), economic behavior (Sterman et al. 1983), public management and policy (Homer and St Clair 1991), theory development in the natural and social sciences(Dill 1997), biological and medical modeling (Hansen and Bie 1987), Energy and Environment (Ford and Lorber 1997), Strategic dynamics(Warren 2002), and supply chain management (Towill1996a; Barlas and Aksogan 1997; Akkermans et al. 1999).

The root of using system dynamics modeling for supply chain management lies in Industrial dynamics (Forrester 1958, 1961). Forrester, in his production-distribution model, used six interacting flows of information, materials, orders, money, labor, and capital equipment. Using his model, Forrester describes, analyses, and explains issues around supply chain management. Many recent research issues, such as demand amplification, inventory oscillations, de-centralized control or the impact of the use of information technology was pointed out by Forrester in 1961. Forrester essentially viewed a supply chain as part of an industrial system.

Recent research in supply chain management by way of system dynamics is divided into three groups; (1) research concerned with contributing to theory building; (2) research using system dynamics modeling for problem solving; and (3) research work on improving the modeling approach (Angerhofer and Angelidas 2000). Research in problem solving addresses various topics in supply chain management. There is researches conducted in the field of inventory management, demand amplification, supply chain re-engineering, and supply chain design.

In the field of inventory management, Barlas and Aksogan(1997) use a case study in apparel supply chain. They use a physical structure of the system governed by an ordering decision rules. They used the data from a cloth manufacturer for parameter estimation. For some certain algorithms, they used a ‘C program’ to perform the calculations. Data collection was done in form of interviews with managers in different departments and stages of the supply chain. Then, they validated the model using data from the apparel case study, following a traditional SD modeling approach (Richardson and Pugh 1981). Subsequently they tested different ordering and production policies under various scenarios for inventory level and demand patterns. Barlas and Aksogan (1997) found out that order policies as used in continuous systems are not adequate for partially discrete, partially continuous inventory systems. The outcome of the modeling efforts then lead to the proposition of new ordering policie that are robust in terms of fluctuations in demand for such inventory systems. (Angerhofer and Angelidas 2000)

Chapter 2: Dynamic hypothesis

In this chapter, we discuss the structure of the model. The structure of the model embodies the hypothesis for this thesis. In this chapter, the big picture of the model is first presented. This shows how different sectors of the model interact with each other, while each sector represents an important resource for the company. Subsequently, more detailed information about each sector and the structure of each sector is provided. The model is built with coding names for different sectors. There are also color codes for easier understanding of the model. A guideline for the naming and color codes, used in the model is presented in Appendix 1. The full list of equations for every variable, which is used in the model, is available in Appendix 2.

2-1. The Big Picture

In order to sell construction equipment, ACE needs to employ salespersons. A salesperson's duty is to visit current customers and receive their inquiries. Of the other task of a salesperson is to discover new customers and persuade them to buy from ACE. Any salesperson have limited time to visit customers and, based on their skill level, needs a certain amount of time for each customer. Therefore, the number of Salesperson at any given time affects the performance of ACE by limiting the number of customers who buy from ACE. The sales staff is one important resource for ACE, which affect the performance of the company. The number of salespersons can increase by recruiting new ones. The sales staff may drain out because of salespersons that retire or resign from ACE.

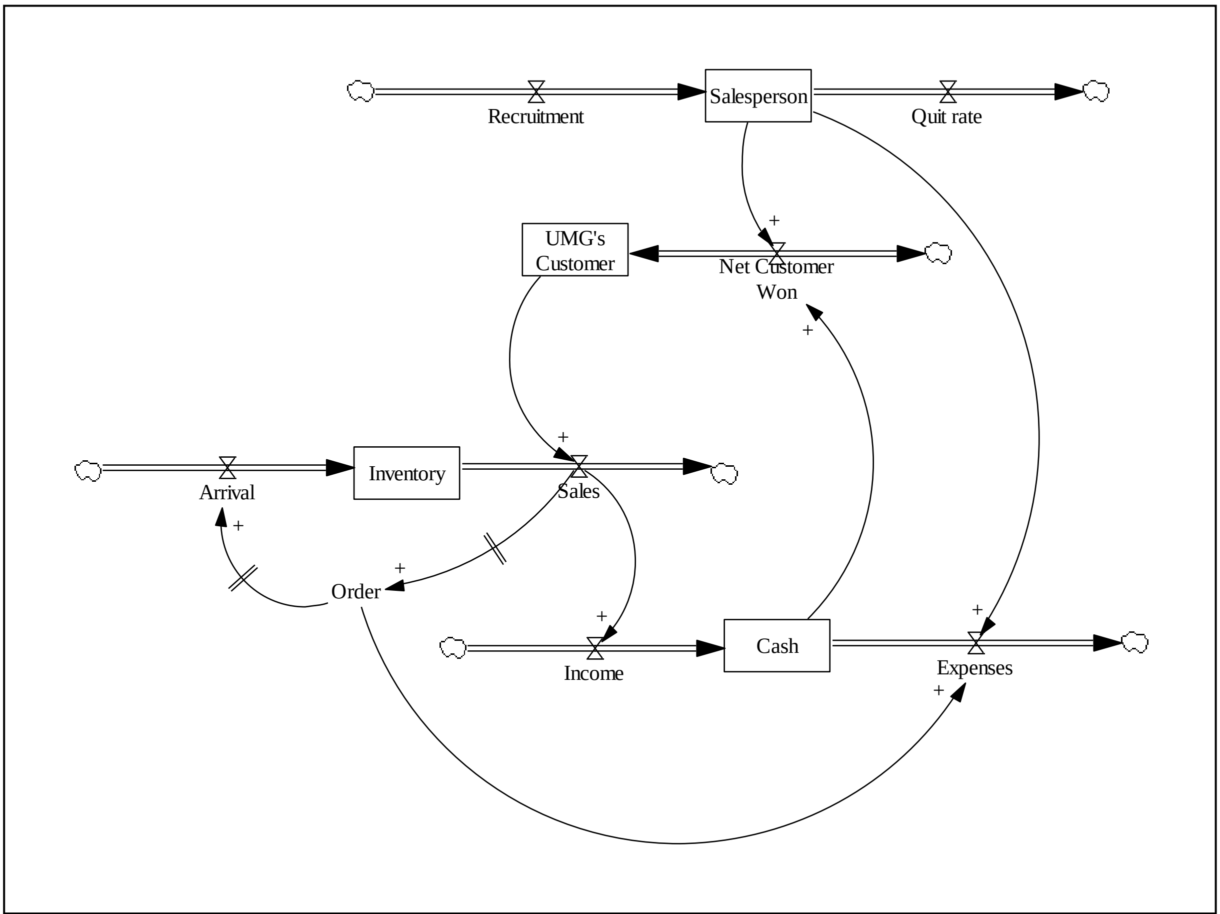
A second resource, which affects the performance of ACE, is the number of customers who purchase from ACE. These are companies operating in Myanmar, which need heavy equipment and construction equipment for their operations. Mining, construction, road building and energy companies are examples of the companies who need this kind of equipment. Among the total number of companies who need these products, some of them are purchasing their required products from ACE, while others purchase from ACE rivals. There are also companies who purchase both from ACE and its rivals, that are called shared customers in this paper. ACE customers and a fraction of shared customers submit inquiries for heavy equipment. The inquiries drive ACE's sales, which will form the revenue of ACE from selling of heavy equipment.

ACE is unable to influence their customers base directly. However, ACE can absorb more customers by increasing its salesmen or by providing more attractive terms of payment. Managers can also influence the number of ACE customers by reducing the delivery time. ACE can also lose customers if rival companies act better in these areas so as to absorb customers.

The third sector of the model addresses the inventory on ACE. Based on Sales in previous years and forecast of the future, ACE managers' order the number of units they want to principal company. These orders should be submitted at the beginning of each year for the coming year. Based on the orders that the principal company receives from ACE and its other customer in the region, the principal company plans its production for the next year. Two times per month, the principal company ships units of heavy equipment to ACE. On average, shipments for ACE arrive two months after the principal company sends them. Upon arrival, ACE distributes the units to its customers. If ACE has units of heavy equipment in its inventory, it can distribute it to the customers as soon as they receive the inquiry. When there is no equipment in the inventory, ACE can't deliver equipment to the customers and has to wait for future orders to principle to arrive. Upon arrival of equipment ACE will allocate them to the customers. In this case, customers have to wait for some time until they can receive their machines, - increasing the delivery time. Facing a longer delivery time, some customers may decide to buy from rival companies of ACE, causing a reduction in ACE inquiries and possibly the loss of a customer.

As mentioned, the inventory resource increases by an inflow of unit arrivals from the principal and reduce by an outflow of sales in each period. The last sector of the model addresses the cash stock of ACE and financial structure of the company. The future cash flow is the main indicator of the company's performance. Managers of ACE try to maximize this stock by their decisions. If the company has enough cash, it can provide attractive terms of payment for its customers, allowing them to purchase the units of heavy equipment and pay for them in the future. It can attract customers to ACE, as many customers need the heavy equipment to start their operation and generate revenues. ACE also needs cash to pay to the principal company in order to receive heavy equipment.

The stock of cash increases by the inflow of income. The income consists of cash collected from current cash sales, down payment of credit sales and cash collected from the debt of customers for customer's previous purchases. The stock of cash is drained by the outflow of expanses. Payment to the principal company and wages are the main factors determining the expenses of ACE. Figure 2.1 shows the interaction



between different resources that ACE needs in order to run its business.

Figure 2.1: The interaction between different resources of ACE

2-2. Marketing and sales sector

As mentioned earlier, the first resource that a distributer of heavy equipment requires to sell units is salesmen. Salesmen links company to customers. Salesmen generate sales for the company by visiting the customers to present company products. On the other hand, they bring the feedback of the customers, in the form of orders and information, to the company.

In ACE, sales force is divided into three different categories; trainee salesmen, junior salesmen and senior salesmen. Figure 2.2 shows the basic structure of this three salesmen segments. In this paper, the sales force is represented by a stock, shown as a rectangle in the model. As shown in the picture below, Trainee salesmen can evolve into junior salesmen and, subsequently, on into senior salesmen.

The stock of senior salesmen will increase by its inflow, the number of recruitment in each month. In this model the recruitment is assumed to be exogenousand with constant value of three persons per year. The value for recruitment is based on the information received from the interviews with the management of the company. For further development, a policy structure can be added to the model, in order to indicate a robust policy for recruitment.

The newly recruited salesmen have to spend some time in order to get trained and acquire the basic skills they require to perform well as a sales force. Upon finishing the training period, not all of the trainee salesmen want to continue working in ACE as a sales force. Some of them fail to pass the training successfully and some realize that being a salesman is not suitable with their personalities. As a result, from the stock of trainee salesmen there will two different outflows, one is, m_SalesmanTraining, which is salesmen advancing to junior salesmen and start operating as a sales force in ACE company, and the other will be m_TraineeReasingment, which is the salesmen who resign or quite from being a trainee sales force. The equation for m_Salesmatraining is:

$$m_{salesmantraining} = m_{TraineeSalesman} * \frac{(1 - m_{FractionTraineeReassignment})}{m_{tsalestraining}}$$

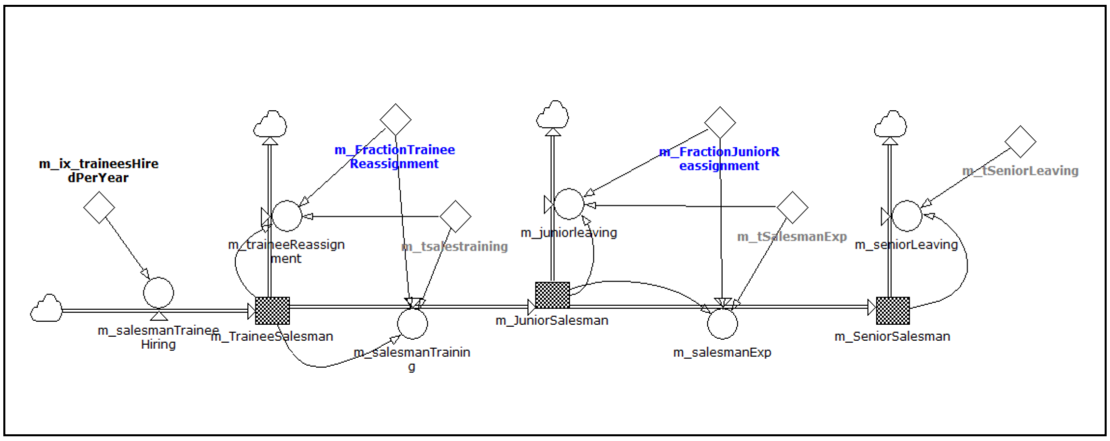


Figure 2.2: The segmentation of Salesmen in ACE

In above equation, m_fractionTraineeReassignment is the fraction of trainee salesmen who cannot proceed into becoming a junior salesmen and after the training period they have to leave the company. In this model, the value for this fraction is assumed to be constant and equal to 0.20, meaning that 1 out of every 5 trainee salesmen would leave the company M_tSalestraining is the average time that the training period will last, which is 12 months for ACE. The equation above expresses that, during each month, one out of twelfth of the trainee salesmen will leave this stock. One out of every five trainee salesmen who leaves this stock fails to become a junior salesman and have to leave the company and the rest will become junior salesmen.

Upon finishing the training period, a trainee salesman promotes to a junior salesman. Junior sales force resource is represented by the m_Juniorsalesman stock in the model. The Junior salesmen start to operate as sales force and generate sales for the company. As mentioned earlier the inflow to the Junior salesmen stock is the outflow from the trainee salesmen. The stock of junior salesmen has two outflows, through which the salesmen drain from this stock. Through the first outflow, the junior salesmen gain experience in the company, their efficiency increases and they become senior salesmen. The rate at which junior salesmen become experienced, is shown by the flow, m_salesmanExp in the model.

Not all of the salesmen continue working in the company until they become senior salesmen. Through the second outflow from the stock of junior salesmen, junior salesmen quit and resign from the company. The later rate, at which junior salesmen quit working for ACE is represented by the flow m_juniorleaving in the model. The equations for these two rates are as follows:

$$m_{SalesmanExp} = m_{JuniorSalesman} * \frac{\left(1 - m_{FractionJuniorReassignment}\right)}{m_{tSalesmanExp}}$$

$$m_{juniorleaving} = m_{JuniorSalesman} * \frac{m_{FractionJuniorReassignment}}{m_{tSalesmanExp}}$$

In above equations m_fractionJuniorreassignment is the fraction of the salesmen who leave the company as a junior salesmen. The value for this variable is 0.2, which means after two years, four out of any five junior salesmen will become senior salesmen and one of them will quit working as a salesman. The constant variable m_tsalesmanExp is the average time required for the salesmen to gain experience with the value of twenty four months for this variable

The Senior salesmen are the most valuable sales force for ACE. These salesmen are the most efficient sales force and it take many years for the company to replace one of them. This resource is represented by the stock of m_Seniorsalesman in the model. Stock of m_seniorsalesman increases by the rate at which junior salesmen gain experience and become senior salesmen and decreases by the rate at which salesmen quit or resign from the company. The inflow for this stock, m_SalesmanExp, is discussed earlier in the discussion of the junior salesmen resource. m_SeniorLeaving is the outflow from the senior salesmen resource, showing the rate at which sales force leave from ACE. The value of this variable depends on the number of senior salesmen, currently working for the company and the average time that a senior salesmen work for ACE. After calculating the number of salesmen who are working at any point of time, it is possible to estimate the number of customers, who are in contact with the company.

In order to calculate the number of customers who remain as ACE customer, first it is necessary to know how many customers can be visited frequently by the sales force In other words, what will be the potential number of customers with any given number of salesmen? In this thesis we refer to this potential number calculated based on the number of salesmen as reference number of customers. To know the reference number of customers, first we have to calculate how many customers can be visited by each salesman.

Each junior salesman can pay frothy visits to the customers during each month, while this number is sixty visits per month for each senior salesman. The sales force should visit each customer two times per month in order to collect the cutomer's inquiries. By dividing the reference number of visits per salesman to the reference number of visits required by each customer, it is possible to calculate the the reference number of customers per each salesman, shown as m_refNoCustomersPerJrSalesman and *refNoCustomersPerSrSalesman* for the junior and the senior salesmen. It is now possible to calculate how many customers can be visited each month by ACE's salesmen by knowing the number of customers that each salesman can pay visit to and the number of the salesmen,. In order to do so, first we have to multiply the number of salesmen and their corresponding reference number of customers that they can visit. Consequently the total reference number of customer that junior and senior salesmen can visit in each month is equal to the following:

$$m_{RefNoCustomersFromJrSalesman} = m_{JuniorSalesman} * m_{RefNoCustomersPerJrSalesman}$$

$$m_{RefNoCustomersFromSrSalesman} = m_{SeniorSalesman} * m_{RefNoCustomersPerSrSalesman}$$

We can know the reference number of customers for ACE by adding up the reference number of junior and senior salesmen,. After calculating the reference number of customers for ACE, the next step is to compare the reference number of customers with the actual number of ACE's customers. This ratio is shown by m_ratioOfActualToRefNoCustomers and the equation for this ratio is shown below:

$$m_{ratioOfActualToRefNoCustomers} = \frac{C_{WinTotalCustomer}}{m_{RefNoCustomer}}$$

his ratio is used to calculate two different effects. The first effect of the ratio of the actual to reference number of customers is on the number of visits to competitors customers. If the ratio is less than one, it means that the company has less customers than what it can potentially have and as a result, it's salesmen have excess time and can search for some sale contract among the competitors customers. In extreme conditions, when the ratio of actual to reference number of customers is zero then the salesmen can use all their time to visit the competitor's customers, while when the ratio is equal to one or more than one, then the salesmen don't have any time to visit the competitor's customers. This effect is modeled, using a graph function, shown in Figure 2.3. Now, it is possible to calculate the number of visits the salesmen can do to the competitor's customers. In chapter 2.3 the customer segmentation and their interaction is explained, where the effect on the competitors visits is used.

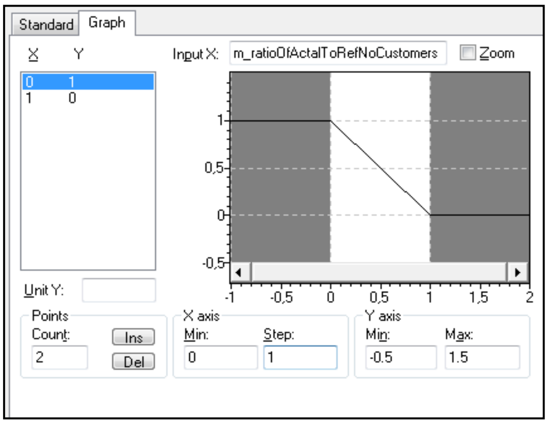


Figure 2.3: Effect of ratio of actual to reference number of customers on visit to competitors customers

The second effect of the ratio of actual to reference number of customers is on the quality of the salesmen's relationship with the customers. When the actual to reference number of customers is greater than one, it shows that the company has more customers than the number of customers the salesmen can visit efficiently. As a result, when company has more customers than its reference number of customers, the salesmen are unable to pay visits to all the customers, and it will consequently damage the relationship between some of the customers and the salesmen. The salesmen relationship with a customer is an intangible variable which means in it's nature it doesn't have any value. In order to quantify this variable we assume that the relationship between the salesmen and the customers will get valuesbetween zero and one. Later on in section 2.3 when customer's behaviors are studied, this value will be used to show why we lost some customers. In order to understand how the number of customers and salesmen affect their relationship, the ration of actual to reference number of customers is used. F The efficiency of the salesmen in building up relationship with the customers is calculated. The formula for this efficiency is shown below:

$$m_{SalesmanRelationshipEfficency} = \frac{1}{m_{ratioOfActalToRefNoCustomers}}$$

This equation states that, when the number of customers increases, the salesmen will have less time to spend on each customer and thus their efficiency to building up relationships decreases. The efficiency of the salesmen relationship has an effect on salesmen relationship with the customers, such that when the efficiency to build relationship increases then the relationship improves and when the efficiency to build relationship decreases,the relationship with the customers decreases. Figure 2.4 shows the graph function used to model this effect.

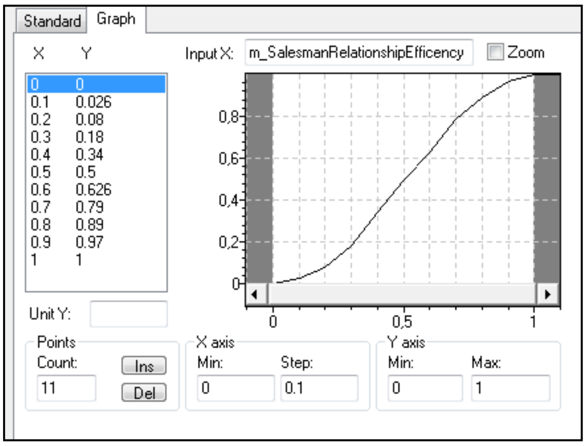


Figure 2.4: Effect of thesalesmegn relationship efficiency on indicated relationship with customers

After a sudden change in the number of customers or salesmen does not change the relationship between salesmen and customer immediately. It takes some time for the customers to change their opinion about the company’s salesmen. This gap in time between the cause and effect is known as time delays in System Dynamic’ literature. In order to model this time delay, a first order information delay with the average delay time of three months is used. The structure for this time delay is shown in Figure 2.5.

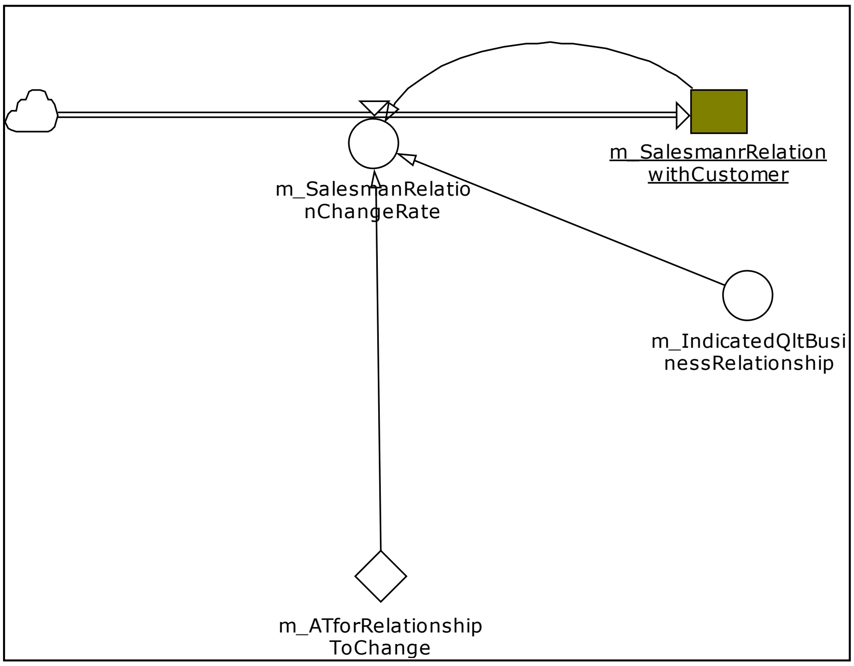


Figure 2.5: Information delay for the relationship with customers

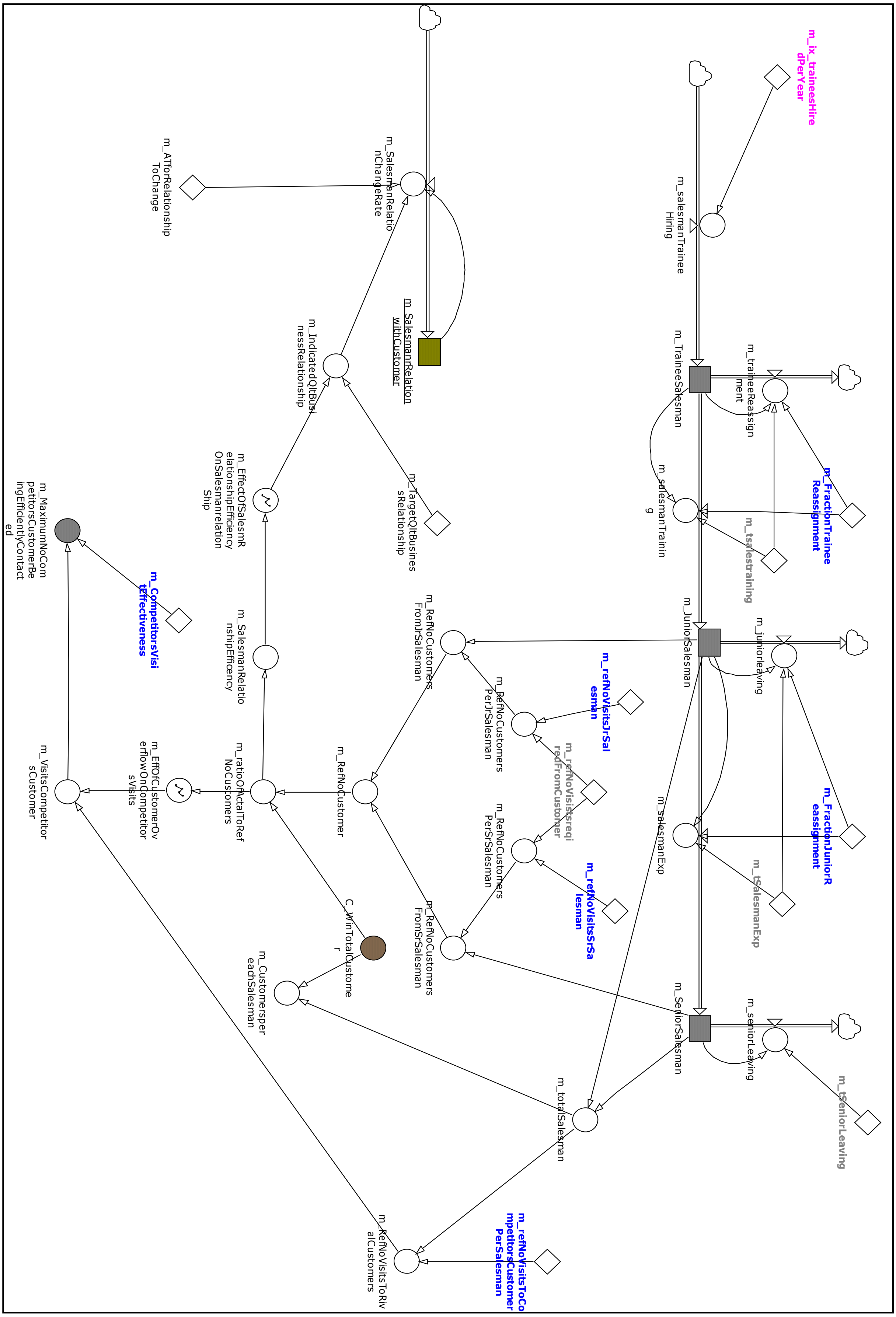


Figure 2.6: the structure of Marketing and Sales Sector

2-3. Customer sector

The purpose of this sector is to calculate the number of equipments that the customers demand from the company. This can be done by understanding how customers choose toward ACE and its competitors. In this sector, first the segmentation of customers is explained, later on, we study how the customers move from one group to another one, and at last, the company's demand is calculated.

In this paper, the customers are divided into three different groups; the company's customers, shared customers and the competitor's customers. By definition, if a customer only buys heavy equipment from ACE then we consider that customer as ACE's customer, while if the customer only purchase from competitor then we consider that customer as competitor's customer. There are also customers who buy from different suppliers, namely buying from ACE and competitors, which we consider them as shared customers. Any ACE's customer can become shared customer as soon as purchasing from competitors. Same can happen to competitor customer by purchasing from ACE. The segmentation of customers is visible in Figure 2.7. Later on there is a detailed information about the factors affecting the flows between different groups of customers.

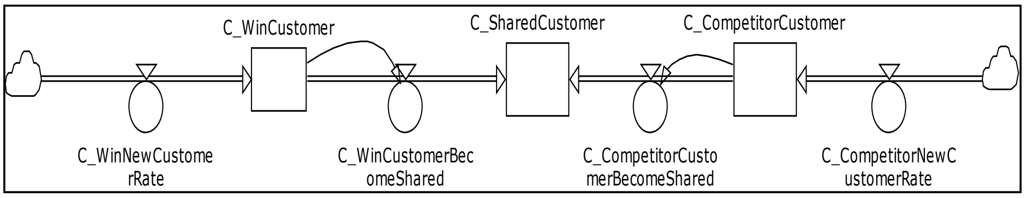


Figure 2.7: segmentation of customer's resources

When a customer wants to purchase heavy equipment, there are various factors affecting customer's choice,. To name a few, a customer considers the price, the quality of equipment, the service quality, etc.. These factors are different for different group of customers, for example a new customer do not have a clear knowledge about the service quality since it has not experience the service of equipment yet to access the quality of service. According to the managers of ACE, a list of factors affecting customer's choice were made. Table 2.1 provides the list of factors used in this thesis for three different group of customers.

The first set of effects, are the factors affecting the new customer's choice when they choose a dealer. When the new customers choose a company, they consider the price of the equipment, the coverage area of the the distributer and the delivery time . The coverage area is an important factor affecting the new customers choice as customers need to find a dealer active in the region that want to operate. . The second set of factors affectthe customerswho purchased from ACE. In addition to the factors for the new customers, these factors include terms of payment, relationship with salesmen and service quality. Finally the last set of effects for the competitor's customers include the following factors: price, terms of payment, coverage area and delivery time.

To calculate the effect of the price, first the price of equipment from ACE is compared to the price that the competitors offer, by dividing ACE's price to competitor's price. Later on this ratio is normalized by dividing it to its initial value. In next step, we used elasticity to calculate the effect of changes in price on customer's choice by calculating the price ratio into the power of its elasticity. This process is shown in Figure2.8. The equation of effect of price on acceptability of ACE for the new customers is shown below.

$$C_{EffectofPriceOnAcceptibility} = \left(\frac{C_{WinVsCompetitorPrice}}{C_{InitialWinvsCompetitorPrice}}\right)^{priceElasticity}$$

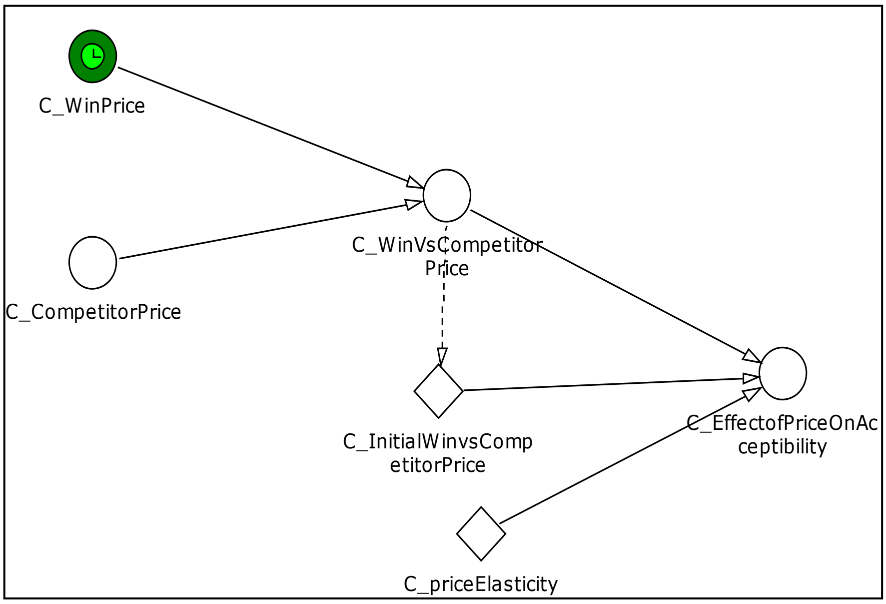


Figure 2.8: Structure of calculating the effect of Price on acceptability of ACE equipment

The same structure is used to calculate the other effects on acceptability of ACE. This way, the model calculates the changes in the choices of customers, based on the changes of important factors we for the customers. If any of the factors doesn't change during the simulation period it dosn't have any effect on the final choices of the customers. By modeling using elasticities , we can only simulate the changes in the customer's choice based on the changes of factors. For example when the price, does not change then the term C_WinVsCompetitorPrice/C_InitialWinvsCompetitorPrice remains with the value of one, and the effect will be one consequently. In contrary, when price of ACE increases more than competitor's price, C_WinVsCompetitorPrice/C_InitialWinvsCompetitorPrice will be greater than one, and will have a negative effect on customers. To have a negative effect on acceptability of ACE after an increase in the price, the elasticity for price should have a negative value to show the same behavior as expected. As a general rule, if an increase in a factor has negative effect on the final effect, like price and delivery time, the elasticity has a negative value. In contrary, if an increase in a factor has a positive effect on ACE's acceptibility, like service quality or coverage area, then the elasticity is positive. Table 2.1, shows the list of factors included in this model and their corresponding value for elasticity.

	New Customers	Current customers	Competitors customers	Elasticity
Win Price	X	X	X	-0,1
Area coverage	X	X	X	0,1
Estimated delivery Time	X	X	X	-0,1
Salesman relation ship		X		0,4
Terms of payment		X	X	0,3

Table 2.1: List of the factors affecting the acceptability of ACE and their corresponding elasticity's.

In order to aggregate various effects into a single effect, which will determine the customer's decision, first the product of the different factors is calculated. For instance, the overall acceptability for new customers is a product of three different effects. The formula for the overall effect on acceptability for the new customers is as follows:

$$C_{OverallEffectOnAcceptabilityOfWinForNewCustomers} = C_{EffectofAreaCoverageOnAcceptibility} * C_{EffectofPriceOnAcceptibility} * C_{EffectofWinDelivaryTimeOnAcceptibility}$$

The overall effect on the acceptability of company for a new customer, expresses the fractional change in the new customer's choice based on different factors. In order to calculate which percentage of new customers purchase from ACE we should use the following formula:

$$C_{SalesEffectivityForNewCustomers} = OverallEffectOnAcceptabilityOfWinForNewCustomers * InitialAcceptibilityForWinNewCustomers$$

By multiplying the initial value for the acceptability of the company and the fractional change in the effectiveness caused by different factors, which are important determinants of customer's choice, we can calculate the fraction of new customers who will purchase from the company in each period of time. By assumption, a fraction of the new customers buy all their needed heavy equipment from ACE, and the rest of them will purchase all their need from the competitors. This assumption is made because the new customers would rather to deal with only one company when they start their business. This way their mechanics and drivers need to learn only for one brand of heavy equipment. After knowing the fraction of the new customers who purchase from ACE, we need to know the number of the new customers who enter the market. The number of total new customers, who enters the market at each period, depends on various external factors. Identifying and modelling these external factors requires us to have detailed market analysis which is out of scope for this thesis. In this thesis, it is assumed that new customers join the market at a constant rate in each year, but it varies among different months. The reason for this assumption is that in Southeast Asia, as a region close to the equator, there is only two seasons, the rainy season and the dry season. During the rainy season, it is impossible for the mining companies to operate and during the dry season mining companies mine continuously. Based on the data of new customers for ACE, a seasonal effect on the new customers is produced. This seasonal effect expresses the fraction of the new customers who enter the market for different months. Figure 2.9 shows the seasonal effect for new customers. After multiplying this seasonal effect and the constant value for new customers who enter the market we will have access to the total new customers who enter the market. Now, we can calculate the rate at which new customers purchase from ACE and consequently enter ACE's resource of customers. This rate is shown by the flow, C_WinNewCustomerRate in the model. Figure 2.10 shows the structure explained for calculating new customer's inflow. With knowing the inflow to Ace's customer, it is easily possible to calculate the inflow to competitor's customers, as the rest of new customers who are not buying from ACE will obviously purchase from competitors. In the following, there is a explanation about the rate at which customers move to share customers resource from ACE customers and competitors customers.

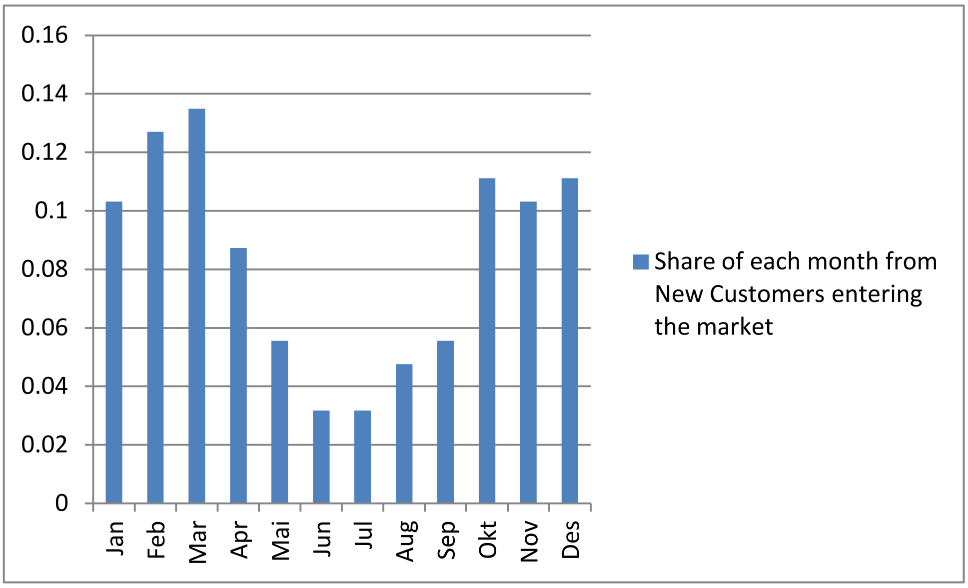


Figure 2.9: Seasonal effect for new customers

The next flow to calculate is the rate at which ACE customers start buying from the competitors and become shared customers. In order to formulate this rate, we use the same method as the one used to calculate ACE's share from new customers. As mentioned earlier, the only difference is that the current customers already experienced the quality of equipment from ACE, thus they are already in contact with the salesmen. As a result the set of factors affecting this rate is more broad. By multiplying the effects of all important factors, we wold know the overall effect on acceptability of the company for the current customers. As the acceptability for current customers increase, fewer customers want to change their dealer and purchase from competitors,thusthey rather to keep purchasing from ACE. For this reason, it is important to calculate the ineffectiveness of sales for current customers. When the sales conditions are ineffective the customers will not purchase from ACE and would rather to buy from the competitors. The formulation for sales ineffectiveness isas follows.

$$C_{SalesIneffectivnessForCurrentCustomers} = \frac{InitialAcceptibilityForCurrentCustomers}{C_{OverallEffectOnAcceptabilityForCurrentCustomers}}$$

After knowing the fraction of the customers not purchasing from the company, next step will be to calculate the rate at which customers move from the ACE customer stock to the shared customers. This rate is shown by the flow

C_WinCustomerBecomeShared, with the equation shown below. to know the value for this flow, the sales ineffectiveness calculated earlier needs to be multiplied by the number of customers that want to buy in each period of time and number of ACE customers. The number of customers who want to purchase in each period is assumed to be an exogenous variable.

$$C_{WinCustomerBecomeShared} = C_{WinCustomer} * C_{fractionOfCustomersHavingDemand} * C_{SalesIneffectivnessForCurrentCustomers}$$

Figure 2.10 shows the structure determining the rate at which ACE's customers move to shared customers stock.

The last rate to calculate is the rate at which the competitor's customers start buying from ACE. The way to calculate this flow is similar to those two flows mentioned earlier. The only difference is the set of affecting factors and possibility to visit competitor's customers. As mentioned in marketing sector, it is only possible to sell to competitor's customers if salesmen have time to visit them. The number of visits to competitor's customer is calculated in the marketing sector.

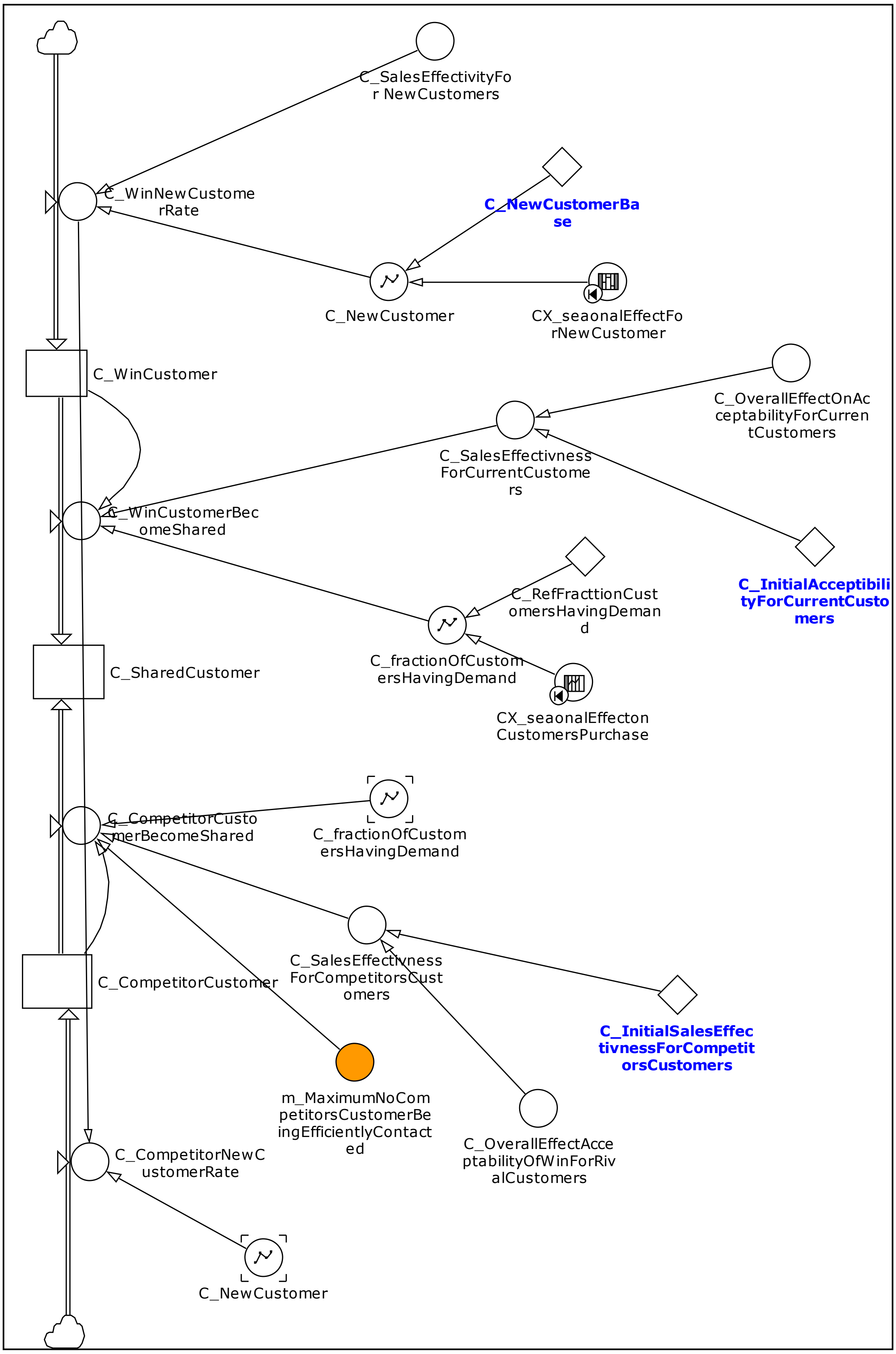


Figure 2.10: Structure of customers and their flows.

The inflow, C_CompetitorCustomerBecomeShared represents the rate at which the competitor's customers start buying from ACE with the following equation. The set of factors affecting the rate at which the competitor's customers start buying from ACE consist of price, coverage area, terms of payment and delivery time. The multiplication of these effects produces the sales effectiveness for the competitor's customers.

$$C_{CompetitorCustomerBecomeShared}$$
$$= MIN\left(m_{MaximumNoCompetitorsCustomerBeingEfficientlyContacted}, C_{CompetitorCustomer}\right)$$
$$* C_{fractionOfCustomersHavingDemand} * C_{SalesEffectivnessForCompetitorsCustomers}$$

After explaining the resource of customers, its segmentation and how different segments relate to each other, it is possible to calculate the demand for heavy equipment for the company. The total demand for the company will be equal to the sum of the demand from ACE's new customers and demand from current customers. The demand from new customers will be generated from the rate at which new customers enter the market and the average purchase from new customers. The demand from the current customers consists of two parts; the ACE's customers and the ACE's share from the shared customer. From the current customers only a fraction of them have demand in each month, which will produce the number of customers that have demand from the company. By knowing the average demand for each customer, it is possible to calculate the current demand for ACE, and consequently the total demand for ACE. Figure 2.11 shows the structure, at which model simulates the total demand for ACE.

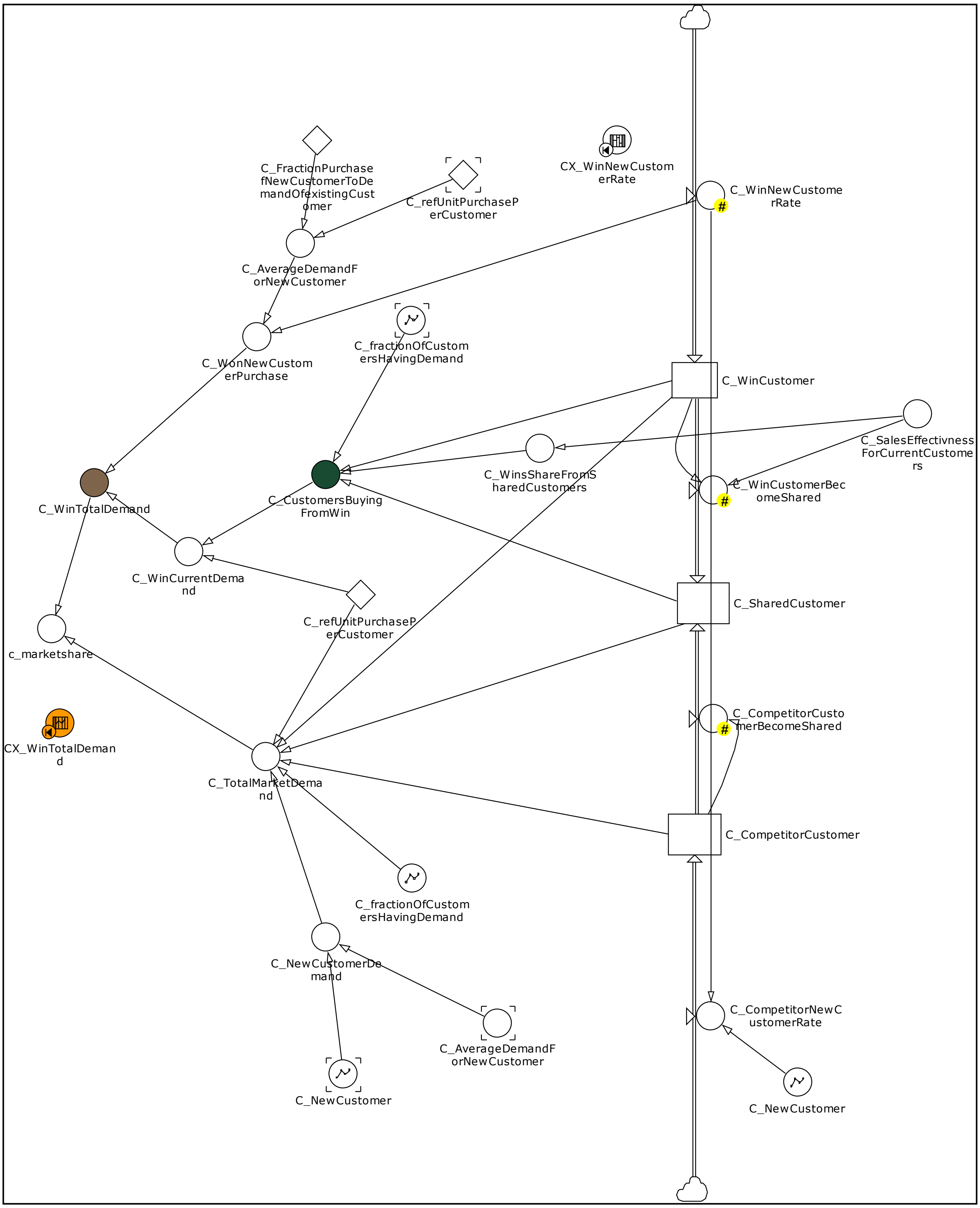


Figure 2.11: Structure of calculating total demand for ACE

2-4. Inventory sector

The third sector in the model addresses the inventory and the supply chain. This sector is the focuse of this thesis, which addresses inventory management by designing a robust policy for unit acquisition. In this part, the structure of the supply chain is explained. The supply chain in this sector consist of the equipment under production in the principal's factory, the equipment in principal's stock, the units in transition and finally the units in the company's stock. Figure 2.12 shows the supply chain for heavy equipment.

The principal company collects orders from the different distributers in the region, at the beginning of each year for the comming year. To simplify the process of ordering, here it is assumed that all distributers have to order on average 6 months in advance. This structure will be explained in more detail later on. After the company orders to the principal company, the principal starts manufacturing the equipment.

After starting to manufacture heavy equipment, under the production equipment proceed to the final phase of production, which is defined as the last month of production in the model. Based on request from distributers, the principal company allows the distributers to adjust their orders. If a distributer wants more equipment than what they ordered, while another distributer needs to reduce the number of orders, the principal company can reallocate the orders between them. The rate at which the company changes its orders is represented by the flow, I_allocationChange in the model. This flow depends on the maximum allowed change by the principal, which is assumed to be constant in the model.

Upon finishing the production phase, the manufactured equipment move to the stock of the principal company. The principal company starts shipping the equipment after coordinating with the distributers. Usually the manufactured equipment doesn't stay for a long time in factory's stockyard, thus in the model the average time before shipment is set to three days. It takes around two months from when the equipment produced and shipped from principal's factory reaches the company's inventory. It should be mentioned that not all of the equipment arrive to the stock of the company and some deliver directly from the border to the customers. While some of the equipment, after custom clearance directly moves to customers, for simplicity, in the model it is assumed that all the equipment first arrive to the company's inventory and then the company will deliver them to the customers. Upon delivering the equipment to the customers, the company will provide service and spare parts for the equipment. All the heavy equipment, have one year guarantee contract, in which the company provides free service and maintenance for the equipment. Although providing guarantee, entitles some costs for the company but it is out of the boundaries of this thesis. In the model presented in this thesis the supply chain of heavy equipment ends with delivery to the customers.

Based on the number of equipments available in the inventory, the company can deliver equipment to the customers. In the model the maximum number of equipment that can be delivered to the customers is represented by the variable I_maxEQreadyForSalePerMonth. In order to calculate the value for the maximum equipment ready for sale, it is required to divide the number of equipment in the inventory by the average time required to deliver units to the customers. Below is the equation to the maximum equipment ready to sale for each month.

$$I\_maxEQreadyForSalePerMonth = I\_EQStockHO / I\_timeRequiredToDelivery$$

In above equation, I_ EQStockHO represents the number of equipment in the company's inventory and I_ timeRequiredToDelivery shows the average time required for the company to deliver the equipment. This average time is assumed to be constant and equal to three days. After knowing the number of equipment that can be sold during each month, the next step is to know how many equipment can be bought by the customers during a month.

From the customer's sector, we know the demand for heavy equipment in each month. Upon collecting customer's inquiries to purchase heavy equipment, a customer confirmed order, CCO, will be signed. The number of signed CCOs shows the number of equipments that the customers willing to purchase from ACE, represented in the model by the stock named I_CCO. The rate at which new CCOs issued is shown by the inflow of I_CCOIssueRate in the model. This inflow, as mentioned, is equal to demand from customers sector. The Figure 2.13 shows the structure of the customer confirmed order and the rates, which change the number of CCOs.

As it is visible in Figure 2.13, the number of CCOs increases at the rate in which company signs CCOs with the customers. On the other hand the stock of CCO decrease through two channels, sales and cancelation.

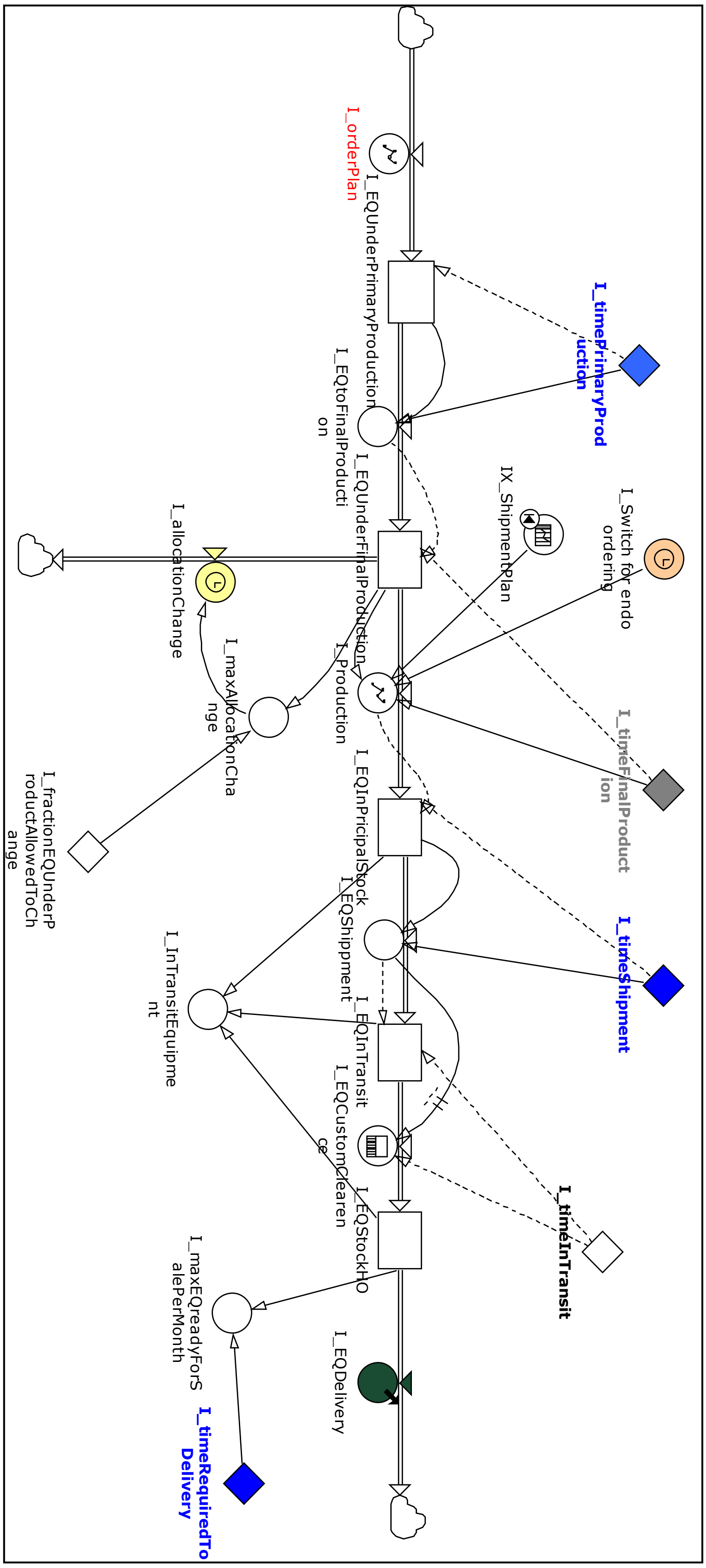


Figure 2.12: Supply chain of heavy equipment

The rate, at which the company sells equipment, is represented by the flow I_sales in the model. I_sales leads to fulfillment of a CCO contract and will decrease CCO stock. On the other hand, it will lead to delivery of a equipment to a customers, which will decrease the stock of company's inventory. The equation for the sales of the company, I_sales is shown below.

$$I_{sales} = MIN\left(I_{maxEQreadyForSalePerMonth}, I_{maxEQreadyToBuyPerMonth}\right)$$

As mentioned earlier, the sales of the company depends on two important factors, the number of equipment available to sale and the number of equipment the customers willing to buy, during each period of time. In economic literature, these two factors are known as supply and demand. In this thesis, we refer to these factors as the maximum number of equipment available to sale by the company and the maximum number of equipment ready to buy by the customers. The number of equipment that the company can sell equals to the minimum value for these two factors.

I_maxEQreadyToBuyPerMonth represents the maximum number of equipment the customers are ready to purchase in each month. All the customers, who signed CCO with the company, are not willing to purchase the equipment upon availability. The customers sign a CCO contract to be sure when they can start operating and actually need the equipment, they can buy it from the company. Another limit to the maximum number of customers who are willing to purchase the equipment is the cash constraints of the customers. Heavy equipment are expensive commodities, which require a strong financial condition for a customer to be able to purchase them. In the model, it is assumed that only a fraction of customers, who signed the CCO with the company are willing to and can afford purchasing the equipment at each month. This fraction is shown by the variable I_fractionOfCustomersReadyToPurchase in the model. Fraction of customers who are ready to purchase is under influence of many external parameters, such as the economic condition of the country, the regulations of the mining and construction industries, the weather and seasonal changes, political conditions of the country and mining areas, etc... This fraction affects the performance of the company by large scale. The equation for the maximum number of equipment ready to buy is shown below.

$$I_{maxEQreadyToBuyPerMonth} = I_{CCO} * I_{fractionOfCustomersReadyToPurchase}$$

By knowing the maximum number of equipment ready to buy, the model can reproduce the number of equipment sold during each month and delivered to the customers.

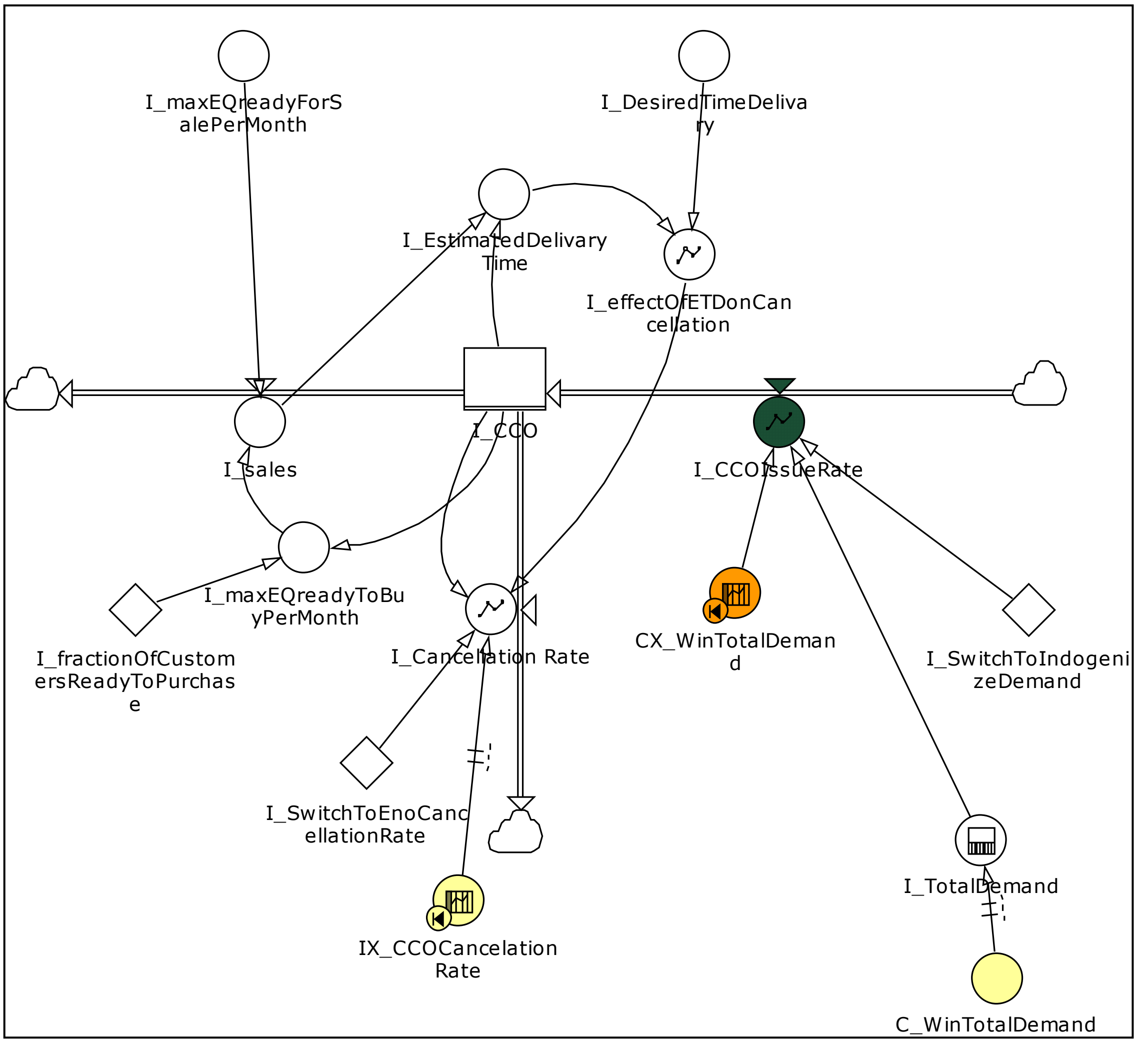


Figure 2.13: Structure of Customer Confirm Order (CCO)

As mentioned earlier, there are two outflows, draining the number of signed CCOs. One of the two outflows from the stock of CCO is the rate of sales in each month, which explained above, and the other one is CCO cancelation rate. CCO cancelation rate is the rate at which the customers cancel their CCO contracts. The most important influence on the CCO cancelation rate is the delivery time. After signing the CCO if the company fails to deliver the equipment on time, some customers would cancel their contract and purchase from the other dealers. Mining season is short because of the seasonal effect in the Southeast Asia and mining companies can't miss their limited working days waiting for heavy equipment to arrive. Thus some of cutomers contact the other suppliers if ACE fails to deliver the unit on time to them. Figure 2.14 shows the effect of the delivery time on cancelation rate, represented by I_Cancellation flow in the model. When the delivery time increases, it causes the cancelation rate increase slightly. When the delivery time increases to more than two months it cause more cancelation rate, as more customers see their operation and business in danger and risk. When the cancelation rate increases to around 0.3 it starts to grow more slowly, as some customer realize other customers are canceling their CCOs. There are also some loyal customers who don't cancel their CCOs at all.

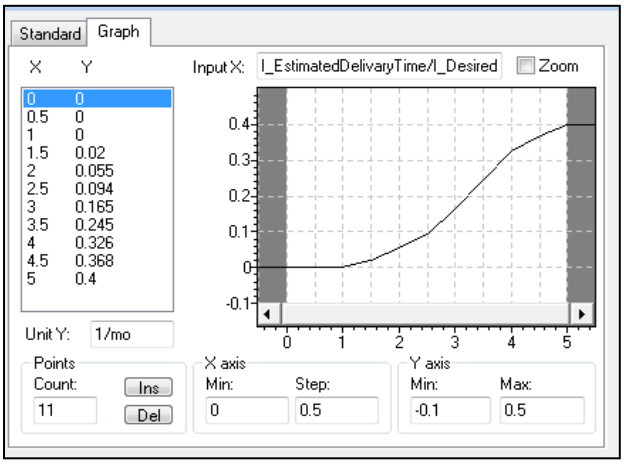


Figure 2.14: Effect of Estimated Time Delivery on cancellation rate

Delivery time for the customers can defined by the number of CCOs signed divided by the rate at which company sells equipment. The equation for delivery time is shown below.

$$I_{EstimatedDelivaryTime} = \frac{I_{CCO}}{I_{sales}}$$

Using above formula, enable us to calculate the delivery time. When the CCO increases, it leads to higher delivery time, while an increase in sale will reduce the delivery time.

2-5. Finance sector

In this sector we study the consequences of company's decision on its cash resource. The company has revenues and costs according to the structures discussed earlier which affect its cash level. The cash resource is very vital for heavy equipment dealers, as low cash level constrains purchasing equipment from Principle Company. Principle company may cease its cooperation with distributer if, the distributer fails to pay it dues on time. The amount of cash that the company access also enables the company to sell its equipment with more attractive terms of payments to the customers, which will lead to absorb more customers to the company and more sales. In ACE's instance, cash from selling heavy equipment helps financing various investments for the cooperation. High amount of cash helps ACE to complete the investments faster while low amount of cash prevents ACE from completing investments and generating profit from it.

The resource of cash is represented by the stock named, f_cash in the model. Company's amount of cash increases by company's income and it decreases by company's expenses. In this model, we only investigate the amount of cash of the company, which means we don't calculate the profit of the company, which is different from the concept of the cash. Level of the cash is the amount of money accessible by the company, while profit refers to the revenues of the company minus its costs.

To highlight the difference between cash and profit, it is helpful to provide an example. Imagine the company buys equipment with the price of 90 and sells them for 100. The company sells the equipment with the condition that customer has to pay half of the price upon delivery and the rest after one month. In this sense when the company sells the equipment it receives only 50. At this time the profit of the company is 10 because it sold the equipment 10 units more than the price that it bought it, while at this time the cash level of the company is -40, assuming the company starts with zero cash. Only after one month when the customer pays for the full price the cash level and the profit of the company will be equal. While the profit of the company and markup margin of the company is important, we don't consider it the key performance indicator of the company. Here in this thesis, as it mentioned in the first chapter, the key performance of the company is amount of cash and its future path. If the future cash level of the company increases, it indicates that the company is generating profit and vice versa.

Figure 2.15 shows expenses, which is the rate at which the cash level decreases. The outflow, f_Expenses represents the expenses of ACE. Expenses of the company consist of three main parts. The equation for the expenses of the company is shown below.

$$f_{Expenses} = f_{cashExpenseFromEquipmentImports} + f_{APcashExpenseFromAPEquipmentImports} + f_{cashExpenseSalesmanCompensation}$$

f_cashExpenseFromEquipmentImports shows the advance payment that the company has to pay to principal upon shipment from the principal's stock. In other words it indicates the amount of money that the company has to pay when principal sends equipment to the company. f_APcashExpenseFromAPEquipmentImports, on the other hands represents the amount of cash that the company has to pay to the principal for previous shipments. The later indicates the amount of cash expenses from account payable. The account payable is the account of cash that the company owes to the principle for the previous shipments. Whenever the principal manufactures the equipment and ships them to the company, the company pays half of the price. In other words, 50% of the price has to be paid to the principle before principle starts the shipment. The other half of the price has to be paid to the principle in three months, 16.66% of the total price each month. Thus by shipment time the company pays 50% of the price, while after one month pays 16.66% more of the price. After one more month, in second month, the company pays another 16.66% of the total price, during the third month the company pays the remaining 16.67% of the total price. The first half of the price is the first component of the expenses equation, mentioned above, while the other half of the price goes to account payable and shown in the second component of expenses equation. The third and the last component of the expenses for ACE is the compensation for the salesmen.

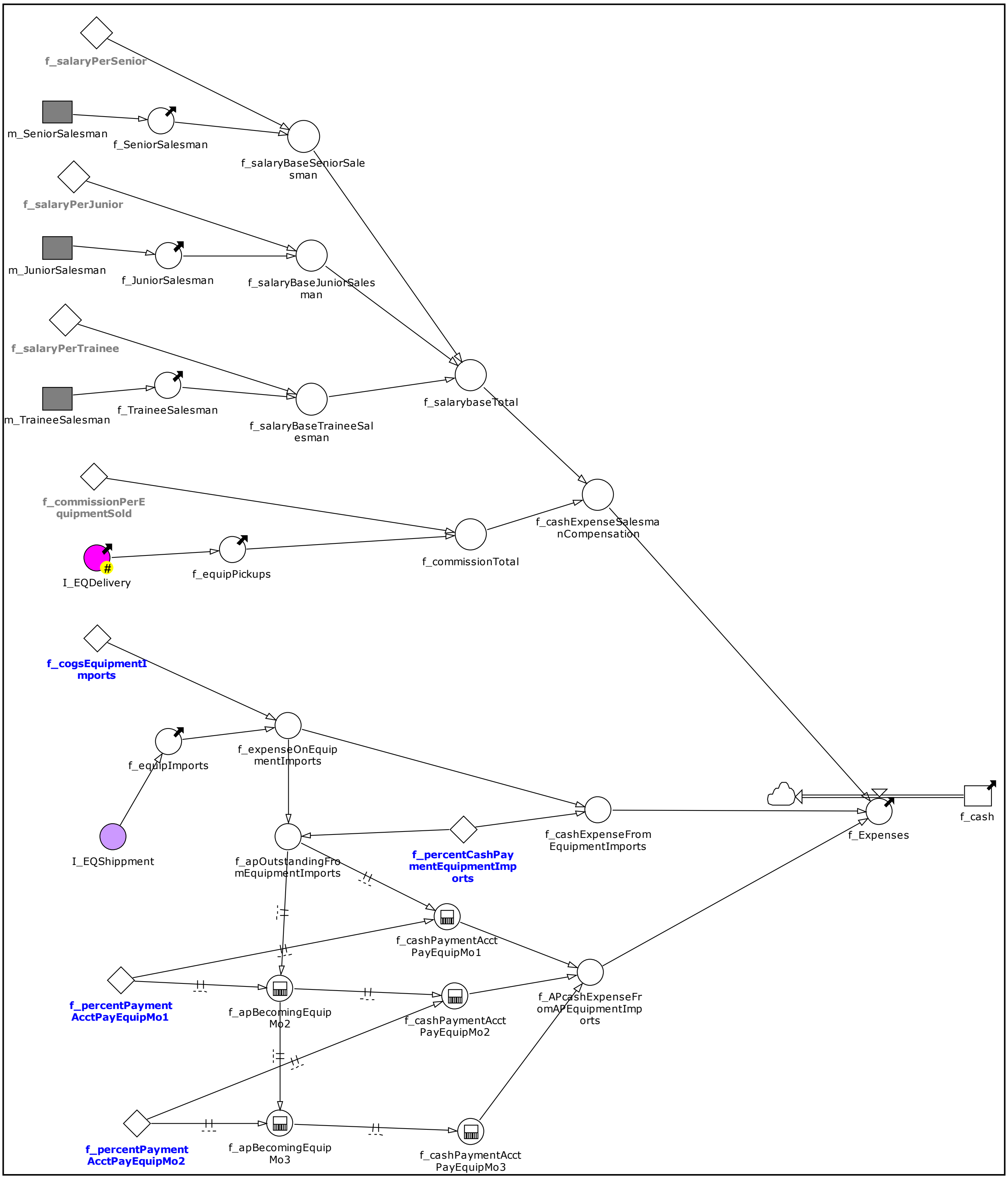


Figure 2.15: Structure of Expenses for ACE

While the expenses were the rate at which cash level of the company decreases, income rate will increase the cash. Figure 2.16 and figure 2.17 shows the income rate of the company which is represented by the inflow named f_Income in the model. The following equation shows how the income of the company is calculated.

$$
\begin{aligned}
f\_Income = \ & f\_cashCollectedFromCreditSalesAtEquipPickup \\
& + f\_cashCollectedFromEquipAR \\
& + f\_cashCollectedFromARDelinquent \\
& + f\_cashCollectedFromCashSalesAtEquipPickup \\
& + f\_cashCollectedFromDownPaymentAtCCO
\end{aligned}
$$

f_cashCollectedFromDownPaymentAtCCO, shows the amount of money that customer have to pay when they sign the CCO contract. f_cashCollectedFromCashSalesAtEquipPickup, indicates the income generates by the cash sales. Customers have to pay the full price of equipment upon delivery in cash sales. Only a fraction of total sales are cash sales, usually for the customers who are new and doesn’t have a strong relationship with the company. f_cashCollectedFromCreditSalesAtEquipPickup, represents the cash collected upon delivery for the credit sales. In credit sales, only a fraction of the total price of the equipment is paid upon delivery and the rest of it has to be paid in six months. Usually ACE, ask its customers to pay 0.25 of the total price upon delivery, in case of credit sales. The rest of the price has to be paid in 6 equal payments for the future 6 months, each 12.5 of the total price. As a result, 0.75 of the credit sales is not paid by the customers upon delivery, which is called account receivable, AR. f_cashCollectedFromEquipAR, indicates the amount of money from account receivable, AR, received each month. Not all of the customers pay their debt to the company on time and as a result some fraction of AR account will become late, which is shown by the variable f_DebtBecomingDeliquentRate, in the model. The company manages to receive some part of delinquent debt of the customers, which is shown by f_cashCollectedFromARDelinquent. f_cashCollectedFromARDelinquentis the last component of the incomes for the company.

Summary

As explained in this chapter, the performance of the company depends on various resources. Salesmen visit customers and collect their inquiries for heavy equipment. A fraction of customers choose ACE between different distributers and sign a CCO with ACE. The company orders equipment to the principal factory, which arrive after several months. Upon arrival, ACE delivers the equipments to the customer who already signed a CCO for that equipment. When the company orders to the principal they pay to the principal factory and by delivering to the customers, ACE collects money from customers. This generates the changes in the cash resource of the company.

In next chapter, the analysis for the model is provided, including simulation results for key variables of the model.

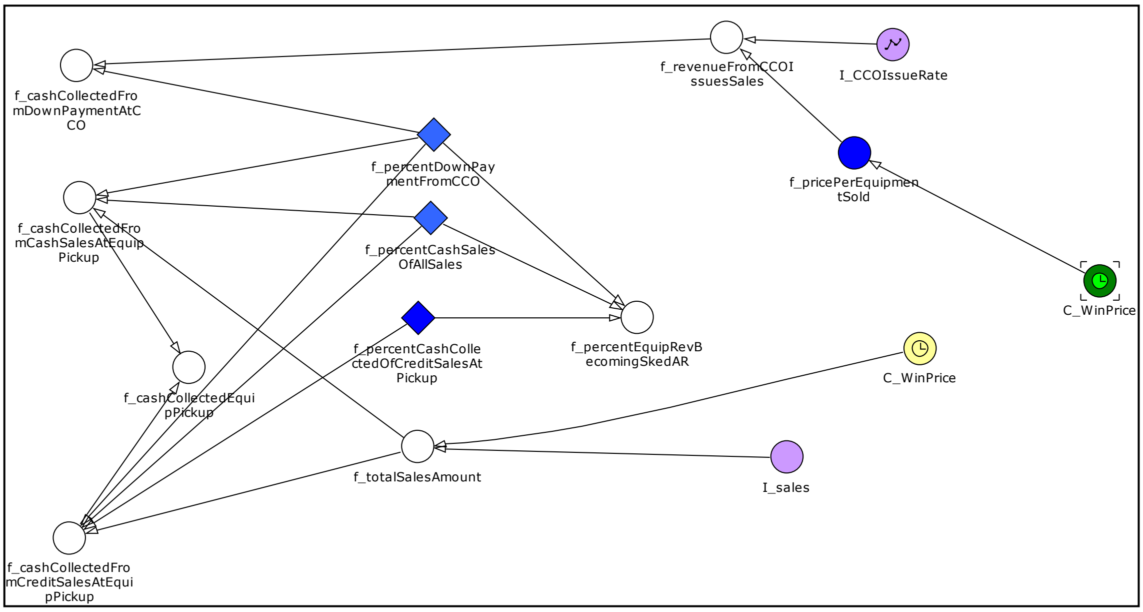


Figure 2.16: structure of Income components

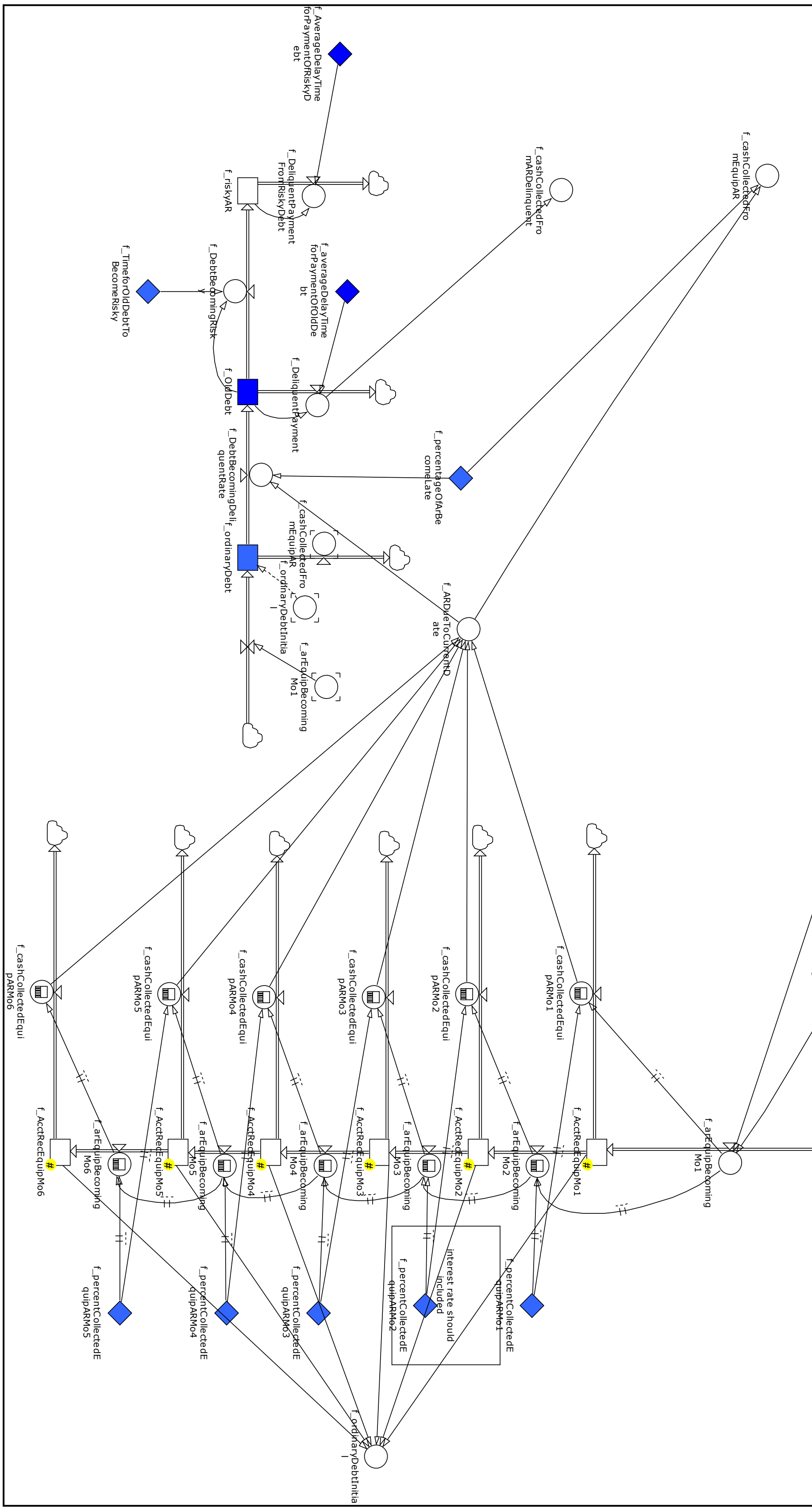


Figure 2.17: Structure of Income components – Account Receivable (AR)

Chapter 3: Analysis

3-1. Introduction to model validation

Last chapter described the dynamic hypothesis, in a form of structure of the model. In this part, we focus on model validation and testing the underlying assumptions of the model, in order to validate the results of the model. In other words, the validity of the results of the model depends on the validity of the structure of the model. Meaning that, in system dynamics models, whereas the model represents the causal relationship of the real system, an accurate output of the model is not sufficient to validate the model. A model may produce close behavior to the behavior of the real system but for different reasons, which make the model unreliable for its purpose. A system dynamic model should produce an accurate behavior to the real system, while it explains why the behavior is generated.

Model validation is a way to examine the usefulness of the model. Model validation in system dynamics modeling is not a single stage right after model construction, but it is a continuous examination started from the very early stages of modeling. After developing each part of the model, validation helps to find out the flaws of the model. In other words validation is like the compass to show the directions for developing the model.

In order to validate the model it is important to first discuss about the concept of validity. To understand the concept of validity, first it is important to differentiate between validity and truth. By definition[2], valid means 'Sound, defensible, well grounded' while the meaning of true means 'conforming with reality'. A system dynamics model is a simplification of the reality, and the question of whether it is true or false should be avoided. The most important question that should been asked is if the model is good enough for its purpose or not? Coyle (1977) summarizes the point that validation is *'the process by which we establish sufficient confidence in a model to be prepared to use it for some particular purpose'*.

---

[2] Based on *The shorter oxford dictionary* and *the Collins English dictionary*

Forrester (1961) lays enormous emphasis on validation. His main point is that the defense of a model should be based on defense on its details. The behavior of selected variables is no guarantee of validity as an endless variety of invalid equations can exist to generate the same behavior. Nevertheless, he mentioned that the behavior of the model should carefully be checked, as flaws in the structure of the model usually expose themselves through failures to reproduce the behaviors as would be expected. Forrester states that an improvement to the model must only be made if they represent the real system, not because they fix the problem. At the end Forrester points out that there is no absolutely objective test to make a model acceptable.

This chapter explains some of the most significant tests conducted for validating the model in this thesis. As this thesis is conducted based on a commercial project and it is based on real case and data from ACE, it is worthwhile to highlight validation differences for commercial projects and academic ones.

As stated earlier the validation of a model relies on the purpose of the model, and whether it is good enough or not? The purpose of a commercial model is to help the client make decisions which may have far-reaching consequences and often have financial ramifications (Coyle and Exelby, 1999). In contrary, an academic seeks to publish results into a scholarly community. The difference between owners of the model has significant implications for the validation of the model. For the commercial model, the client owns the problem and usually the client got more knowledge about the problem. Coyle concludes that *the client is the ultimate arbiter as he has a personal interest at stake.* For this reason, the process of validation for commercial models is jointly done by the consultant and the client. Validation for academic models in contrary is done by the researcher himself. In both cases, the models are open to inspection or review, and if inadequacies are founded, the professional reputation of the modeler could be damaged. At the same time, the risk for commercial modeling is higher, since the consultant risks financially with possibility of litigation.

For this thesis, managers of different departments in ACE checked the model from early stages of development. The results of the model also been presented to the managing board of ACE. Managing board approved both the structure and behavior of the model and it considers the biggest validity test for the model to achieve its purpose.

Below some tests are briefly explained. These tests were used many times through the development of the model to increase the confidence of the author in the model before presentations to the managing board. There are two group of tests used for this model; structure tests and behavior tests.

3-2. Structure validity

3-2-1. Boundary Adequacy Test

Boundary adequacy test assess the suitability of the model boundaries for its purpose. This test assists us to judge whether the endogenous and exogenous variables is set appropriately or not. In other words, does an endogenous variable deliver more value to the model in order to address model's purpose? Same question rises about exogenous variables in the model to examine whether the modeler should include them endogenously in the model. Another topic about the boundary of a model is the level of aggregation and the question of whether the model is disaggregated enough to answer the problems that it intend to answer or not.

For this thesis, the model's purpose is to desifind reasons for the increase in the inventory level. To address this problem, we include important resources determining the level of inventory and their dynamics. The most important resource that first came to mind to be included into the model was customer's base of the company so we can calculate the demand for ACE endogenously. In the process of developing the model, the need to include salesmen as the most important factor to maintain customers is included into the model. In order to observe the consequences of increase in the inventory level on the performance of the company, financial sector added to the model to enable the model to deliver its message clearly.

Many exogenous variables in the model need to be calculated endogenously, in order to reproduce the system's behavior more accurately. At the end of this thesis, some of exogenous variables are mentioned to make the model more accurate. Nevertheless, the time and data available to the modeler should also be considered.

Another important question to ask is the level of aggregation. Level aggregation refers to the level of details in the model. There are two main areas in this model for disaggregation and adding more detail to the model.

In this thesis, all the heavy equipment are aggregated into a single product. In other words, in this model, we do not differentiate between different models of heavy equipment. Different types and models of heavy equipment have different production and delivery times, which make their dynamics different. The purpose of this model is to highlight the important dynamics in ordering equipment for the managers of the company. To use the model as a tool to generate exact values for ordering the heavy equipment should disaggregated into different types and different sizes of equipment. Consequently, customers stock could disaggregate into different businesses who demand different kind of equipment from ACE.

3-2-2. Parameter assessment test

All the parameters in the model should correspond to a real world concept. A reader or user of the model should be able to interpret any parameter into a condition, characteristic, or a measurement in the real system. In addition, the values for the parameters should be consistent with their corresponding real world concept.

There are two methods to estimate a value of a parameter in the model: a formal statistical estimation based on the available data and a judgmental estimation based on our knowledge (Sterman 2000). Usually, the modeler has to estimate some of the parameters based on its own knowledge because there is no recorded data about all of the variables in a model.

In this model, there are three types of variables regarding the estimation for their value: parameters with data basis, parameters with strong estimation, and parameters with weak estimation. As shown in appendix 1, all the parameters are in bold names.

Parameters with black bold names are the ones with recorded data basis. These parameters derived directly from the recorded data in the ACE. As a result, it is easy to test if their values are correct or not.

The parameters in gray bold names derived from the estimation of the managers in ACE. When the managers were familiar with the concept and meaning of a parameter and they could roughly estimate the value for the parameter, the variable is in gray color, which means the value is not based on recorded data but on the people who know the system well.

At last, there are parameters with weak estimation, which are variables, that not even the managers have clear idea about their value. The latest group has blue bold names in the model. There are parameters with weak estimation in the model for two reasons. First, it is hard or impossible to measure some parameters like the customers of the competitors. Second, because the managers never thought about a parameter in a way the parameter is presented in the model, for instance, the managers in selling heavy equipment never thought about coverage area as the percentage of the country's area that they can provide service.

3-2-3. Dimensional consistency test

Dimensional consistency test is among the most important tests in validation of the model. Every model should be consistent dimensionally or it contains major errors. Forrester (1961) insists that the equations must be dimensionally consistent and that all constants in the model must be clearly defined and their dimensions must be stated. Dimensional consistency simply means that both sides of an equation should have the same unit of measurement.

Dimensional consistency test can be a very lengthy process to do. Fortunately, some software, like Powersim checks the dimensional consistency automatically. As a result, during development and making of the model for this thesis, Powersim checked all the equations automatically and all are dimensionally consistent.

3-3. behavior validity

After verifying the tests for the structure of the model, one should assess the confidence in the behavior of the model. Behavior tests are to measure how accurately the model can reproduce the patterns of behavior that real system produces. In other words, the behavior tests are the way to measure the capacity of the model to reproduce the dynamic behavior observed in real system, endogenously.

It is important to point out that the goal of model is to reproduce the corresponding patterns to understand the dynamics of the system, and not the exact duplication of the observed behavior.

As mentioned earlier, whereas failing a test shows that the model is not good enough for its purpose, passing a behavior test does not mean that the model is valid. All the tests mentioned here are to reduce the risk of mistakes and flaws in the model and passing all of them does not guarantee that the model is valid.

There are three tests mentioned as behavior tests for the model presented in the model. First, we mention an important but mostly neglected test of integration error test, later we talk check the behavior of some parameters against their corresponding real system behavior. Extreme condition tests are additional tests to be sure that the model can react reasonably to some extreme shocks. At last, we analyze the sensitivity of some parameters to exogenous variables.

3-3-1. Integration error test

The purpose of this test it to be sure that the behavior of the system is not because of integration method of the software. System dynamics is a continuous simulation method, which uses differential equations for equations of stocks. In order to calculate the value for stocks at each point in time, the software uses *time* step to the integral of the differential equation. The purpose of integration error test is to ensure that the behavior of the model is not sensitive to the times step. High time step may cause the system to oscillate and the purpose of this test is to make sure there is no oscillation because of high time step. On the other hand low time step makes the simulation more time consuming. To make sure that time step doesn't change the behavior pattern of the system, we made a comparison between the behavior of total demand for ACE with two different time steps as it is shown in Figure 3.1.

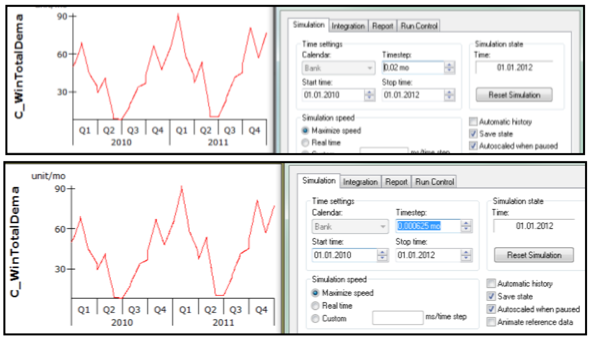


Figure 3.1: comparison between simulation results with different time step

3-3-2. behavior comparison of the model and real system

We did the comparison between the simulation results and the real data, for the variables that recorded data was available in ACE. Charts in this section show the behavior of the real system only from 2010 until 2011, as recorded data in most instances is only available for this period.

Figure 3.2 shows the rate; at which ACE absorb new customers. The blue line shows the historical data of new customers in ACE, while the red line is the simulated behavior for new customers. As shown in figure 3.2, the model can reproduce the trends of new customers.

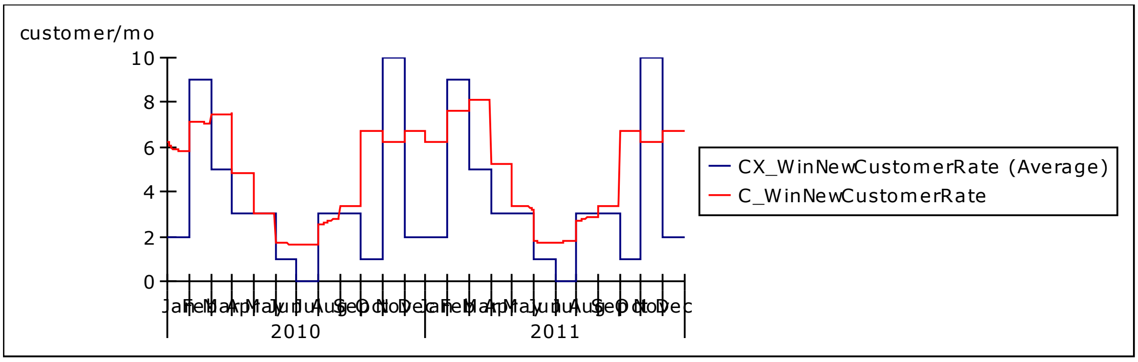


Figure 3.2: the behavior comparison of new custoemrs won by ACE.

Figure 3.3 shows the chart of total demand for ACE and compares it with simulation results. Except some period the model, successfully reproduce the real system behavior. The model fails to replicate the growth during May- August 2010, and the recession in late 2011.Managers at ACE mentioned that at August 2011, the government changed the regulations for construction fund. Reduction in construction funds to help developing the country, resulted in a recession in construction industry and consequently in the demand for ACE. Change in government's regulations is out of boundaries of the model and can only be shown by changing exogenous variables, such as the average demand per customer.

Figure 3.4 compares the inventory level according to real data and the simulated behavior of the inventory in the model. Inventory level is one of the key parameters in this thesis that we try to understand its dynamics, and design policies to reduce it. While figure 3.4 indicates that the simulated model replicates the trend of inventory in real system, simulated behavior is slightly lower than real system's behavior. Nevertheless the model shows the critical moments when the inventory level raises and decreases the liquidity of the company.

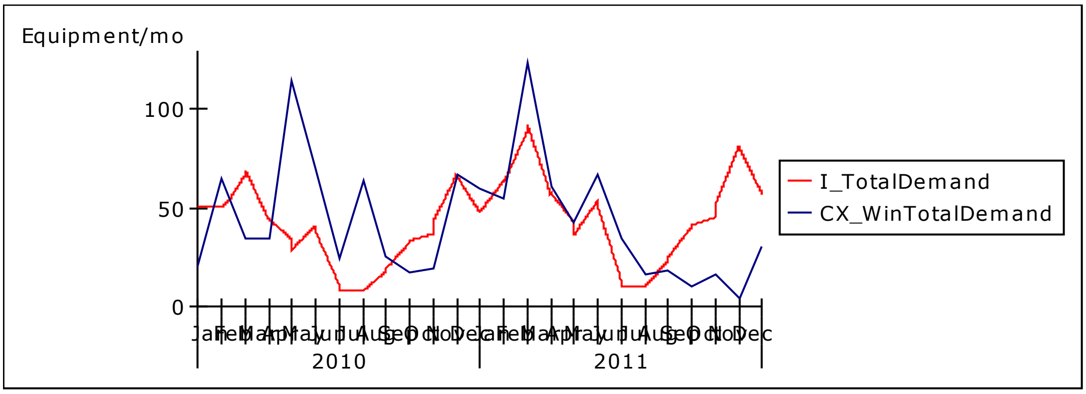


Figure 3.3: the comparison between real system's behavior of demand for ACE and its corresponding simulated behavior

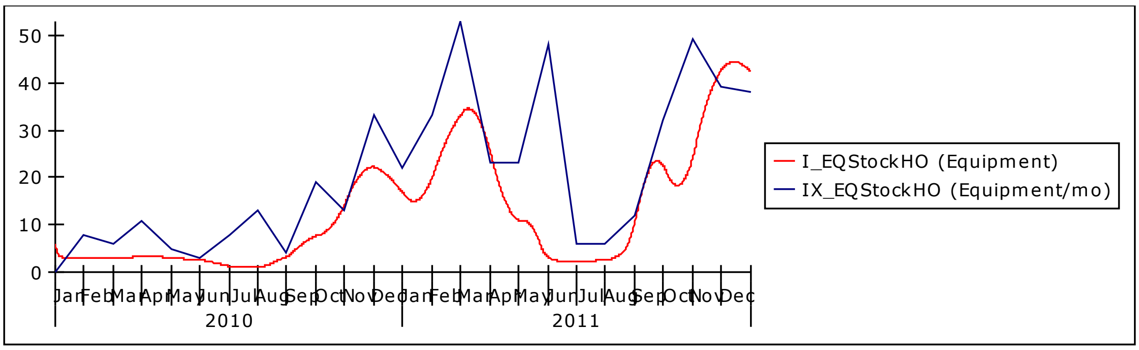


Figure 3.4: the comparison between Inventory level in real system and the simulated behavior of inventory

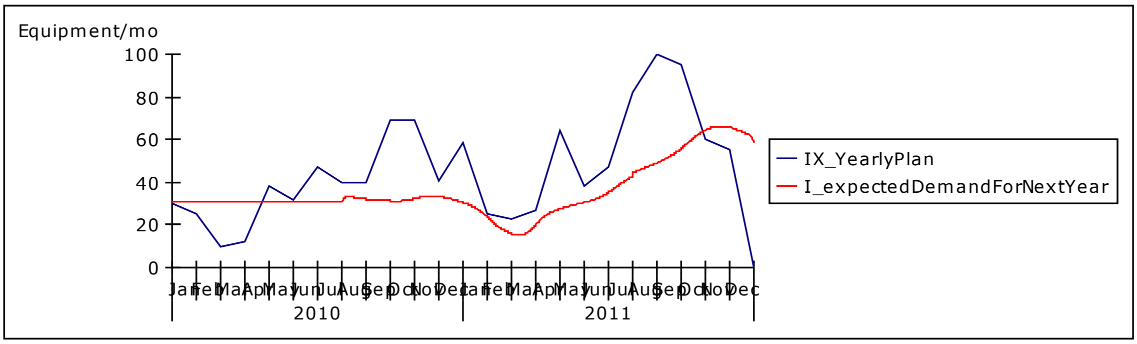


Figure 3.5: comparison of orders of heavy equipment by ACE and the corresponding simulated order rate

Figure 3.5 shows the numbers of equipment ordered by ACE to the principle company. As it mentioned earlier the decision rule at which ACE orders to the principle is absent from the model. The simulated behavior, shown as expected demand for next year is the basic component of orders to the principle. More components of order rate are available in chapter 4 in policy structure. The model simulates expectation for next year's demand only from 2011, as there is no previous data to calculate the order rate in 2010 endogenously.

3-3-3. Extreme condition test

According to extreme condition test, the validity of the model will be assessed under extreme conditions. More precisely, extreme condition test assesses the behavior of the model under extreme scenarios, against anticipation of what would happen under similar condition in real system. This kind of test have been run for every variable of the model, but here we only mention an example of extreme condition test.

The example for extreme condition test is for price, in order to see whether the system behaves properly to extreme changes in the price set by ACE. Price is one of the variables that ACE can change and it influences its performance. We show the test for a scenarios; a sudden increase in the price to more than double the original price, with a shock at the end of year 2010.

Figure 3.6 shows how the model would respond when the price increases to more than double. The changes in two variables, the new customers absorbed by ACE and total demand of ACE, to the shock in price are shown in figure 3.6. while the green line shows the behavior of the system without any change in price, the red line shows how system would react to an sudden increase in price. With a sudden increase in price, as expected, no new customer wants to purchase from ACE and all would purchase from the competitor. At the same time, total demand for ace reduces extremely. Some old customers continue purchasing from ACE, as it might be more expensive for some companies to change their brand and train their employees for new brand.

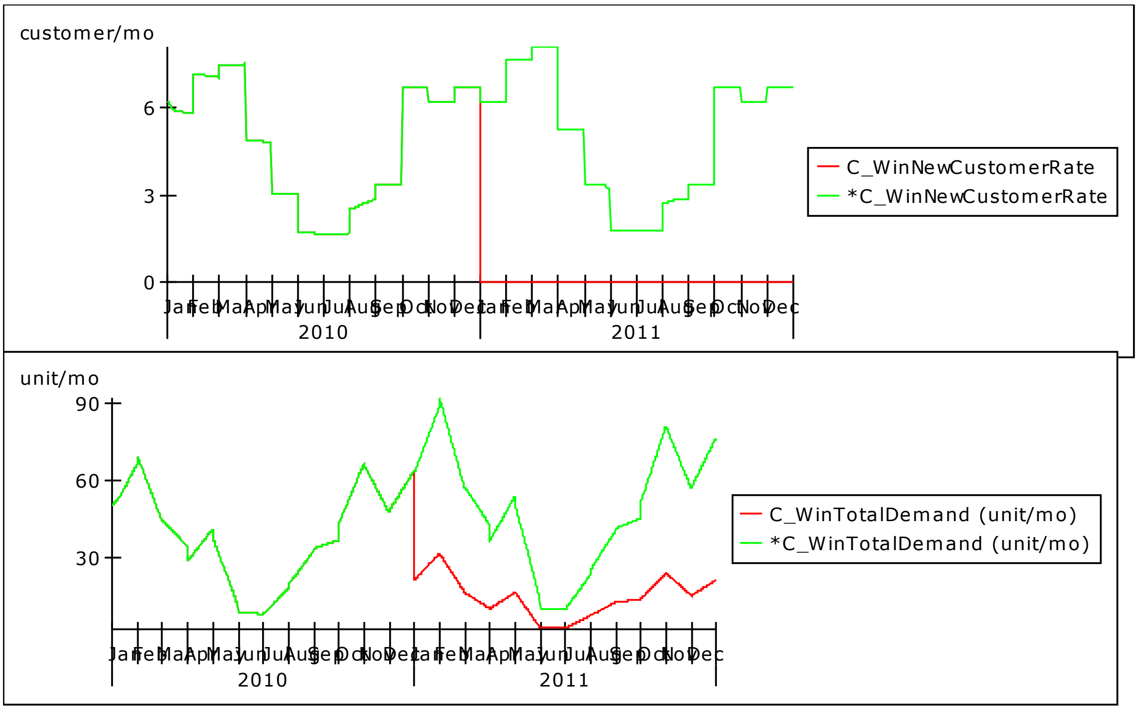


Figure 3.6: extreme condition test for a sudden increase in price to more than double.

3-3-4. Sensitivity test

Sensitivity test consist of measuring the relative in the behavior of the model, in response to changes in one or more parameters. There are two benefits of using sensitivity tests. First, it enables the modeler to identify variables to which the model is sensitive, and therefor concentrate on estimation for those particular variables. Second, sensitivity test establish a level of confidence for the results of the model.

To perform sensitivity analysis, risk assessment of Powersim has been used. For this task, assumptions, decisions, and effects been selected. The Latin Hypercube sampling technique has been used with 500 samples from the distribution of each assumption.

The result of sensitivity test for two variables, are shown below. Figure 3.7 shows the sensitivity of three key performance indicators: sales, inventory, and cash to changes in new customer rate. By assumption, the distribution of base new customer rate uniform with expected value of ten and standard deviation of one. Figure 3.7 shows that with assuming a distribution for new customer rate how the distribution for three performance indicators will be.

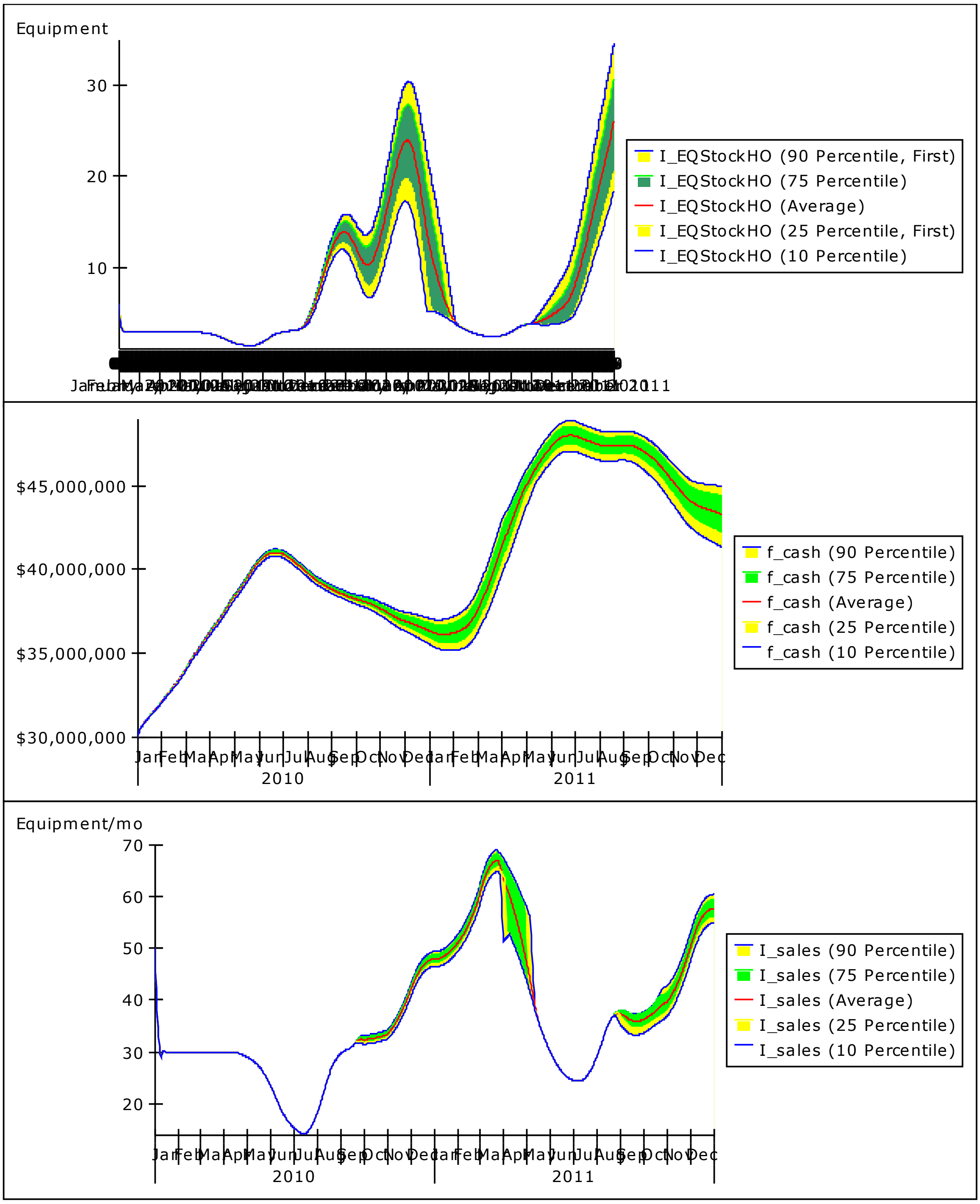


Figure 3.7: Sensitivity test for new customer base parameter.

Chapter 4: Policy design

Ordering is one of the decisions that managers in ACE have to take each year. In this chapter, first we investigate the structure for ordering, and policy structure of the model. Later on, we mention the process of calibration and the results of applying policy into the model. Next section, dedicates to limitations of the current study and improvement suggestions. At last, in conclusion section, we summarize the thesis and its insights.

4-1. Policy structure

Here we study the policy suggestion for ordering heavy equipment to the principle company. Ordering process, takes place at the end of each year for ACE. At this time, managers have to decide for heavy equipment they want to purchase for the next year and the distribution of this amount among the months. The Ordering process in this model doesn't completely corresponds the ordering policy in ACE. In the model, we assume the process of ordering is a continuous process, in which at any point of time company has to submit their orders of the next year to the principal. More details about the difference between the real process and the model are available in next section, as limitations of the model.

During this thesis, the most challenging part of modeling a problem was to simulate the mentality of the managers when they make decision, in particular when they order to principal. During the interviews managers provide many helpful insights about how they decide how many equipment to order, but still their explanations didn't explain the complete process of their decision making. During the fieldwork in ACE, we developed an interactive game in which managers were deciding about the orders and they could observe how the system would react to their decisions. In other words the decision rule was absent from the model in the primarily presentation to the managers.

A feedback loop from the system is added to the model to automatically decide about the ordering amount. This decision rule can be considered as the basic policy design to guide managers for ordering by providing quantitative suggestions. Later on some adjustments were added to the policy design. This Section shows the evolutionary path that policy design for this model went through.

4-1-1. Basic policy design

Primarily policy for acquisition of heavy equipment, aims to provide the basic way to formulate the decision rule of managers. According to managers, they use the sales of the last year as the basis for ordering, and they add their expected market growth for the next year to it. From the model, we know the value for sales at each month, but the managers don’t know about the sales at the current month until the month finishes. This process is shown by an information delay with one month delay time. In the model, we show the sales of previous month that managers notice and use for ordering is represented by P_PerceivedSales. Managers can also use only previous data to calculate the growth of the market. To do so, they compare the sales in previous year with the sales of the year before it. p_growthrate represents the growth rate observed by the managers of the company. Below is the formulation for growth rate:

$$p_{growthrate} = \frac{P_{SaleForOneYearAgo} - p_{SalesForTwoYearsAgo}}{p_{SalesForTwoYearsAgo} * 1 \ll yr \gg}$$

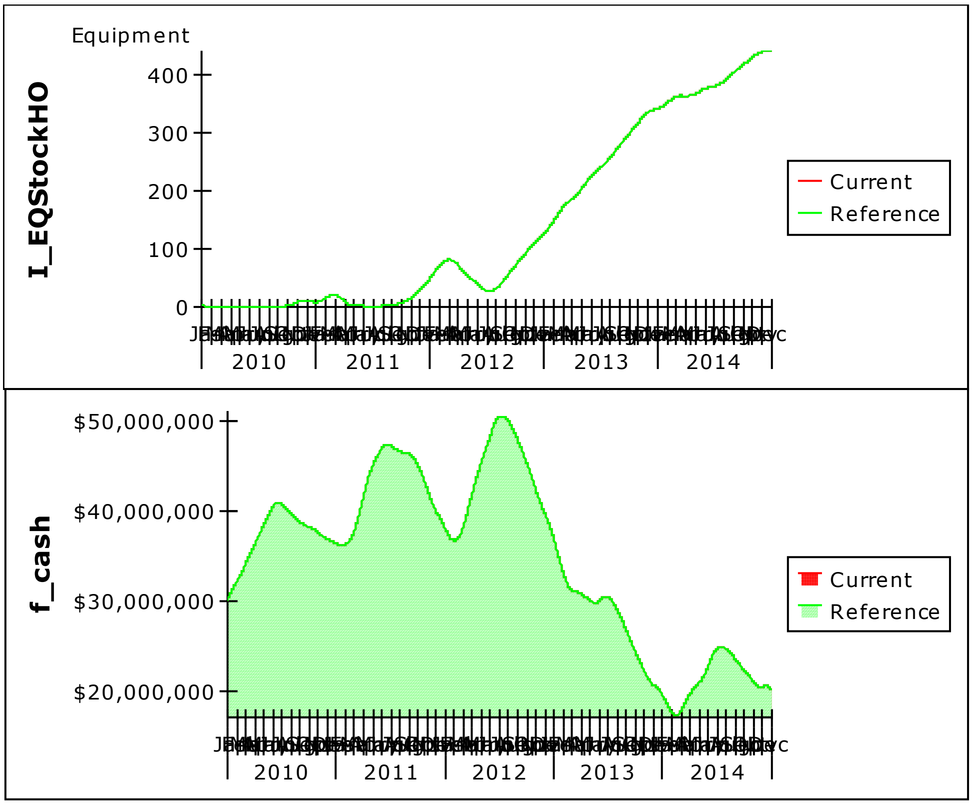
This formulation shows that the growth is different between sales of last year and the year before that. To calculate the growth as a rate we have to divide it to the sales of two years ago and 1 year. The division to 1 year is because this growth rate is calculated as a growth rate for one year. In other words, it equals to the growth during one year. By knowing the value for growth rate and sales, the managers will order to the principal.

Managers in ACE, use the data of sale from previous month to forecast the sale at the same month in next year, or next eleven month. For example, managers know the volume of sale in January, during February. Based on the sales of January they want to forecast the sale for next January. Managers are aware that it takes four months for an order to be produced and shipped to their company. As a result, when they forecast the sale for next January, they are forecasting the order for four months before January, which is September. Thus, during February that managers are notify about the sales in

January, they are forecasting the sales in September which 7 month later. In other words, the one-year span between the current sales and the next year's forecast composed of 1 month to perceive the sales, 7 months advance ordering, and 4 months delivery time. The formulation for expected demand of the next year is shown below.

$$I_{expectedDemandForNextYear} = DELAYPPL(P\_PerceivedSales * (1 + 1 \ll yr \gg * \; p\_growthrate\ ), 7 \ll mo \gg)$$

Simulating the model with above formulation didn't improve the management of inventory and also the future cash flow of the company was very oscillatory with little growth. Figure 4.1 shows the behavior of the company with this formulation. As shown in the figure, the company will face huge excessive inventory. The cash level of the company will also decrease to 20M$. [3]



3 Based on assumption, the cash level of ACE at the beginning of 2010 is 30M$ (30,000,000 US dollars)

The main problem in mentioned decision rule is that, it only depends on the sales and it's growth rate during past years. In reality when company is facing high inventory it doesn't order more equipment, but in this case the simulation model doesn't react like the real system to high inventory. To make the policy structure realistic, we have to include more structure to the policy structure.

4-1-2. Inventory adjustment

When Inventory level rises, the company doesn't order more equipment to increase the inventory to a higher level. To understand when company stops ordering equipment, first we have to define what the desire level for inventory is. To find out what is the desired inventory level, first we have to define the desired inventory coverage.

Inventory coverage is the time that inventory will last if no more equipment arrives at inventory. In other words, inventory coverage is the average number of day's equipment remains in the inventory. Desired inventory coverage is the ideal average number of days that equipment stays in Inventory. For heavy equipment, the desired inventory coverage is a short time, as the company is unwilling to keep equipment in its inventory. There is only a minor time for the company to check the equipment before delivering them to the customers. In this case, the desired inventory coverage is three days. To calculate desired inventory we use the following formula.

$$I\_desiredInventory = P\_PerceivedSales * I\_desiredInventoryCoverage$$

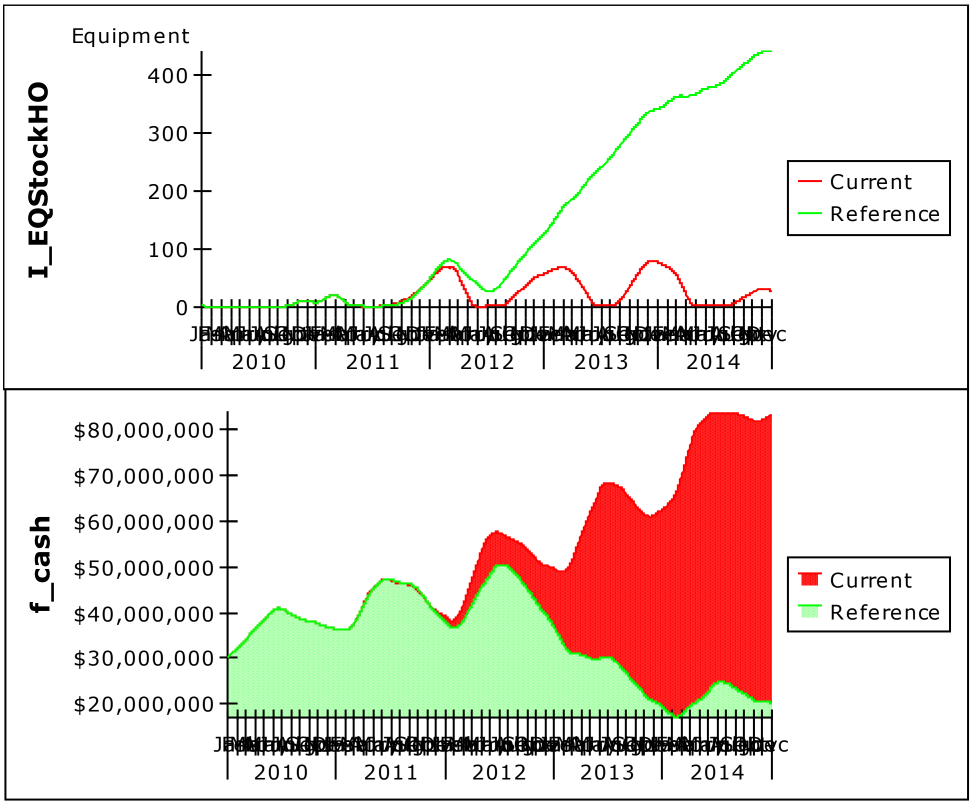
By this definition, desired inventory is the product of the desire time that we want the equipment to stay in inventory and the current rate at which the company sells equipment. Now that the company is aware of how much inventory it wants to have, it can adjust the orders according to inventory. Below is the formulation for the adjustment of inventory.

$$P_{AdjInventory} = \frac{I_{desiredInventory} - I_{EQStockHO}}{P_{timetoadjInv}}$$

Time to adjust inventory is the variable that shows the aggressiveness of the company to close the gap between actual and desired level of inventory. Smaller time to adjust inventory shows how fast the company wants to adjust the inventory level to approach its desired level.

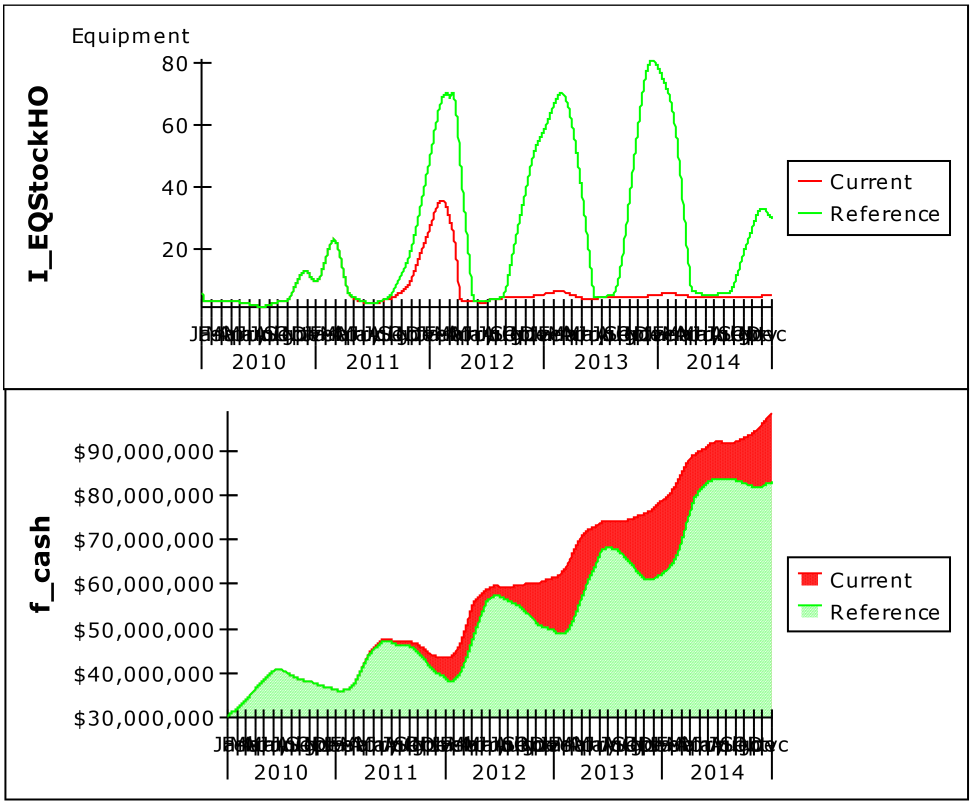
Before applying the inventory adjustment to the model, we can make adjustments for different parts of supply chain by using the same method used for inventory adjustment. There are more factors that we have to consider, other than sales and inventory level. Equipment under production and equipment in transit are two parts of supply chain that we should consider for making robust policy design. The formulation for adjustments for in transit equipment and under production equipment is the same as inventory adjustment. The only difference is the values for time to adjustment and the desired coverage time for any of them.

At last, we can make the same adjustment also for Number of CCO. Adjusting the number of CCO would help the company to prevent high level of CCO and consequently high cancelation rate. Figure 4.2 shows the performance of the company after including the adjustments. The reference behavior in the figure corresponds to the figure 4.1.



Including adjustment for inventory enhances the performance of the company tremendously. The Inventory doesn’t increase linearly, and it shows more realistic inventory behavior. The cash level, as the performance indicator of the company also increases to 80M$ by 2015. It is important to mention that optimization method, available in Powersim, is used to choose best values for adjustment time to maximize the performance of the company.

Albeit the huge increase in the performance, at the same time, inventory level still oscillates to high peaks, similar to the end of 2011. In order to reduce the oscillations in the Inventory level, we should reconsider the growth rate calculated in the model. As mentioned earlier, the growth rate is calculated based on previous years. Usually there are balancing feedback loops that limit the growth of a company, meaning that past growth rate is usually higher than current growth rate if nothing else changes. One controversial finding of this thesis might be the fact that by decreasing the growth rate the company’s performance will improve. Figure 4.3 shows the performance of the company with using a tenth of growth rate calculated in the model. The reason for better performance by being more conservative is a topic should be investigated separately. One reason for this behavior might be due to the fact that, by being more conservative inventory oscillations reduce and thus reduces the costs for the company.



4-2. Further research and improvement

In marketing sector, junior salesmen's flow, m_juniorleaving can be described independently from the variable m_salesmanexp. Currently it is assumed that all the salesmen are working for 24 months as a junior salesmen and after 24 months fraction of them gain experience and advance to the next level which is senior salesmen and the rest will quit working in ACE. Although in more realistic way, not the entire junior salesmen who quit, continue working for 24 months. Many of junior salesmen leave earlier than 24 months. This improvement can enhance the study of maintaining and development of salesmen for the company.

In customer's sector, share customers can eventually become ACE's customer if they choose to purchase from ACE for three years, which is the average lifetime of heavy equipment. Same flow is missing from shared customers to competitor's customers. Currently there is no flow from share customers to ACE customers as the focus of this thesis is mainly on policy design for inventory management. In order to design a policy for customer relationship, it is essential to include these flows.

In customer's section, the new customer base is assumed as a constant. This assumption is not completely realistic, as there are many factors determining how many new customers will join the market. The most important factor will be the profitability of the business. There are feedback loops in the rate at which new customers will join the market. When the market is profitable, new customers would attract by the profit and will join the market. The more new customers who join the market, makes the market less profitable. In case of mining industries, it leads to faster depletion of the resource, which will reduce the profit margin. Consequently, the rate at which new customers enter the market will reduce. For further research and improvement, it is beneficial to add the market situation for important industries affecting ACE's performance.

Another important structure, which is missing from the current model, is the rate at which customers quit operating, because of bankruptcy, changing the field of operation or merging with other companies. It is important for ACE to have a systematic understanding of why and for which reasons customers can't continue operating. The customers who quit the market can become costly for ACE as in the case of bankruptcy.

In inventory sector, it is assumed that when a customer has demand, it will lead them to sign CCO with the company. In practice, there is slight difference from receiving inquiry from customers and signing a CCO. After receiving an inquiry, customer and company sign a purchase order, PO. After signing a PO, company tells the customers about the estimated delivery time, which on agreement, will lead to signing a CCO. In order to simplify the model, it is assumed that all the inquiries will lead to CCO. For more complete and detailed model, it is recommended to include purchase orders into the model.

In inventory sector, CCO cancelation rate is discussed. One aspect of CCO cancelation rate is not discussed in this thesis. Sometimes customers cancel their CCO contracts, without notifying the company. When the company doesn't know that a CCO is cancelled, the company would still plan to fulfill the CCO contract while the customer doesn't intend to buy any equipment, which may cause inventory level to rise. Although the company notify the CCO is cancelled after contacting the customer and trying to deliver the equipment to the customer, this delay in transferring information produce other feedback loops. This effect is absent from this thesis and it is recommended to be added to the model for further development.

In financial sector, salesmen compensation is included in to the expenses of the company. While the salesmen are not the only employed people in the company, only the wages for the salesmen is included in the model. While the salaries paid to the workforce of the company are relatively low to the expenses of the company, it should be included into the model. ACE is a cooperation with high number of workforce, but since this model focuses on inventory management, only salesmen compensation is mentioned in the expenses of the company. Nevertheless, salaries of other workforce of the company should be included in the model.

While the ordering process for the company is discrete with continuous adjustments, in this thesis it is assumed that the ordering process is continuous. For robust policy design, the discrete process and continuous process should combine to reproduce the partially continuous-discrete system's behavior. There are examples of this combination in Angerhofer (2000)

The are many flaws in this policy structure, in policy design sector,. The first one is the structure that ACE managers calculate growth. In system dynamic literature it is possible to use a trend function to calculate the growth rate. Trend function calculates the trend in the change rate of an input. Using trend function has the benefit of not using the data of two years ago in order to calculate the growth rate. The problem with trend function is that seasonal changes effect the growth rate, and as a result growth rate oscillates.

4-3. Conclusion

Acquisition of heavy equipment is one of the most important influences on the performance of the company. While low amount of orders constrains the sales, high amont of orders puts pressure on the cash resource of the company. At the end of each year, when company has to submit its orders to the manufacturer, top managers of the company gather together to decide about their acquisition for the next year. Experienced managers understand have a more clear idea about the future of the company and market. The managers of the company use their available information such as data of the company and the market analysis, to forecast next year's demand. The goal of this thesis is to provide a reliable tool to enhance in the decision making of the managers.

The model, presented in this thesis, consist of four sectors, each representing the dynamics of an important resource for the company. First, we analyzed the Salesmen dynamics and their relationship with the customers. Next, we investigate customers choice between ACE and it competitors, and its consequences as demand for ACE. Later on, the dynamics of supply chain from factory to customers addressed in inventory sector. In this sector, we understand how ordering equipment could affect sales and inventory level. At last, in financial sector, the parameters affecting cash flow of the company were identified.

In chapter three, an overview of the validation tests for the model was mentioned. Examples of different structural and behavioral validation tests, that have been applied to the model were presented.

In last chapter the structure for ordering equipment were discussed and possibilities for improvement of ordering were studied.

References

Akkermans, H. "Developing a Logistics Strategy through Participative Business Modelling." *International Journal of Operations & Production Management* 15, no. 11 (1995): 100-12.

Angerhofer, B. J., and M. C. Angelides. "System Dynamics Modelling in Supply Chain Management: Research Review." 2000.

Barlas, Y., and A. Aksogan. "Product Diversification and Quick Response Order Strategies in Supply Chain Management." 1997.

Coyle, G., and D. Exelby. "The Validation of Commercial System Dynamics Models." *System Dynamics Review* 16, no. 1 (2000): 27-41.

Coyle, R. G., and R. G. Coyle. *Management System Dynamics*. Vol. 6: Wiley New York, 1977.

Dill, M. "Capital Investment Cycles: A System Dynamics Modelling Approach to Social Theory Development." 1997.

Factbook, C. I. A. "The World Factbook." 2008.

Ford, A., and H. W. Lorber. "Methodology for the Analysis of the Impacts of Electric Power Production in the West." *NASA STI/Recon Technical Report N* 77 (1977): 31428.

Forrester, J. W. "Industrial Dynamics. 1961." *Pegasus Communications, Waltham, MA* (1961).

Forrester, J. W. "Industrial Dynamics: A Major Breakthrough for Decision Makers." *Harvard business review* 36, no. 4 (1958): 37-66.

Forrester, J. W. "Lessons from System Dynamics Modeling." *System Dynamics Review* 3, no. 2 (1987): 136-49.

Forrester, J. W. "System Dynamics and the Lessons of 35 Years." *The systemic basis of policy making in the 1990s* 29 (1991).

Hansen, J. E., and P. Bie. "Distribution of Body Fluids, Plasma Protein, and Sodium in Dogs: A System Dynamics Model." *System Dynamics Review* 3, no. 2 (1987): 116-35.

Harland, C. M. "Supply Chain Management: Relationships, Chains and Networks." *British Journal of management* 7 (1996): S63-S80.

Homer, J. B., and C. L. St. Clair. "A Model of Hiv Transmission through Needle Sharing." *Interfaces* (1991): 26-49.

Lane, D. C., and R. Oliva. "The Greater Whole: Towards a Synthesis of System Dynamics and Soft Systems Methodology." *European Journal of Operational Research* 107, no. 1 (1998): 214-35.

Lyneis, J. M. *Corporate Planning and Policy Design: A System Dynamics Approach*. MIT Press, 1980.

Richardson, G. P., and A. I. Pugh Iii. *Introduction to System Dynamics Modeling with Dynamo*. Productivity Press Inc., 1981.

Sterman, J. *Business Dynamics*. Irwin, 2000.

Sterman, J. D. "Modeling Managerial Behavior: Misperceptions of Feedback in a Dynamic Decision Making Experiment." *Management science* (1989): 321-39.

Sterman, J. D., J. W. Forrester, A. K. Graham, and P. M. Senge. "An Integrated Approach to the Economic Long Wave. Paper Read at Long Waves." *Depression, Innovation, Siena-Florence, Italy* (1983).

Sweeney, L. B., and J. D. Sterman. "Bathtub Dynamics: Initial Results of a Systems Thinking Inventory." *System Dynamics Review* 16, no. 4 (2000): 249-86.

Towill, D. R. "Industrial Dynamics Modelling of Supply Chains." *Logistics Information Management* 9, no. 4 (1996): 43-56.

Vennix, J. A. M. *Group Model Building: Facilitating Team Learning Using System Dynamics*. J. Wiley, 1996.

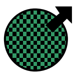
Warren, K. *Competitive Strategy Dynamics*. John Wiley & Sons Inc, 2002.

Appendix 1. Guideline for the model

For easier use and understanding of the model, some naming and color codes were used. Every sector has a prefix associated with that sector and aa special color as background.

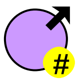
	Example	Meaning
Bold Black name	**m_tSeniorLeaving**	Estimation with strong accuracy
Bold gray name	**m_tSalesmanExp**	Estimation with medium accuracy
Bold Blue name	**m_refNoVisitsJrSalesman**	Estimation with weak accuracy
M_ prefix	m_tSeniorLeaving	Marketing and sales Sector
C_ prefix	C_NewCustomer	Custoemrs sector
I_ prefix	I_EQInTransit	Inventory sector
F_ prefix	F_cash	Finance Sector
P_prefix	P_AdjInTransit	Policy structure
Orange background		Marketing and sales Sector
Yellow background		Custoemrs sector
Purple Background		Inventory sector
Green Background		Finance Sector

Any variable used in other sector, it is filled with a chessboard pattern in its home sector. For example, Delivery in inventory sector view (home)

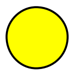


I_EQDelivery

When a variable is imported to another sector, it is filled with the color of its sector. For example, Delivery used in finance sector.



I_EQDelivery

All the policy structure variables are shown in dark yellow .  P_adjCCO

Appendix 2. List of Equations

	Name	Unit	Definition
1	C_AreaCoverageElasticity		0.1
2	C_AverageDemandForNewCustomer	unit/customer	C_refUnitPurchasePerCustomer*C_FractionPurchasefNewCustomerToDemandOfexistingCustomer
3	C_CompetitorCustomer	customer	60<<customer>>
4	C_CompetitorCustomerBecomeShared	customer/yr	MIN(m_MaximumNoCompetitorsCustomerBeingEfficientlyContacted*1<<mo>>, C_CompetitorCustomer)*C_fractionOfCustomersHavingDemand*C_SalesEffectivnessForCompetitorsCustomers
5	C_CompetitorNewCustomerRate	customer/mo	C_NewCustomer - C_WinNewCustomerRate
6	C_CompetitorPrice	USD/Equipment	162000<<USD/Equipment>>
7	C_CompetitorsAreaCoverage		1
8	C_CompetitorsDelivaryTime	mo	2<<mo>>
9	C_CompetitorsTermsOfpayment		1
10	C_CustomersBuyingFromWin	customer/mo	C_fractionOfCustomersHavingDemand*(C_WinCustomer+C_WinsShareFromSharedCustomers*C_SharedCustomer)
11	C_EffectofAreaCoverageOnAcceptibility		(C_WinVsCompetitorsAreaCoverage/C_InitialWinVsCompetitorsAreaCoverage)^C_AreaCoverageElasticity
12	C_EffectofPriceOnAcceptibility		(C_WinVsCompetitorPrice/C_InitialWinvsCompetitorPrice)^C_priceElasticity

13	C_EffectOfSalesmanRelationOnSalesAcceptibility		(m_SalesmanrRelationwithCustomer/m_InitialSalesmanrRelationwithCustomer)^C_ElasicityfSalesRelationForCurrentCustomer
14	C_EffectOfServiceQualityForCurrentCustomer		(C_WinServiceQuality/C_InitialWinServiceQuality)^C_ElasticityOfServiceQualityForCurrentCustomer
15	C_EffectofWinDelivaryTimeOnAcceptibility		(C_WinVsRivalsDelivaryTime/C_InitialWinVsRivalsDelivaryTime)^C_ElasticityOfDelivaryTimeForNewCustomers
16	C_EffectOfWinPartsDelivaryDelay		(C_WinPartsDelivaryDelay/C_InitialWinPartsDelivaryDelay)^C_ElasiticityOfWinPartsDelivaryDelay
17	C_EffectOfWinTermsOfPayment		(C_WinVsCompetitorsTermsOfPayment/C_InitialWinVsCompetitorsTermsOfPayment)^C_ElasticityTermsOfPaymentForCurrentCustomer
18	C_ElasicityfSalesRelationForCurrentCustomer		0.4
19	C_ElasiticityOfWinPartsDelivaryDelay		-0.1
20	C_ElasticityOfDelivaryTimeForNewCustomers		-0.1
21	C_ElasticityOfServiceQualityForCurrentCustomer		0.8
22	C_ElasticityTermsOfPaymentForCurrentCustomer		0.3
23	C_fractionOfCustomersHavingDemand	mo^-1	CX_seaonalEffectonCustomersPurchase*C_RefFracttionCustomersHavingDemand
24	C_FractionPurchasefNewCustomerToDemandOfexistingCustomer		0.2

25	C_InitialAcceptibilityForCurrentCustomers		0.6
26	C_InitialAcceptibilityForWinNewCustomers		0.5
27	C_InitialSalesEffectivnessForCompetitorsCustomers		0.2
28	C_InitialWinPartsDelivaryDelay		INIT(C_WinPartsDelivaryDelay)
29	C_InitialWinServiceQuality		INIT(C_WinServiceQuality)
30	C_InitialWinvsCompetitorPrice		INIT(C_WinVsCompetitorPrice)
31	C_InitialWinVsCompetitorsAreaCoverage		INIT(C_WinVsCompetitorsAreaCoverage)
32	C_InitialWinVsCompetitorsTermsOfPayment		INIT(C_WinVsCompetitorsTermsOfPayment)
33	C_InitialWinVsRivalsDeliveryTime		INIT(C_WinVsRivalsDelivaryTime)
34	c_marketshare		C_WinTotalDemand/C_TotalMarketDemand
35	C_NewCustomer	customer/mo	CX_seaonalEffectForNewCustomer*C_NewCustomerBase
36	C_NewCustomerBase	customer/mo	10 <<customer/mo>>
37	C_NewCustomerDemand	unit/mo	C_NewCustomer*C_AverageDemandForNewCustomer
38	C_newRelationWiThWinSalesforce		0.8
39	C_OverallEffectAcceptabilityOfWinForRivalCustomers		C_EffectOfWinTermsOfPayment*C_EffectofAreaCoverageOnAcceptibility*C_EffectofPriceOnAcceptibility*C_EffectofWinDelivaryTimeOnAc

			ceptibility
40	C_OverallEffectOnAcceptabilityForCurrentCustomers		C_EffectOfSalesmanRelationOnSalesAcceptibility*C_EffectOfWinTermsOfPayment*C_EffectofPriceOnAcceptibility*C_EffectofWinDelivaryTimeOnAcceptibility*C_EffectofAreaCoverageOnAcceptibility
41	C_OverallEffectOnAcceptabilityOfWinForNewCustomers		C_EffectofAreaCoverageOnAcceptibility*C_EffectofPriceOnAcceptibility*C_EffectofWinDelivaryTimeOnAcceptibility
42	C_priceElasticity		-3
43	C_RefFracttionCustomersHavingDemand	mo^-1	0.016<<1/mo>>
44	C_refUnitPurchasePerCustomer	unit/customer	10<<unit/customer>>
45	C_SalesEffectivityForNewCustomers		C_OverallEffectOnAcceptabilityOfWinForNewCustomers*C_InitialAcceptibilityForWinNewCustomers
46	C_SalesEffectivnessForCompetitorsCustomers		C_OverallEffectAcceptabilityOfWinForRivalCustomers*C_InitialSalesEffectivnessForCompetitorsCustomers
47	C_SalesEffectivnessForCurrentCustomers		C_OverallEffectOnAcceptabilityForCurrentCustomers*C_InitialAcceptibilityForCurrentCustomers
48	C_SharedCustomer	customer	200<<customer>>
49	C_TotalMarketDemand	unit/mo	((C_WinCustomer+C_SharedCustomer+C_CompetitorCustomer)*C_refUnitPurchasePerCustomer*C_fractionOfCustomersHavingDemand)+C_NewCustomerDemand
50	C_WinAreaCoverage		0.8

51	C_WinCurrentDemand	unit/mo	C_CustomersBuyingFromWin*C_refUnitPurchasePerCustomer
52	C_WinCustomer	customer	40<<customer>>
53	C_WinCustomerBecomeShared	customer/mo	C_WinCustomer*C_fractionOfCustomersHavingDemand*C_SalesEffectivnessForCurrentCustomers
54	C_WinDelivaryTime	mo	I_EstimatedDeliveryTime
55	C_WinNewCustomerRate	customer/mo	C_NewCustomer*'C_SalesEffectivityFor NewCustomers'
56	C_WinPartsDelivaryDelay		1
57	C_WinPrice	USD/Equipment	170000<<USD/Equipment>>
58	C_WinServiceQuality		0.7
59	C_WinsShareFromShared Customers		C_SalesEffectivnessForCurrentCustomers
60	C_WinTermsOfPayment		1
61	C_WinTotalCustomer	customer	C_SharedCustomer+C_WinCustomer
62	C_WinTotalDemand	unit/mo	C_WonNewCustomerPurchase+C_WinCurrentDemand
63	C_WinVsCompetitorPrice		C_WinPrice/C_CompetitorPrice
64	C_WinVsCompetitorsArea Coverage		C_WinAreaCoverage/C_CompetitorsAreaCoverage
65	C_WinVsCompetitorsTermsOfPayment		C_WinTermsOfPayment/C_CompetitorsTermsOfpayment
66	C_WinVsRivalsDelivaryTime		C_WinDelivaryTime/C_CompetitorsDelivaryTime
67	C_WinWordOfMouth		0.5
68	C_WonNewCustomerPurc	unit/mo	C_AverageDemandForNewCustomer*C_WinNe

	hase		wCustomerRate
69	CX_seaonalEffectForNew Customer	1	XLDATA("data/data inv.xlsx","Input Data", "D9", FLIP)<<1>>
70	CX_seaonalEffectonCustomersPurchase	1	XLDATA("data/data inv.xlsx","Input Data", "D11", FLIP)
71	CX_WinNewCustomerRate	customer/mo	XLDATA("data/data inv.xlsx","Input Data", "D8", FLIP)<<customer/mo>>
72	CX_WinTotalDemand	Equipment/mo	XLDATA("data/data inv.xlsx","Input Data", "D5", FLIP)<<Equipment/mo>>
73	f_AcctRecEquipMo1	USD	1<<mo>> * f_arEquipBecomingMo1
74	f_AcctRecEquipMo2	USD	1<<mo>> * f_arEquipBecomingMo2
75	f_AcctRecEquipMo3	USD	1<<mo>> * f_arEquipBecomingMo3
76	f_AcctRecEquipMo4	USD	1<<mo>> * f_arEquipBecomingMo4
77	f_AcctRecEquipMo5	USD	1<<mo>> * f_arEquipBecomingMo5
78	f_AcctRecEquipMo6	USD	1<<mo>> * f_arEquipBecomingMo6
79	f_apBecomingEquipMo2	USD/mo	DELAYPPL (f_apOutstandingFromEquipmentImports * (1 - f_percentPaymentAcctPayEquipMo1) , 1<<mo>> , f_apOutstandingFromEquipmentImports * (1 - f_percentPaymentAcctPayEquipMo1))
80	f_apBecomingEquipMo3	USD/mo	DELAYPPL (f_apBecomingEquipMo2 * (1- f_percentPaymentAcctPayEquipMo2) , 1<<mo>> , f_apBecomingEquipMo2 * (1- f_percentPaymentAcctPayEquipMo2))
81	f_APcashExpenseFromAP EquipmentImports	USD/mo	f_cashPaymentAcctPayEquipMo1+f_cashPaymentAcctPayEquipMo2+f_cashPaymentAcctPayEquipMo3

82	f_apOutstandingFromEquipmentImports	USD/mo	f_expenseOnEquipmentImports *(1-f_percentCashPaymentEquipmentImports)
83	f_ARDueToCurrentDate	USD/mo	f_cashCollectedEquipARMo1+f_cashCollectedEquipARMo2+f_cashCollectedEquipARMo3+f_cashCollectedEquipARMo4+f_cashCollectedEquipARMo5+f_cashCollectedEquipARMo6
84	f_arEquipBecomingMo1	USD/mo	f_totalSalesAmount *f_percentEquipRevBecomingSkedAR
85	f_arEquipBecomingMo2	USD/mo	DELAYPPL(f_arEquipBecomingMo1 * (1 - f_percentCollectedEquipARMo1) , 1<<mo>> , f_arEquipBecomingMo1 * (1 - f_percentCollectedEquipARMo1))
86	f_arEquipBecomingMo3	USD/mo	DELAYPPL(f_arEquipBecomingMo2 * (1 - f_percentCollectedEquipARMo2) , 1<<mo>> , f_arEquipBecomingMo2 * (1 - f_percentCollectedEquipARMo2))
87	f_arEquipBecomingMo4	USD/mo	DELAYPPL(f_arEquipBecomingMo3 * (1 - f_percentCollectedEquipARMo3) , 1<<mo>> , f_arEquipBecomingMo3 * (1 - f_percentCollectedEquipARMo3))
88	f_arEquipBecomingMo5	USD/mo	DELAYPPL(f_arEquipBecomingMo4 * (1 - f_percentCollectedEquipARMo4) , 1<<mo>> , f_arEquipBecomingMo4 * (1 - f_percentCollectedEquipARMo4))
89	f_arEquipBecomingMo6	USD/mo	DELAYPPL(f_arEquipBecomingMo5 * (1 - f_percentCollectedEquipARMo5) , 1<<mo>> , f_arEquipBecomingMo5 * (1 - f_percentCollectedEquipARMo5))
90	f_averageDelayTimeforPaymentOfOldDebt	mo	3<<mo>>
91	f_AverageDelayTimeforPaymentOfRiskyDebt	mo	18<<mo>>

92	f_cash	USD	3E+07
93	f_cashCollectedEquipARMo1	USD/mo	DELAYPPL((f_arEquipBecomingMo1 * f_percentCollectedEquipARMo1), 1<<mo>> , f_arEquipBecomingMo1 * f_percentCollectedEquipARMo1)
94	f_cashCollectedEquipARMo2	USD/mo	DELAYPPL(f_arEquipBecomingMo2 * f_percentCollectedEquipARMo2, 1<<mo>> , f_arEquipBecomingMo2 * f_percentCollectedEquipARMo2)
95	f_cashCollectedEquipARMo3	USD/mo	DELAYPPL((f_arEquipBecomingMo3 * f_percentCollectedEquipARMo3), 1<<mo>> , f_arEquipBecomingMo3 * f_percentCollectedEquipARMo3)
96	f_cashCollectedEquipARMo4	USD/mo	DELAYPPL(f_arEquipBecomingMo4 * f_percentCollectedEquipARMo4, 1<<mo>> , f_arEquipBecomingMo4 * f_percentCollectedEquipARMo4)
97	f_cashCollectedEquipARMo5	USD/mo	DELAYPPL(f_arEquipBecomingMo5 * f_percentCollectedEquipARMo5, 1<<mo>> , f_arEquipBecomingMo5 * f_percentCollectedEquipARMo5)
98	f_cashCollectedEquipARMo6	USD/mo	DELAYPPL(f_arEquipBecomingMo6 , 1<<mo>> , f_arEquipBecomingMo6)
99	f_cashCollectedEquipPickup	USD/mo	f_cashCollectedFromCashSalesAtEquipPickup+f_cashCollectedFromCreditSalesAtEquipPickup
100	f_cashCollectedFromARDelinquent	USD/mo	f_DeliquentPayment
101	f_cashCollectedFromCashSalesAtEquipPickup	USD/mo	f_totalSalesAmount*(1-f_percentDownPaymentFromCCO) *f_percentCashSalesOfAllSales

102	f_cashCollectedFromCreditSalesAtEquipPickup	USD/mo	f_totalSalesAmount *(1-f_percentDownPaymentFromCCO) *(1-f_percentCashSalesOfAllSales) *f_percentCashCollectedOfCreditSalesAtPickup
103	f_cashCollectedFromDownPaymentAtCCO	USD/mo	f_percentDownPaymentFromCCO*f_revenueFromCCOIssuesSales
104	f_cashCollectedFromEquipAR	USD/mo	f_ARDueToCurrentDate*(1-f_percentageOfArBecomeLate)
105	f_cashExpenseFromEquipmentImports	USD/mo	f_expenseOnEquipmentImports *f_percentCashPaymentEquipmentImports
106	f_cashExpenseSalesmanCompensation	USD/mo	f_commissionTotal+f_salarybaseTotal
107	f_cashPaymentAcctPayEquipMo1	USD/mo	DELAYPPL(f_apOutstandingFromEquipmentImports * f_percentPaymentAcctPayEquipMo1 , 1<<mo>> , f_apOutstandingFromEquipmentImports * f_percentPaymentAcctPayEquipMo1)
108	f_cashPaymentAcctPayEquipMo2	USD/mo	DELAYPPL(f_apBecomingEquipMo2 * f_percentPaymentAcctPayEquipMo2 , 1<<mo>> , f_apBecomingEquipMo2 * f_percentPaymentAcctPayEquipMo2)
109	f_cashPaymentAcctPayEquipMo3	USD/mo	DELAYPPL(f_apBecomingEquipMo3, 1<<mo>> , f_apBecomingEquipMo3)
110	f_cogsEquipmentImports	USD/Equipment	150000
111	f_commissionPerEquipmentSold	USD/Equipment	120
112	f_commissionTotal	USD/mo	f_equipPickups*f_commissionPerEquipmentSold
113	f_DebtBecomingDeliquentRate	USD/mo	f_ARDueToCurrentDate*f_percentageOfArBecomeLate

114	f_DebtBecomingRisky	USD/mo	f_OldDebt/f_TimeforOldDebtToBecomeRisky
115	f_DeliquentPayment	USD/mo	f_OldDebt/f_averageDelayTimeforPaymentOfOldDebt
116	f_DeliquentPaymentFromRiskyDebt	USD/mo	f_riskyAR/f_AverageDelayTimeforPaymentOfRiskyDebt
117	f_equipImports	Equipment/mo	I_EQShippment
118	f_equipPickups	Equipment/mo	I_EQDelivery
119	f_expenseOnEquipmentImports	USD/mo	f_equipImports *f_cogsEquipmentImports
120	f_Expenses	USD/mo	f_APcashExpenseFromAPEquipmentImports+f_cashExpenseFromEquipmentImports+f_cashExpenseSalesmanCompensation
121	f_Income	USD/mo	f_cashCollectedFromCreditSalesAtEquipPickup+f_cashCollectedFromEquipAR+f_cashCollectedFromARDelinquent+f_cashCollectedFromCashSalesAtEquipPickup+f_cashCollectedFromDownPaymentAtCCO
122	f_JuniorSalesman	person	m_JuniorSalesman
123	f_OldDebt	USD	0<<USD>>
124	f_ordinaryDebt	USD	f_ordinaryDebtInitial
125	f_ordinaryDebtInitial	USD	f_AcctRecEquipMo1+f_AcctRecEquipMo2+f_AcctRecEquipMo3+f_AcctRecEquipMo4+f_AcctRecEquipMo5+f_AcctRecEquipMo6
126	f_percentageOfArBecomeLate		0.1
127	f_percentCashCollectedOfCreditSalesAtPickup		0.25
128	f_percentCashPaymentEquipmentImports	1	0.5

129	f_percentCashSalesOfAllSales		0.7
130	f_percentCollectedEquipARMo1		0.166667
131	f_percentCollectedEquipARMo2		0.2
132	f_percentCollectedEquipARMo3		0.25
133	f_percentCollectedEquipARMo4		0.3333
134	f_percentCollectedEquipARMo5		0.5
135	f_percentDownPaymentFromCCO		0.2
136	f_percentEquipRevBecomingSkedAR		(1 - f_percentDownPaymentFromCCO) *(1 - f_percentCashSalesOfAllSales) *(1 - f_percentCashCollectedOfCreditSalesAtPickup)
137	f_percentPaymentAcctPayEquipMo1		0.33
138	f_percentPaymentAcctPayEquipMo2	1	0.5
139	f_pricePerEquipmentSold	USD/Equipment	C_WinPrice
140	f_revenueFromCCOIssuesSales	USD/mo	I_CCOIssueRate*f_pricePerEquipmentSold
141	f_riskyAR	USD	0<<USD>>
142	f_salaryBaseJuniorSalesman	USD/mo	f_JuniorSalesman*f_salaryPerJunior
143	f_salaryBaseSeniorSalesman	USD/mo	f_SeniorSalesman*f_salaryPerSenior

144	f_salarybaseTotal	USD/mo	f_salaryBaseJuniorSalesman+f_salaryBaseSeniorSalesman+f_salaryBaseTraineeSalesman
145	f_salaryBaseTraineeSalesman	USD/mo	f_TraineeSalesman*f_salaryPerTrainee
146	f_salaryPerJunior	USD/person/mo	130
147	f_salaryPerSenior	USD/person/mo	130
148	f_salaryPerTrainee	USD/person/mo	100
149	f_SeniorSalesman	person	m_SeniorSalesman
150	f_TimeforOldDebtToBecomeRisky	mo	8<<mo>>
151	f_totalSalesAmount	USD/mo	I_sales*C_WinPrice
152	f_TraineeSalesman	person	m_TraineeSalesman
153	I_allocationChange	Equipment/mo	STEP(1,2012<<@yr>>)*(MAX(I_maxAllocationSubtract,MIN(I_MaxAllocationAddition,p_PolicySwitch*(P_AdjInventory+P_adjCCO))))
154	I_Cancellation Rate	Equipment/mo	(I_CCO*I_effectOfETDonCancellation)*I_SwitchToEnoCancellationRate+DELAYPPL(IX_CCOCancelationRate, 2<<mo>>)*(1-I_SwitchToEnoCancellationRate)
155	I_CCO	Equipment	100
156	I_CCOIssueRate	Equipment/mo	I_TotalDemand*I_SwitchToIndogenizeDemand+CX_WinTotalDemand*(1-I_SwitchToIndogenizeDemand)
157	I_desiredInventory	Equipment	P_PerceivedSales*I_desiredInventoryCoverage
158	I_desiredInventoryCoverage	mo	0.1<<mo>>
159	I_DesiredTimeDelivary	mo	2<<mo>>

160	I_effectOfETDonCancellation	mo^-1	GRAPH(I_EstimatedDelivaryTime/I_DesiredTimeDelivary,0,0.5,{0,0.00,0,0.02,0.055,0.094,0.165,0.245,0.326,0.368,0.4//Min:-0.5;Max:0.5//}<<1/mo>>)
161	I_EQCustomClearence	Equipment/mo	DELAYPPL(I_EQShippment,I_timeInTransit)
162	I_EQDelivery	Equipment/mo	I_sales
163	I_EQInPricipalStock	Equipment	I_timeShipment*I_Production
164	I_EQinProduction	Equipment	I_EQUnderFinalProduction+I_EQUnderPrimaryProduction
165	I_EQInTransit	Equipment	I_EQShippment*I_timeInTransit
166	I_EQShippment	Equipment/mo	DELAYPPL(I_Production,I_timeShipment)
167	I_EQStockHO	Equipment	6
168	I_EQtoFinalProduction	Equipment/mo	DELAYPPL(I_orderPlan,I_timePrimaryProduction)
169	I_EQUnderFinalProduction	Equipment	I_EQtoFinalProduction*I_timeFinalProduction
170	I_EQUnderPrimaryProduction	Equipment	IX_YearlyPlan*I_timePrimaryProduction
171	I_EstimatedDelivaryTime	mo	I_CCO/I_sales
172	I_expectedDemandForNextYear	Equipment/mo	DELAYPPL(P_PerceivedSales*(1+p_growthrate/10),7<<mo>>)
173	I_fractionEQUnderProductAllowedToChange	mo^-1	0.5<<1/mo>>
174	I_fractionOfCustomersReadyToPurchase	mo^-1	0.5<<1/mo>>
175	I_InTransitEquipment	Equipment	I_EQInPricipalStock+I_EQInTransit
176	I_InventoryCoverge	mo	I_EQStockHO/I_EQDelivery

177	I_MaxAllocationAddition	Equipment/mo	I_fractionEQUnderProductAllowedToChange*I_EQUnderFinalProduction
178	I_maxAllocationSubtract	Equipment/mo	######
179	I_maxEQreadyForSalePerMonth	Equipment/mo	MAX(0<<Equipment/mo>>,I_EQStockHO/I_timeRequiredToDelivery)
180	I_maxEQreadyToBuyPerMonth	Equipment/mo	I_CCO*I_fractionOfCustomersReadyToPurchase
181	I_orderPlan	Equipment/mo	MAX(0<<Equipment/mo>>,(I_expectedDemandForNextYear+p_PolicySwitch*P_PercevedAdj))*(1-I_YearlyPlanTimeSwitch)+(IX_YearlyPlan*I_YearlyPlanTimeSwitch)
182	I_Production	Equipment/mo	'I_Switch for endo ordering'*((I_EQUnderFinalProduction/I_timeFinalProduction)- I_allocationChange)+(1-'I_Switch for endo ordering')*IX_ShipmentPlan
183	I_sales	Equipment/mo	MAX(0<<Equipment/mo>>,MIN(I_maxEQreadyForSalePerMonth, I_maxEQreadyToBuyPerMonth))
184	I_Switch for endo ordering		STEP(1, 2010<<@yr>>)
185	I_SwitchToEnoCancellationRate		1
186	I_SwitchToIndogenizeDemand		1
187	I_timeFinalProduction	mo	1<<mo>>
188	I_timeInTransit	mo	2<<mo>>
189	I_timePrimaryProduction	mo	1<<mo>>
190	I_timeRequiredToDelivery	mo	3<<da>>
191	I_timeShipment	mo	3<<da>>

192	I_TotalDemand	Equipment/mo	DELAYPPL(C_WinTotalDemand*1<<Equipment/unit>>,1<<mo>>)
193	I_YearlyPlanTimeSwitch		1+STEP(-0.5,2011<<@yr>>)+STEP(-0.5,2012<<@yr>>)
194	IX_CCOCancelationRate	Equipment/mo	XLDATA("data/data inv.xlsx","Input Data", "D7", FLIP)<<Equipment/mo>>
195	IX_EQStockHO	Equipment/mo	XLDATA("data/data inv.xlsx","Input Data", "D12", FLIP)<<Equipment/mo>>
196	IX_ShipmentPlan	Equipment/mo	XLDATA("data/data inv.xlsx","Input Data", "D3", FLIP)<<Equipment/mo>>
197	IX_YearlyPlan	Equipment/mo	XLDATA("data/data inv.xlsx","Input Data", "D6", FLIP)<<Equipment/mo>>
198	m_ATforRelationshipToChange	mo	3<<mo>>
199	m_CompetitorsVisitEffectiveness	customer/visit	0.05<<customer/visit>>
200	m_CustomerspereachSalesman	customer/person	C_WinTotalCustomer/m_totalSalesman
201	m_EffectOfSalesmRelationshipEfficiencyOnSalesmanrelationShip	1	GRAPH(m_SalesmanRelationshipEfficency,0,0.1,{0,0.026,0.08,0.18,0.34,0.5,0.626,0.79,0.89,0.97,1//Min:0;Max:1//})
202	m_EffOfCustomerOverflowOnCompetitorsVisits	1	GRAPH(m_ratioOfActalToRefNoCustomers,0,1,{1,0.0//Min:-1;Max:11//})
203	m_FractionJuniorReassignment	1	0.20
204	m_FractionTraineeReassignment	1	0.20
205	m_IndicatedQltBusinessRelationship	1	m_EffectOfSalesmRelationshipEfficiencyOnSalesmanrelationShip*m_TargetQltBusinessRelations

			hip
206	m_InitialSalesmanrRelationwithCustomer	1	INIT(m_SalesmanrRelationwithCustomer)
207	m_ix_traineesHiredPerYear	person/yr	3
208	m_juniorleaving	person/mo	m_JuniorSalesman*m_FractionJuniorReassignment/m_tSalesmanExp
209	m_JuniorSalesman	person	11
210	m_MaximumNoCompetitorsCustomerBeingEfficientlyContacted	customer/mo	m_VisitsCompetitorsCustomer*m_CompetitorsVisitEffectiveness
211	m_ratioOfActalToRefNoCustomers		C_WinTotalCustomer/m_RefNoCustomer
212	m_RefNoCustomer	customer	m_RefNoCustomersFromJrSalesman+m_RefNoCustomersFromSrSalesman
213	m_RefNoCustomersFromJrSalesman	customer	m_JuniorSalesman*m_RefNoCustomersPerJrSalesman
214	m_RefNoCustomersFromSrSalesman	customer	m_SeniorSalesman*m_RefNoCustomersPerSrSalesman
215	m_RefNoCustomersPerJrSalesman	customer/person	m_refNoVisitsJrSalesman/m_refNoVisistsreqiredFromCustomer
216	m_RefNoCustomersPerSrSalesman	customer/person	m_refNoVisitsSrSalesman/m_refNoVisistsreqiredFromCustomer
217	m_refNoVisistsreqiredFromCustomer	visit/(mo*customer)	2<<visit/customer/mo>>
218	m_refNoVisitsJrSalesman	visit/(mo*person)	30<<visit/person/mo>>
219	m_refNoVisitsSrSalesman	visit/(mo*perso	40<<visit/person/mo>>

		n)	
220	m_refNoVisitsToCompetitorsCustomerPerSalesman	visit/(mo*person)	30<<visit/person/mo>>
221	m_RefNoVisitsToRivalCustomers	visit/mo	m_totalSalesman*m_refNoVisitsToCompetitorsCustomerPerSalesman
222	m_salesmanExp	person/mo	m_JuniorSalesman*(1-m_FractionJuniorReassignment)/m_tSalesmanExp
223	m_SalesmanRelationChangeRate	mo^-1	(m_IndicatedQltBusinessRelationship-m_SalesmanrRelationwithCustomer)/m_ATforRelationshipToChange
224	m_SalesmanRelationshipEfficency		1/m_ratioOfActalToRefNoCustomers
225	m_SalesmanrRelationwithCustomer		1
226	m_salesmanTraineeHiring	person/mo	m_ix_traineesHiredPerYear/12<<mo/yr>>
227	m_salesmanTraining	person/mo	m_TraineeSalesman*(1-m_FractionTraineeReassignment)/m_tsalestraining
228	m_seniorLeaving	person/mo	m_SeniorSalesman/m_tSeniorLeaving
229	m_SeniorSalesman	person	17
230	m_TargetQltBusinessRelationship		1
231	m_totalSalesman	person	m_JuniorSalesman+m_SeniorSalesman
232	m_traineeReassignment	person/mo	m_TraineeSalesman*m_FractionTraineeReassignment/m_tsalestraining
233	m_TraineeSalesman	person	3
234	m_tSalesmanExp	mo	24

235	m_tsalestraining	mo	12
236	m_tSeniorLeaving	mo	48
237	m_VisitsCompetitorsCustomer	visit/mo	m_RefNoVisitsToRivalCustomers*m_EffOfCustomerOverflowOnCompetitorsVisits
238	p_AccumulativeSale	Equipment	0<<Equipment>>
239	P_adjCCO	Equipment/mo	(I_CCO-p_DesiredCCO)/p_timeToAdjCCO
240	P_adjInOrdering	Equipment/mo	P_AdjInTransit+P_AdjInventory+P_adjInProduction-I_allocationChange
241	P_adjInProduction	Equipment/mo	(P_desiredInProduction-I_EQinProduction)/P_TimeToAdjIP
242	P_AdjInTransit	Equipment/mo	0*(P_DesiredInTransit-I_InTransitEquipment)/P_TimeToAdjIT
243	P_AdjInventory	Equipment/mo	(I_desiredInventory-I_EQStockHO)/P_timetoadjInv
244	p_AnnualAccGrowthRate		0
245	P_AnnualGrowthRateTrend	yr^-1	P_GrowthRateofLastYear/1<<yr>>
246	P_AnnualTimePulse		PULSE(TIMESTEP,2011<<@yr>>,1<<yr>>)
247	P_ATSalesPerception	mo	1<<mo>>
248	P_changeInPerceivedAdj	Equipment/mo^2	(P_adjInOrdering-P_PercevedAdj)/TIMESTEP
249	P_changeInPerceivedSales	Equipment/mo^2	(I_sales-P_PerceivedSales)/P_ATSalesPerception
250	p_DesiredCCO	Equipment	P_PerceivedSales*P_desiredCCOCoverage
251	P_desiredCCOCoverage	mo	3<<mo>>
252	P_desiredInProduction	Equipment	P_desiredInProductionCoverage*P_PerceivedSales

253	P_desiredInProductionCoverage	mo	2<<mo>>
254	P_DesiredInTransit	Equipment	P_PerceivedSales*P_desiredInTransitCoverage
255	P_desiredInTransitCoverage	mo	2.1<<mo>>
256	p_growthrate		(P_SaleForOneYearAgo-p_SalesForTwoYearsAgo)/p_SalesForTwoYearsAgo
257	P_GrowthRatebecomingOneyearOld	mo^-1	p_AnnualAccGrowthRate*P_AnnualTimePulse/TIMESTEP
258	p_growthrateByTrend	yr^-1	TREND(p_AccumulativeSale,1<<yr>>,200<<Equipment>>)
259	P_growthRateClearing	mo^-1	P_GrowthRateofLastYear*P_AnnualTimePulse/TIMESTEP
260	P_GrowthRateofLastYear		0.1
261	P_PerceivedSales	Equipment/mo	30<<Equipment/mo>>
262	P_PercevedAdj	Equipment/mo	0<<Equipment/mo>>
263	p_PolicySwitch		0
264	p_SaleAging1year	Equipment/mo	P_AnnualTimePulse*p_AccumulativeSale/TIMESTEP
265	p_SaleAging2year	Equipment/mo	P_SaleForOneYearAgo*P_AnnualTimePulse/TIMESTEP
266	P_SaleAging3year	Equipment/mo	P_AnnualTimePulse*p_SalesForTwoYearsAgo/TIMESTEP
267	P_SaleForOneYearAgo	Equipment	250<<Equipment>>
268	p_SalesForTwoYearsAgo	Equipment	200<<Equipment>>
269	p_timeToAdjCCO	mo	7.56<<mo>>

270	P_timetoadjInv	mo	2.48<<mo>>
271	P_TimeToAdjIP	mo	7.74<<mo>>
272	P_TimeToAdjIT	mo	7.74<<mo>>