DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MODELLING AND ANALYSIS OF COMPLEXITY IN SERVICE SYSTEMS

by
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İZMİR

MODELLING AND ANALYSIS OF COMPLEXITY IN SERVICE SYSTEMS

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MODELLING AND ANALYSIS OF COMPLEXITY IN SERVICE SYSTEMS

ABSTRACT

Complexity is a topic of interest nowadays and even still there is no consensus about the definition of it. This PhD study starts with building up a generic definition of the term and understanding the characteristics of the complexity.

Aim of this study is to explain the complexity from retail supply chain perspective. Existing complexity literature for manufacturing systems and supply chains has been analyzed and a new classification scheme has been proposed.

An important contribution of this research is the use of system dynamic modeling in a retail supply chain to derive insight about the dynamic behavior and to represent the complex interactions. Four different retail supply chain management scenarios have been simulated on system dynamics software STELLA. Using the new classification scheme for complexity and suggested performance metrics for the retail supply chain, a multi-perspective analysis has been performed on the system dynamics output. Complexity of the scenarios has been reviewed to investigate if the complexity is useful -so that increasing its performance and flexibility- or creating issues. The used complexity metrics also indicate the problematic areas in the system to be sorted out.

Keywords: Retail supply chains, complexity, entropy, system dynamics

SERVİS SİSTEMLERİNDE KARMAŞIKLIĞIN MODELLENMESİ VE ANALİZİ

ÖZ

Karmaşıklık günümüzde oldukça ilgi çeken konulardan biri olmasına rağmen henüz fikir birliğine varılmış genel bir tanımı yapılmamıştır. Bu doktora çalışması öncelikli olarak kavramın tanımının oluşturulması ve özelliklerinin kavranması ile başlamaktadır.

Çalışmanın amacı karmaşıklığı perakende tedarik zinciri bakış açısıyla açıklamaktır. Literatürde üretim sistemleri ve tedarik zinciriyle ilgili karmaşıklık çalışmaları araştırılmış ve yeni bir sınıflandırma planı oluşturulmuştur.

Bu çalışmanın en önemli katkılarından biri de perakende tedarik zincirinin dinamik davranış biçimini ve kompleks ilişkilerini ortaya koyabilmek amacıyla sistem dinamiği modellemesinin kullanılmasıdır. Sistem dinamiği yazılımı STELLA kullanılarak dört farklı perakende tedarik zinciri yönetim senaryosu simule edilmiştir. Karmaşıklık için yeni oluşturulan sınıflandırma planı ve perakende tedarik zinciri özelinde önerilen performans ölçümleri çerçevesinde, system dinamik model çıktıları çok yönlü olarak değerlendirilmiştir. Senaryoların karmaşıklığı değerlendirilip, karmaşıklığın sistemin performansı ve esnekliği üzerinde olumlu ya da problem yaratıcı bir etkisi olup olmadığı araştırılmıştır. Burada kullanılan karmaşıklık ölçütleri aynı zamanda sistemdeki problemli alanların belirlenmesinde de kullanılabilir.

Anahtar kelimeler: Perakende tedarik zincirleri, karmaşıklık, entropi, sistem dinamiği

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CHAPTER ONE
INTRODUCTION

1.1 Motivation

Nowadays, one can easily observe that technological changes increasingly happen throughout time and sometimes people can feel that they are bombarded with the new information in every field; therefore, they have to keep themselves updated. According to “The law of accelerating returns” proposed by Kurzweil (1999), technological progress grows exponentially because of the evolutionary nature of it. According to Kurzweil (1999), as existing technology comes to a point, close to a barrier; a paradigm shift happens (which will occur increasingly common in the future and today) and it will lead to more changes rapidly. Paradigm shift can be better understood by seeing Figure 1.1 (Kuhn, 1962) If the current technology allows seeing the picture as rabbit, completely new technological enhancement can make us see what we already know is wrong and the picture starts to be observed as the duck. In the 21st century, we will not face with 100 years of progress in technology; but we will experience 20,000 years of progress according to today’s rate of change. He claims that technological singularity can be a point the world can end-up-with which means that artificial intelligence can exceed the limitations of human intelligence. With this fast pace change, we can even sometimes notice that our daily lives are becoming complex to manage. Therefore, in the coming years, managing complexity will be a hot topic that will acquire interest of many researchers (Kurzweil, 1999).

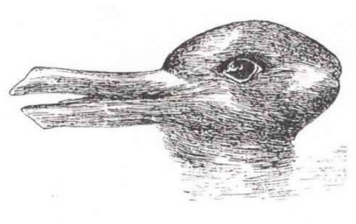

Figure 1.1 Optical illusion used by Kuhn describing paradigm shift (Kuhn, 1962)

On the other hand, companies also need to struggle with the technological changes that can lead to process and product re-design, increasing costs, organizational re-arrangements. Therefore, everyday practitioners -like planners, R&D developers and managers- have to make decisions to keep up with the changes in technology and the changing customer demands. However, in reality they spent majority of their time on daily problems of material shortages, machine failures, last minute changes, accidents, adverse effects of the plans (fluctuations of the plans) rather than making and applying the plans fully. The plans that are in use don't offer optimal solutions of the whole system but concentrate on a specific section of a whole with suboptimal solutions. In this study, understanding the basics of complexity will help us to realize why making decision in reality is so complicated, and how measuring and managing complexity can be possible.

Supply chains show the characteristics of complex systems due to the variety, connectedness in their nature. There is a vast amount of literature on complexity of supply chains from manufacturer point of view. However, retail supply chains have lately started to attract academics with the open problems on operations research and inventory management. It should also be noted that retail industry is starting point of the "bullwhip" effect and causing chaos on the rest of the supply chain due to its fluctuating nature. Therefore, understanding the complexity of it can help the practitioners on their decision making process.

Although significant research has been carried out in analyzing the complexity of the supply chains, up until now there is no research specifically concentrates on retail supply chains. The objective of this research is to model and measure the complexity of the retail supply chains. Since complexity can only be understood with systems thinking, system dynamics modeling is being used in the research. Moreover, describing the relationship between complexity and performance measures is another interest of this study.

1.2 Research Questions

The following research questions have been identified in order to achieve the objective stated in Section 1.1:

- What are the factors driving complexity in retail supply chains specifically?
- How systems thinking can be embedded into the model proposed to measure complexity of retail supply chains?
- How system dynamics modelling can be used in a best way to model the dynamic nature of the retail supply chains?
- How can complexity be quantified in a retail supply chain?
- How changes in the retail supply chain can affect the complexity of the retail supply chain? What can be the possible realistic scenarios to be analyzed?
- How can the relationship be described between complexity and performance measures?
- How can practitioners understand the complexity is “good” or “bad” for the system?

CHAPTER TWO
BACKGROUND & FUNDAMENTAL CONCEPTS

2.1 Definition of Complexity

Even though complexity became a popular and important multidisciplinary topic in science and technology, there is still no consensus about its definition. But the characteristics of it have been provided in numerous papers. Word ***Complex*** has been generated from the Latin word "*cumplexus*" which means "*entwined*" or "*twisted together*". In Oxford dictionary, complex is defined as something that is made of (usually several) closely connected parts. In system theory, complex system consists of at least two components that are not possible to consider independently; therefore, decomposition of the system into its components (or breaking the interactions) would destroy the nature of it (Kinsner, 2010; Sussman, 2002).

System is a set of components interacting with each other and it is distinguished by a real or fictitious boundary from any other components outside the system (Kinsner, 2010). ***Components*** of a system could be elements, building blocks, parts or ingredients of it. ***Interactions*** on a system can take place by interfaces, functional dependencies, communication channels or by any other kind of relation (Marti, 2007).

Condition of a system can be represented with variables that can be qualitative or quantitative values and they are called as ***States***. A state could also be a specification of a system or a process at a particular instant. ***Behavior*** is change of states showing defined patterns that occur over time as in relation to or in combination of other states (Patel & Nagl, 2010). In other words, internal conditions of a system can be shown using state variables; inputs and variables create the behaviour of the system (Kinsner, 2010). Mathematically, linearity of a behaviour can be defined as satisfying the below properties:

$$\textbf{Additivity} \quad : f(x) + f(y) = f(x+y) \tag{2.1}$$

$$\textbf{Homogenity:} \; a \cdot f(x) = f(ax) \tag{2.2}$$

If either of these properties cannot be satisfied by a system, it is called as ***nonlinear***. In a linear system, behavior of the system states can be predicted having knowledge about the previous states and summing it with a fix functional amount using a parametric index (this index is usually time). Complex systems show non-linear behavior because of tightly interrelated components and their behavior cannot be interpreted by investigating components of the system separately (Patel & Nagl, 2010). Mathematically, a dynamic system composes of a set of rules showing the evolution of system in terms of its states in time t on the phase space (space showing all possible states). If the model of the system is linear, the overall effect on the system output is generated from individual causes at the input of the system which is represented as the summation of each cause separately. Therefore, using Laplacian scientific reductionist approach, one can decompose the system into its components and analyze them separately. However, if the dynamic system is nonlinear, a small cause can end up with larger effects and reductionist approach would be no longer valid (Kinsner, 2010). Therefore; idea of managing complexity conflicts with the nature of scientific management and planning paradigm (Sunderraman, 1998).

It could be thought that complexity is something that composes of many interacting components. But it could not define complexity totally. Complex systems should show ***emergence*** phenomenon. In a complex system, even though one can have the complete knowledge on the system components, system’s behavior cannot be deduced investigating the components in isolation. The whole is greater than the sum of its parts; therefore, emergence concept is related with non-linearity, non-additivity and non-homogeneity. The system shows different characteristics from that of each component, leading to a collective, highly structured behavior. An example of emergence phenomenon is the snow crystals (Patel & Nagl, 2010; Kinsner, 2010; Marczyk & Deshpande, 2010).

Another important characteristic of complexity is ***Self-organization*** which is formation or adaptation of a system as a result of some interactions between components from an initially disordered system (Kinsner, 2010). Even though, sometimes the terms self-organization and emergence are used as synonyms of each other, they are two distinct phenomena. Emergence is a macro level behaviour which happens as a result of interactions between components of the system. But, self-organization is the dynamic and adaptive increase in the order and structure of the system without external control. In most of the complex systems, self-organization and emergence exists together (Wolf & Holvoet, 2005). Examples are Big Bang, immune system adapting against body invaders, emergence of personality from brain.

There is also a relation between robustness and self-organization. Complex systems are not managed totally by the external control, but it can also control and adjust itself. For example, a company can face with a number of problems due to environmental effect, but self-organization characteristic makes it possible to solve most of the problems within the subsystems. But management has to deal with on the residual variety. However, if the system is highly complex and the environment is highly uncertain so that self-organization is not sufficient to cope with, then this system can be called as fragile rather than robust (Schwaninger, 2006; Rensburg, 2012).

In general, systems can be classified into groups based on their structure and behavior:

1. Simple systems: Simple system composes of small number components with ignorable interactions with each other.
2. Complicated systems: They can have large number of components with negligible interactions. Since the level of interaction is low, they can be separated into its components for analysis based on reductionist approach. For example microprocessors are complicated systems with millions of electronic components. However, engineers are capable of understanding in detail the components of it and it can operate on the predefined specifications

under the expected conditions (i.e. temperature). To make a complicated system robust, considerable effort should be provided. Unlike complex systems (due to its emergence and self organization characteristics), complicated systems don't have robustness characteristic (Kinsner, 2010).

3. Complex systems: Based on the above mentioned characteristics, we can use the below definition for complex systems:

   Complex systems are made up of multiple components -which are tightly interrelated and decomposable-, that leading the system to show nonlinear, emergence and self-organization behavior.

There are a number of complexity types we encounter in systems:

a) Static (Structural) Complexity: Microprocessor chip is a complicated system because its structural complexity is deterministic and very low. But with increasing its security level, its structural complexity increases (without changing functional complexity) and its reverse engineering would be extremely difficult.
b) Dynamic (Operational) Complexity: Dynamic complexity is more concerned with changing the behavior of the system over time and its unpredictable nature. It arises when there is difficulty in tracing back and prediction of future behavior.
c) Functional complexity: The emergence of new functions in a system makes it complex. Evolution is a key subject on this type of complexity.
d) Synergetic complexity: It refers to the difficulty in understanding the societal development, being part of an organization. For example, synergetic complexity of microprocessor chip production plant is much more critical than the structural and functional complexity of the chip itself.
e) Design complexity: It refers to the difficulty of design, verification, testing and maintaining a complex system. Since natural and artificial systems are "open" systems (interacting with many other systems outside), our knowledge on the system we design is not always enough to describe (emergence in complex systems) (Marti, 2007).

As mentioned at the very beginning of the study, focus of the research will be on system complexity and it should be noted that computational complexity is a quite different subject. Computational complexity helps us to compare different heuristics or algorithms in terms of resources needed to solve the problem, but it cannot help us to understand how the performance of the system affected in all aspects by the used heuristic/algorithm. The quality of the solution can be understood by comparing their computational complexity and system complexity together (Deshmukh et al., 1998).

2.2 Measuring Complexity

Complex systems are essential in the evolution of life, human society, mind, economics and artificial systems. Self-organization and emergence can shift complexity from lower level to higher in a dynamic complex system over a time period. Therefore, measuring complexity is important in order to understand the randomness and correlation, and as a result of an analysis we can understand and resolve many issues. The purpose of understanding and measuring complexity is to derive some insight about the complexity of the system so that new strategies can be developed by the management to protect the system from the uncertainty (Rensburg, 2012).

Complexity is directly related with lack of understanding and comes out in cases of uncertainty and having variety. Mathematically variety can be calculated using the following two formulas (Schwaninger, 2006):

$$\text{Formula 1: } V = m \cdot \frac{n \cdot (n-1)}{2} \tag{2.3}$$

$$\text{Formula 2: } V = z^n \tag{2.4}$$

where;

V: Variety
m: number of relationships between each pair of components

n: number of components

z: number of potential states for each component

In each of the variety formula used, enhancing the relationship between components or enhancing the component itself has more effect than adding a new component to the system. This principle can guide us on managing variety and in the end managing complexity. We can also conclude that adaptive strategies have more effect than complicated strategies in complexity.

Using entropy metric is also a common method in measuring complexity in literature. Entropy is an indicator of variety and connectedness and surprises hidden in the system. Actually entropy measures the rate of information transmitted. According to Shannon's formula in information theory, information content is calculated by the following formula:

$$I(E)=log_2(1/p) \tag{2.5}$$

where E is the event, p is the probability and I is the information content of the event.

Information is transmitted using a coding from a sender to a receiver. Since computers use binary system consisting 0s and 1s, one bit of information can be either 0 or 1 each having a probability of ½. If we apply the above formula $I=log_2(1/(1/2))=log_2 2=1$, then this shows us also that the information (one bit) has a length of 1 unit(bit). As the length of the information increases, entropy and the complexity increase as well. In reality, this reflects the truth, because receiver cannot not know what kind of information it will get until the full information has not been received. The information could be irreducible, because we cannot always understand total information until we get the whole code.

Shannon Entropy calculation is:

$$H = -\sum_{i=1}^{n} p_i \, ln \, p_i \tag{2.6}$$

where n is the total number available states in state phase for a system and p_i is the probability mass function of state i.

According to Shannon's entropy metric, entropy of one toss of a "fair" coin is 1 since getting heads or tails have the equal probability of ½. But when the coin is unfair (let's assume that getting heads and tails have 0.7 and 0.3 probabilities respectively), then the entropy will decrease to 0.88. Because before tossing the coin, you can predict to get heads (frequent outcome) and get the correct result more often than wrong one. Since you can predict better, entropy and complexity will decrease.

2.3 Complexity in Supply Chains

Supply chains show the characteristics of complex systems due to the variety, connectedness in their nature. Wilding (1998) introduced the supply chain complexity triangle that shows the three independent causes of dynamic behavior of a supply chain. They are;

- Demand amplification: it can also be referred as bullwhip effect.
- Parallel interactions: it is the interactions between elements in the same echelon/tier of the supply chain. For instance, if there is product shortage in one of the suppliers, company can demand the same order from an alternative supplier which can be seen as an uncertainty.
- Deterministic chaos: supply chains are theoretically predictable, but depending on the initial conditions, behavior can be chaotic. If the managerial decision making rules are inappropriately designed, chaos can be generated as a result of increasing uncertainty. For example, if a company aggressively lowers the level of stock holding, it can end up with stock-outs, poor customer delivery, etc.

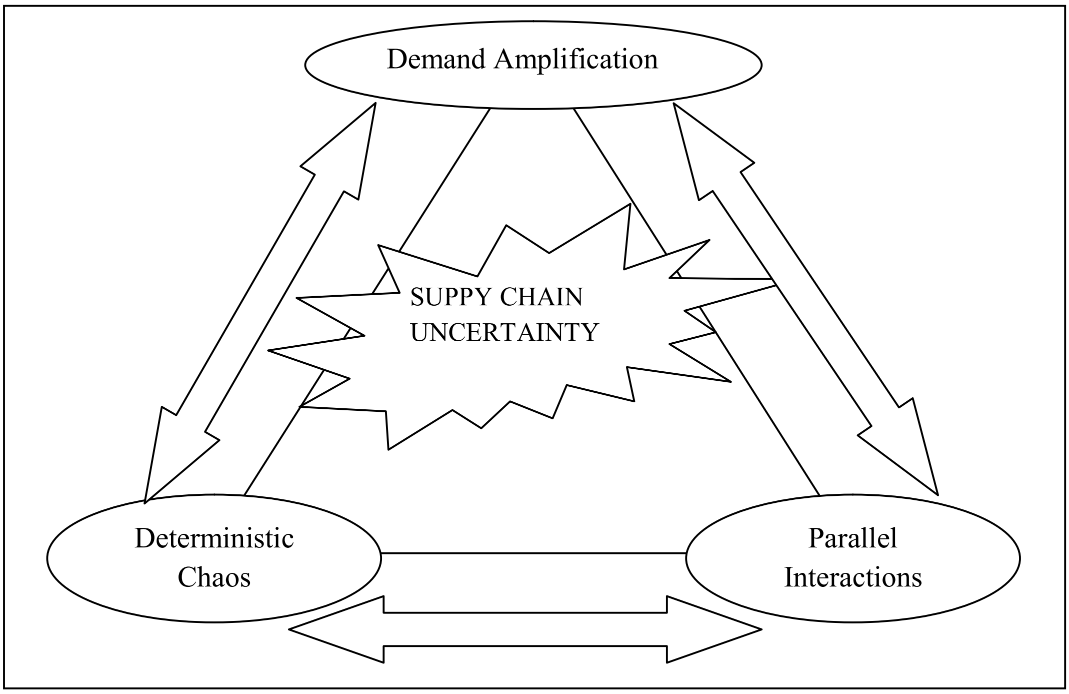

Figure 2.1 Supply chain complexity triangle

These factors also interact with each other and trigger the effect of one another as shown in Figure 2.1.

Entropy can also be adapted to supply chains as a measure to calculate how much information they carry. If a high entropy manufacturer (lots of information needed in order to understand the state of the system) is examined, then it means that it creates information with a high rate and decision makers need to stay more focused to the system to get each any every update and keep it under control. Those types of companies require huge management information systems to handle the schedule and production processes. The more things vary like lot size, production rate, supplier delivery performance, having customized products, the more information has to be considered in deciding the production schedule.

One can encounter with several researchers that compare job shops and continuous flow lines to understand efficiency using simulation studies and there can be seen many evidences in which job shops outperform to handle time gaps. However, in reality to run such a system, the need for a sophisticated IT system can emerge which can cost very expensive to deal with all the data available. This is why most of the time to cope with this high entropy, managers make educated guesses. In the end, high entropy leading to high complexity can be good or bad. Complexity can be an indicator of flexibility or it can be an indicator of inefficient use of resources and paying high costs. Whatever the reason is, if there is complexity, there is always a cost associated with it. If we have highly automated job shop, cost is incurred in IT system. If we are not able to handle customer demand variations, we keep stock as symptom of complexity and pay stock holding cost (Mitleton, 2002; Gottfredson & Aspinall, 2005).

CHAPTER THREE
LITERATURE REVIEW

3.1 Assessment Strategy

In this chapter, a review of the literature on the topic of complexity is provided. For this study, the articles pertaining to supply chain complexity have been examined. On the other hand, since the methodology used in a manufacturing system can be most of the time adaptable to supply chains with minor modifications, the research related with manufacturing system complexity has been included in this analysis as well.

Related literature of complexity has been analyzed using the below assessment criteria:

1. Type of complexity: Does the related article concentrate on static or dynamic complexity?
2. Type of system it is used for: Is the model developed for manufacturing systems or supply chain systems?
3. Quantification of complexity: How the model measures the complexity of the system? Does it use entropy metric, simulation or combines different methods?
4. Applicability of complexity: Has the developed model been applied to industry in practice? It can be an indicator of showing method's ease of applicability.
5. Aspect of complexity: Even though similar measuring methods can be applied in numerous articles, same method can concentrate on different aspect of the system.

In Table 3.1, based on the assessment criteria, each article has been categorized. Existing literature is described in the succeeding subsections based on type of complexity and the approach of measuring it.

Table 3.1 Categorization of related literature based on assessment criteria

Article	Type of complexity	Type of System	Quantification of Complexity	Applicability of Complexity	Aspect of Complexity
Frizelle & Woodcock (1995)	Static & Dynamic	Manufacturing systems	Entropy	3 real case scenarios	Product variation, machine variation, process variation, queue length, machine status
Deshmukh et al. (1998)	Static	Manufacturing systems	Entropy	Theoretical	Precedence relations of operation in the manufacturing environment, product variation, machine variation
Huatuco et al. (2001)	Dynamic	Manufacturing systems	Entropy	Production schedule of a bottle supplier	Deviations from the Schedules are classified as in control & out-of-control and value adding & non-value adding.
Milgate (2001)	Dynamic	Supply chains	Regression analysis of the complexity metrics and delivery performance metrics	Archival data of an international database containing 284 cases	Database contain customer delivery data, supplier delivery data, product and part details, firm sizes, make-to-order and export details, country economic development status
Sivadasan et al. (2002) & Sivadasan et al. (2006)	Dynamic	Supply chains	Entropy	Hypothetical example	order quantity and delivery time analysis including product types, reasons of deviation, out-of-control states
Wu et al. (2002)	Dynamic	Supply chains	Entropy & Simulation (Arena & Excel)	4 scenarios with different production plans	production plan, actual demand of customer, data for simulating production
Makui & Sadjadi (2003)	Static	Manufacturing systems	Entropy & Linear programming	Hypothetical example	Machines, machine status
Arteta & Giachetti (2004)	Static	Business processes	Entropy, Petri nets & Simulation (Arena)	Business system with as-is processes and after business process reengineering project	Business flow of systems and simulation output of transition probabilities

Table 3.1 Categorization of related literature based on assessment criteria (continuing)

Article	**Type of complexity**	**Type of System**	**Quantification of Complexity**	**Applicability of Complexity**	**Aspect of Complexity**
Perona & Miragliotta (2004)	Static	Supply chains	Questionnaire & empirical data	14 manufacturing companies	Questionnaire and empirical evidence to understand the sales, inbound & outbound logistics, production and organizational issues
Turner & Williams (2005)	Dynamic	Supply chains	Simulation	3 different scenarios in automotive industry	Flow of stock in the supply chain, customer service level, rate of matching the customer demand with exact specifications
Makui & Madadi (2006)	Dynamic	Supply chains	Entropy & Chaos theory – Lyapunov Exponent	Theoretical	Demand amplification between echelons
Battini et al. (2007)	Static	Supply chains	Entropy & Average Mutual Information	2 case scenarios tested on a supply chain network	Cost value flow
Wu et al. (2007)	Dynamic	Supply chains	Entropy & Simulation (Arena & Excel)	2 real cases compared : Make-to-stock & Make-to-order supply chains	Processes, flow mappings, orders, production schedules, production, inventories, and deliveries
Flowers & Cheng (2008)	Static & Dynamic	Global manufacturing systems	Entropy	Theoretical	Applicability to global manufacturing systems
Hu et al. (2008)	Static	Manufacturing systems	Entropy	Theoretical	Assembly systems, multiple part selection, multiple station
Kinra & Kotzab (2008)	Static	Supply chains	Analytic Hierarchy Process	Data of 5 countries compared for site selection	Transportation infrastructure, economical indicators, regulations, political and judicial systems.

Table 3.1 Categorization of related literature based on assessment criteria (continuing)

Article	**Type of complexity**	**Type of System**	**Quantification of Complexity**	**Applicability of Complexity**	**Aspect of Complexity**
Schaffer & Schleich (2008)	Static	Manufacturing systems	Software for cost model developed	A real case scenario on automotive industry cost structure	All value adding & non-value adding costs
Bozarth et al. (2009)	Static & Dynamic	Supply chains	Questionnaire & Statistical analysis	Data of 209 plants over 7 countries	Upstream and downstream echelon data including (supplier details, customer details), manufacturing data (details of parts and products, production schedule stability, batch sizes)
Huatuco et al. (2010)	Static	Supply chains	Entropy	Business Process Re-engineering results of a real supply chain	Supplier delivery delay performance, internal production delay performance, customer delivery delay performance
Leitao & Barbosa (2010)	Dynamic	Manufacturing systems	Biological Methods	Theoretical	Biological techniques that can be used in manufacturing systems
Yang&Yang (2010)	Dynamic	Supply chains	Normal accident theory	Theoretical	Discussion on understanding the impact of postponement
Garbie & Shikdar (2011)	Static	Manufacturing systems	Fuzzy logic approach	7 real cases compared	Interview results on complexity driving factors
Hall et al. (2011)	Dynamic	Supply chains	Kauffman's NK theory	Brazilian sustainable energy supply chains	Interviews, previous researches
Isık (2011)	Static & Dynamic	Supply chains	Entropy	Hypothetical example demand forecasting	Actual and scheduled demand data
Manuj & Sahin (2011)	Static & Dynamic	Supply chains	Interviews	Theoretical	Main drivers of supply chain complexity

Table 3.1 Categorization of related literature based on assessment criteria (continuing)

Article	Type of complexity	Type of System	Quantification of Complexity	Applicability of Complexity	Aspect of Complexity
Mattsson et al. (2011)	Static & Dynamic	Manufacturing systems	Evaluation of the complexity parameters over a scale by the people groups	Volvo Cars Corporation Robustness Index calculation method revised	Parameters considered are products & variants, methods of production, layout & equipment, organization & environment
Wang et al. (2011)	Static	Manufacturing systems	Entropy, Combinatorial optimization problem & Genetic algorithm	Hypothetical example consisting of manufacturing details	Product types, part types, rules for fixtures, tools and assembly procedures, consumer demand and choice
Zhang (2011)	Static	Manufacturing systems	Entropy	Hypothetical example on manufacturing layout types	Job shop & cellular manufacturing schedule comparison, machine variation, states of the machines
Gerschberger & Staberhofer (2012b) Gerschberger&Staberhofer (2012a)	Static	Supply network (Supplier base)	New metric	1 real case scenario	Delivery data performance, time and money required to find an alternative supplier, percentage usage of components delivered from suppliers, index calculated to show the ease of working with different countries
Modrak & Marton (2012)	Static	Supply chains	3 existing metrics & 3 new metrics	20 general supply chain structures	Topological analysis of supply chain structures
Modrak & Semanco (2012)	Static	Supply chains	3 existing metrics & 1 new metric	20 general supply chain & 20 assembly supply chain structures	Topological analysis of supply chain structures

Table 3.1 Categorization of related literature based on assessment criteria (continuing)

Article	Type of complexity	Type of System	Quantification of Complexity	Applicability of Complexity	Aspect of Complexity
Rensburg (2012)	Static	Business system	Entropy & Average Mutual Information & Fuzzy cognitive map	Hypothetical example of business units and their interactions	Key performance indicator values of 4 different business units
Zhang (2012)	Static	Manufacturing systems	Entropy	Hypothetical example of manufacturing schedules	Actual versus planned schedule complexity comparison, schedule of time planned for each state and the actualized values
Cheng et al. (2013)	Static	Supply chains	Entropy & Average Mutual Information	8 different supply chain structures	Topological analysis of supply chain structures

3.2 Static Complexity

As described in the earlier chapter, static complexity is more focused on structure of the system and the strength of the interactions currently taking place. There is a vast amount of literature on this category of the complexity. The article both concerning static and dynamic complexity will be described in the succeeding part of the chapter. Researches under this topic will be classified based on the measurement technique used.

3.2.1 Entropy Measure

Most common way in measurement of complexity is using entropy metric or combining it with other methods. The first article using entropy metric in manufacturing systems is Frizelle & Woodcock (1995) for both static and dynamic complexity. Details of this paper will be provided in the "Dynamic complexity" section. Later, Deshmukh et al. (1998) used entropy metric of Shannon & Weaver (1949) for quantifying static system complexity. Based on the analysis, it has been suggested that if same sized systems are compared (*n* part, *m* operations, *r* machines), Flexible Manufacturing Systems (FMS) –that can handle *n* parts in *r* machines which are capable of doing maximum of *m* operations having flexible routings- are more complex than job shop manufacturing environment –that can handle *n* parts in *r* machines which are capable of doing maximum of *m* operations without flexible routings. And, job shop manufacturing has higher complexity than a transfer line – that has *r* machines which can handle a single operation. Also, under optimal control policy, increase in static complexity results with improved system performance. But this means that company needs to invest in increasing flexibility, and on the other hand decision making and planning activities gets more critical since optimality required.

Besides comparing different system structures, entropy measure can also be used for getting insights in what-if scenario analysis. Huatuco et al. (2010) applied entropy metric to a supply chain based on real observations before and after a BPR

(Business Process Reengineering) study. The aim of the study is to understand how complexity changed observing the results in supplier deliveries, shop-floor, customer deliveries and on the overall system. Article claims that decreasing the complexity level in a supply chain is a way to manage robustness of a supply chain. By applying BPR, complexity level of the supply chain structure can be managed leading to increased level of robustness of the system. Even though article reviewed the real results of the system before and after BPR study, complexity level analysis can be done for What-if scenario analysis before applying changes.

Hu et al. (2008) modified the Shannon's entropy so as to compute complexity of assemble systems consisting of multiple echelons. In the proposed model, alternative part selection can be possible and there are multiple stations. In a station, technically the part selection in the upstream echelons affects the operation which makes decision making of a technician more complicated. Considering these factors, entropy measures the manufacturing system complexity and the transfer complexity caused by the decisions on upstream echelons. For a manufacturing environment, possible system configurations can be evaluated using the developed metric.

Zhang (2011) and Zhang (2012) both adapted entropy metric for manufacturing system complexity as well. Zhang (2011) compared effect of a change in a manufacturing environment in terms of static complexity. Initial layout of the plant is job shop type system which allows a high number of variations in scheduling with enabling processing every type of product in every single machine. However, with the cellular layout, the machines are grouped and each cell dedicated to produce a limited variation of product. The entropy metric showed that the second layout has lower complexity due to less effort needs to be paid for managing the operation. In Zhang (2012), entropy metric proposed in Zhang (2011) applied to a production schedule. Its usage is enhanced to measure adherence to the original schedule. Metric is used to understand which part of the production schedule creating abnormal deviation impacting the complexity the most. Based on the results management can take action.

3.2.2 Combining Entropy Measure with Other Methods

There are many articles integrating entropy metric with other techniques in literature to stretch the evaluation and overcome the shortfalls of the metric. Makui & Sadjadi (2003) extended the entropy metric using a linear programming model. In the static complexity metric, complexity is measured using probability of the states of the system, but it doesn't concentrate on the state itself. For example, if the machine has only two states busy and idle with likelihood of 0.9 and 0.1 respectively, it is equally complex with a machine having two states with likelihoods 0.1 and 0.9. In this article, the effect of each state is re-weighted based on a linear programming model. On the proposed metric, system complexity is higher when the likelihood of system in busy status is higher than idle. But it can give misleading results when there are multiple machines and there are bottlenecks between them.

Similarly, Wang et al. (2011) proposed an optimization approach to decide on product variety selection in a manufacturing plant. Model seeks to minimize complexity in the production environment but maximize the market share as multiple objectives. The developed combinatorial optimization model calculates complexity using Shannon's entropy metric and for finding the solution genetic algorithm is used.

In Battini et al. (2007), Supply Chain Network complexity is evaluated using a modified entropy metric which is used in ecosystem theory. In the method, based on the flow between entities of the supply chain a matrix is formed. Battini et al. (2007) investigated the complexity of the whole supply chain network including, raw material suppliers, other vendors, manufacturing plants, warehouses, wholesalers and retailers. The flow between entities is represented using exchanged cost values. In order to illustrate a proposed model an example supply chain has been modified. Warehouses replaced by a single third party company and rather than working with many suppliers directly and some suppliers started to consolidate their shipments using a vendor managed inventory system. Complexity of the two supply chains compared and it has been realized that the change has improved the complexity of the system as a whole.

Matrix of the flow can be prepared as below:

$$\begin{bmatrix} t_{11} & \cdots & t_{1N} \\ \vdots & \ddots & \vdots \\ t_{N1} & \cdots & t_{NN} \end{bmatrix} \tag{3.1}$$

Entropy of the flow -leaving entity i and entering entity j- is called joint entropy $H_{O,I}$:

$$H_{O,I} = -\sum_{i=1}^{N}\sum_{j=1}^{N} p_{O,I}(i,j) \cdot log p_{O,I}(i,j) = -\sum_{i=1}^{N}\sum_{j=1}^{N} \frac{t_{ij}}{t_{..}} log \frac{t_{ij}}{t_{..}} \tag{3.2}$$

To shorten the formula $t_{..}$ represents the sum of all rows and columns.

Entropy of the entity outputs is:

$$H_O = -\sum_{j=1}^{N} p_O(i) \cdot log p_O(i) = -\sum_{j=1}^{N} \frac{t_{i.}}{t_{..}} log \frac{t_{i.}}{t_{..}} \tag{3.3}$$

Entropy of the entity inputs is:

$$H_I = -\sum_{j=1}^{N} p_I(j) \cdot log p_I(j) = -\sum_{j=1}^{N} \frac{t_{.j}}{t_{..}} log \frac{t_{.j}}{t_{..}} \tag{3.4}$$

Average mutual information (AMI) entropy which is proposed in Battini&Persona(2007) calculated by:

$$AMI = H_O + H_I - H_{O,I} \tag{3.5}$$

In Cheng et al. (2013), model of Battini et al. (2007) extended so as to cover two factors affecting the static complexity of a supply chain. These two factors are:

1. Degree of order: If the linkage between elements in a supply chain is higher, then the degree of order is higher as well. Examples are given in Figure 3.1.
2. Diversity: If the connections between elements have greater number of combinations, then this supply chain has more diversity factor.

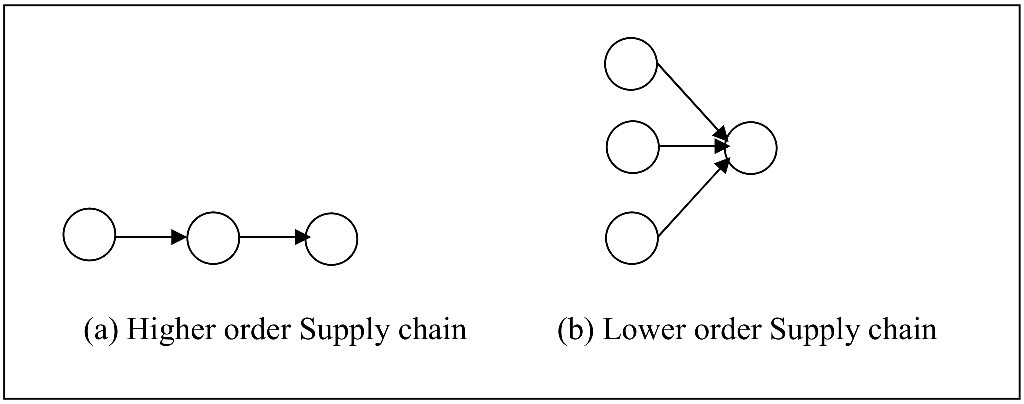

Figure 3.1 Examples of degree of order in a supply chain

In the proposed complexity metric, both of these factors are considered. The method is applied to 8 different supply chain structures and effects of the above factors had been proved and tested.

Rensburg (2012) applied the AMI to calculate the complexity of the business units and used fuzzy cognitive approach to understand the correlations between them. Using statistical methods to calculate correlation would be insufficient in a complex system because of its non-linear behavior. Therefore; proposed approach can be usable to understand the hidden relationships in the system due to complex nature of it.

Another use of entropy metric is combining it with simulation output which is used in Arteta & Giachetti (2004). It argues that if an enterprise is more complex, it could be an indicator of less agility (less adaptability to change). In order to test this idea, a case study is used. An enterprise is selected with its as-is processes. The processes of the same enterprise are improved in terms of efficiency with a new workflow management system. The state probabilities of the as-is system are calculated using Petri nets and real transition rates of the system. The re-engineered system is simulated using ARENA and the transition rates are used in Petri nets again to calculate the state probabilities. Using the entropy metric, it has been observed that reengineered system has less complexity. To measure the agility of both systems, a specific change has been assessed in terms of information flows and departments and based on this evaluation, reengineered system is easier to change, which means more agile. This paper has the main contribution of discussing the inverse relationship between agility and complexity.

3.2.3 Developing Original Measures

Besides using entropy metric, another approach in the existing literature is to create new and original measures. Gerschberger & Staberhofer (2012b) uses a supply network data to rank the suppliers based on uncertainty, variety and geographical components. Suppliers are evaluated on the basis of delivery performance, time and money required to find an alternative supplier, percentage usage of components delivered from them, and index calculated to show the ease of working with suppliers geographically apart. By ranking the parameter results from worst to best and selecting the top 20 suppliers, they produce an overall parameter. If the supplier is repeated multiple times in top20 lists, it shows the complexity to manage the related supplier and in other words how critical is the supplier. Results of the metric used is reviewed in Gerschberger & Staberhofer (2012a) and evaluated with practitioners to understand if the results are sensible. Sometimes rather than evaluating the results of the metrics, solely practitioner views can be used for measuring complexity. Garbie & Shikdar (2011) developed software using fuzzy logic approach to calculate complexity of the manufacturing environment. Interview results of the experts are embedded into the study to calculate the static complexity of the system.

Alternatively, Schaffer & Schleich (2008) focused on automotive industry in their research to investigate the cost model and the complexity related costs in the environment instead of representing complexity with a single number. Automotive market is especially suitable to this process because of the high product diversity. Research starts with the list of factors creating non-value adding costs which are generated by the complexity of the system. Examples can be set-up costs, line balancing (waiting time) costs, production planning costs, stock holding costs that are mainly related with the amount of variation in products in the manufacturing environment. Software is developed to observe the complexity related costs on the system and it can support the management to see the functions driving complexity and improve when necessary.

Another study that analyzes the complexity of several companies and aims to support decision making process is Perona & Miragliotta (2004). In Perona & Miragliotta (2004), key managers in 14 manufacturing company have been interviewed so as to understand the sales, inbound & outbound logistics, production and organizational issues. Complexity has been calculated by simple empirical formulations and the index calculated is compared with respect to other performance indicators of the companies. Partnership with the suppliers, product modularization and advanced production planning information systems have been discussed in terms of complexity and their support on the performance of companies. Research also offers two different levers to handle complexity in a company: complexity reduction levers (complexity is reduced at physical level), complexity management levers (complexity is reduced by managerial decisions to improve physical complexity). Outsourced production can be an example of complexity reduction levers, and using a production planning information system can be a part of complexity management lever. Based on the empirical study (non including statistical analysis), research supported the idea that there is a linkage between complexity and performance.

Rather than concentrating solely on a single manufacturing environment, a globalized supply chain focused decision making process has been incorporated in Kinra & Kotzab (2008). Kinra & Kotzab (2008) quantified complexity of the environmental factors using Analytic Hierarchy Process. Transportation infrastructure, internet usage, economical indicators, regulations, political and judicial systems are incorporated into the analysis to design operational strategy in a centrally managed supply chain.

Modrak & Semanco (2012) is an example of comparison study of the existing complexity measures. It compares the results of 3 existing complexity metrics in literature and a new one on 40 different supply chain topologies. Supply chain topologies are selected from previous studies. 20 of them are general supply chain structures and rest of them are assembly supply chain structures. Similarly, Modrak & Marton (2012) compared the existing 6 complexity metrics on 20 general supply chain networks.

3.3 Dynamic Complexity

Dynamic complexity concentrates on the unpredictable nature of the systems over a time period. Dynamic nature of the system is not only concerned with the unexplainable interrelations between the components but also the emergence behaviour of the systems.

3.3.1 Entropy Measure

Frizelle & Woodcock (1995) proposed the entropy metric for the first time to be applied in complex systems. This paper is critical also for using entropy metric in dynamic complexity by including queue length. The main idea of the model is using queues as indicators of obstacles in the processes. In the below Equation (3.6);

M: number of resources

N_j: number of possible states at resource j

p_{ij}: probability of resource j in state i

P: probability of the system being under control.

$$H_{dynamic} = -P\log_2 P - (1-P)\log_2(1-P) - (1-P)\Big(\sum_{M^q}\sum_{N_j^q} p_{ij}^q \log_2 p_{ij}^q + \sum_{M^m}\sum_{N_j^m} p_{ij}^m \log_2 p_{ij}^m + \sum_{M^b}\sum_{N_j^b} p_{ij}^b \log_2 p_{ij}^b\Big) \quad (3.6)$$

Since P represents the probability of system being under control, (1-P) corresponds to the dynamic part of the model. p^q is the probability of having queues of length greater than 1, p^m is the probability of having queue length of 0 and 1 and p^b is the probability of the non-programmable states like machine breakdowns or quality rejects. Therefore, total number of states in resource j is $N_j = N_j^q + N_j^m + N_j^b$. If there are more than one parts waiting for the resource, then it can be sign of a bottleneck in the machine. p^m shows the "makestates" of the resource with the queue length of 0 indicating idle time, with queue length of 1 indicating the running time. If the consideration is the make component over a long period of time, P becomes zero and dynamic pieces of the model are ignored like machine breakdowns and queue length probabilities. Then the equation measures only the complexity of the structure or design of the system as in Equation (3.7).

$$H_{static} = -\sum_{M} \sum_{N_j} p_{ij} \log_2 p_{ij} \tag{3.7}$$

Model proposed in the article is used on 3 different trial cases to compare the complexity figures. The numbers are used to interpret the complexity of each system. By using the metric, decision makers can take actions for better managing or simplifying the operations. If there are alternative ways to take actions, these actions can be prioritized based on their impact on the results of the metric. For example if the dynamic complexity gives higher results due to the contribution of the long queue length, then the processes can be improved on the bottleneck area.

Huatuco et al. (2001) used a very similar version of Frizelle & Woodcock(1995) entropy metric to measure the complexity of a production schedule. To calculate the state probabilities, deviations from the schedule has been classified based on being in-control or not and if the products created are value adding or not. For example, the production can deviate from the schedule as a managerial decision to satisfy a customer request as an emergency, this can be considered as a out-of-control state but value adding situation since it contributes to the customer satisfaction. This research also shows that the complexity can be a "good" or a "bad" thing for the company based on the measurement results. If the complexity is high due to the non value adding states, then the complexity has to be handled.

Isik (2011) solely focused on modifying entropy metric by adding deviation factor and applied to calculate the complexity of the supply chain in terms of demand forecasting. Both static and dynamic complexity factors have been evaluated. Modified static complexity metric is:

$$H_{Static} = -\sum_{i=1}^{M} \sum_{j=1}^{N} [\log_2 p_{ij}] \, d_{ij} p_{ij} \tag{3.8}$$

where M is the number of resources and N is the number of possible states for resource i. d_{ij} is the absolute value of the deviation of planned versus forecasted demand. Modified dynamic complexity metric is:

$$H_{Dynamic} = -(1-P) \sum_{i=1}^{M} \sum_{j=1}^{N} [\log_2 p_{ij}] \, d_{ij} p_{ij} \tag{3.9}$$

where P is the probability of the system “in control (scheduled)” and (1-P) is the probability of system “out of control (unscheduled)”. Variability factor d_{ij} is critical since the more the demand variation gets apart from the target, the more complexity index gets larger. Therefore, the quantum deviation is incorporated into the model which is sensible to understand magnitude of complexity.

Other adapted version of the entropy metric into the dynamic complexity concept proposed in Sivadasan et al. (2006) and Sivadasan et al. (2002). They use complexity analysis to measure the information required to describe the state of the system. This approach provides insight to management how much the supply chain suffers from uncertainty, the degree of monitoring and control required to manage the complexity. For the complexity measurement, Shannon & Weaver (1949) modified as below:

$$H_{Dynamic} = -\sum_{i=1}^{F} c_i \sum_{j=1}^{U} (1-P_{ij}) \sum_{k=1}^{R} \sum_{l=1}^{NS} [\log_2 p_{ijkl}] \, p_{ijkl} \tag{3.10}$$

where

F : number of flow variations (order forecast and delivery deviations are under consideration on the research)

c_i : number of observations required on a specified time interval for the Flow variation i is monitored. (This criterion added on Sivadasan et al. (2006))

U : number of products

R : number of reasons of out-of-control states

P_{ij} : probability of product j for flow variation i in control state

NS : number of out of control states for flow i and product j and reason k.

p_{ijkl} : probability of product j for flow i being in out of control state l due to reason k.

With the use of this entropy metric, it could be possible to compare information requirement to describe the state of the system. Also, dynamic complexity can be analyzed based on different levels of detail. The complexity measurement can be in detail but also can be aggregated to product, flow, reason level. This measure can be used to identify the areas where further control and information handling required.

3.3.2 Combining Entropy Measure with Other Methods

A common way of representing the dynamic nature of the complexity is using simulation tools. Wu et al. (2002) conducted simulation to 4 different scenarios of a supply chain with different production planning strategies. For stock and demand, the variation between the plan and the actual values are analyzed as an index of the complexity of the system. It has been observed that this way of measuring complexity is reasonable way of evaluating uncertainty and the results do not rely on the data sets. It has been also demonstrated that information sharing decreases complexity of the supply chain and decreases the bullwhip effect along the supply chain. Likewise, Wu et al. (2007) applied dynamic complexity metric developed in Frizelle & Woodcock (1995) to two real supply chain cases in UK industry which are examples of make-to-stock and make-to-order systems. Aim of the study is to understand the relation between costs of the systems and the complexity index. In make-to-order supply chains, it has been observed that there is a direct relation with cost and complexity index. As uncertainty increases, system suffers from higher costs and complexity metric provides higher values. In the make-to-order model, costs calculated do not cover the cost of customer loss due to delivery delays; therefore, the cost and complexity metric results are not in line. But it can be said that dynamic complexity metric indicates the issues of the system better than a simple cost analysis.

Relationship and dissimilarities of complexity and chaos theory is discussed in many studies, but both of them incorporated into a study in Makui & Madadi (2006). It uses both entropy metric and chaos theory (Lyapunov exponent) to measure the demand amplification on the upstream echelons of the supply chain, in other words to quantify the uncertainty caused by the bullwhip effect. It has been shown that on the upstream echelons, due to the higher effect of bullwhip, dynamic complexity is higher and one can conclude that complexity is transferred to upper echelons due to elevated uncertainty. Lyapunov exponent also prove that bullwhip effect can cause chaos in the supply chain and it show how much demand is amplified between echelons and the transfer of the dynamic complexity to the upper echelons.

3.3.3 Developing Original Measures

Deciding on the complexity drivers of the system and using simulation to observe their effects on the performance measures is a method that can be used in understanding dynamic complexity of the system. Turner & Williams (2005) shows that the factors creating complexity in an automotive supply chain (like product variations, dealers holding the stock for customer sales, demand seasonality, etc.) that can be modeled using a simulation model. Three different scenarios are analyzed with the simulation model and their results are compared using the customer service level and the percentage of satisfying a customer demand with exact specifications (i.e. paint of the car, sunroof, air conditioner). Based on the 1st initial scenario, a distribution center added into the system on the 2nd scenario. On the final scenario, simulation results are analyzed when postponement is also added. Simulation enables the researchers to drive insight from the dynamic performance of the complex systems.

Volvo Cars Corporation uses a robustness index to quantify the robustness of the parts/products in order to understand how much the products are sustainable to cope with the frequent changes in the demand. This robustness index is easily applicable in the company and is a part of the normal working procedure since people get used to it. This procedure is modified by Mattsson et al. (2011) so as calculate the complexity of the system in a holistic approach. Parameters that can have an effect on the complexity have been gathered such as products & variants, methods of production, layout & equipment, organization & environment. People from different units of the system evaluated them in detail using a scale from (0 to 9) from their own point of view. For instance, a logistics personnel respond “product & variant” parameter considering how storage and logistics affected by the products and variants. But production personnel answer the same parameter based on difficulty of handling the production control and workload. Method provides a perceived complexity figure bringing many aspects of the system together.

3.3.4 Discussion Articles

In dynamic complexity, using interviews with the practitioners is a frequently used method to identify the factors leading complexity to increase. Hall et al. (2011) analyzed the Brazilian energy supply chains (Oil & gas, sugarcane ethanol, biodiesel supply chains) in terms of financial, social and environmental aspects. Article also realizes that these supply chains can also affect the performance of each other. The discussions on the article are based on interviews and previous researches on this topic. Kaufmann’s NK theory has been applied by using a matrix of interactions. According to Kaufmann, N refers to the number of elements of the system and K denotes the interactions between these elements. If these interactions and their intensity are reflected on a fitness landscape, complexity of the system can be anticipated. If the landscape becomes more rugged, the system becomes more complex. Full NK analysis has not been conducted, but based on the matrix showing interactions, some outcomes of the interactions has been conducted.

Similarly Manuj & Sahin (2011) gathered in a structure way the interviews made with 11 supply chain professionals majority of them working in different companies and sectors. Based on the research, main drivers of the supply chain complexity are derived and their impact on decision making and on performance of the supply chain discussed.

Besides using interviews with the practitioners, another approach can be using the actual data gathered from many companies to produce some generic idea about complexity. Milgate (2001) presents a classification of complexity dimensions of a supply chain which are uncertainty, technological intricacy and organizational systems. The research proposes measures for each dimension based on an international database containing data of 284 cases. The relation between the complexity of the supply chain and the customer delivery performance has been analyzed using a regression analysis. Results show that there is a significant relation between delivery performance and uncertainty (caused by the downstream and upstream echelons). However, there seems to be no statistical evidence showing relationship between delivery performance and the other dimensions namely technological intricacy, organizational systems. It shows that managers struggle handling the complexity caused by uncertainty in order to avoid issues in delivery performance. For example if there is an issue on the supplier deliveries, managers can decide on keeping safety stock or extended lead times. However, technological intricacy (product and process complexity) or organizational systems (number of layers, communication and departmental interactions within a firm or number of suppliers) can be viewed as deterministic dimensions of complexity. Their impact on delivery performance can be controlled by the management by additional information technology, training the workforce or other strategic decisions.

Another important advantage of discussion papers is that they can provide the relationship of complexity with other terms in literature. Bozarth et al. (2009) focused on the impact of complexity on performance measures. Research studied the supply chain complexity in three sections; upstream echelon, internal manufacturing complexity and downstream echelons. For every section of the supply chain complexity analysis, both the static and the dynamic drivers are analyzed. Static factors are named as detail complexity drivers. For instance, for internal manufacturing complexity number of products and parts are called as detail complexity indicators; whereas, production schedule stability is shown as dynamic complexity measure. With the support of a questionnaire via professionals in the manufacturing plants from various roles and departments, complexity factors have been quantified. Statistical analysis performed in order to indicate the effect of complexity on performance. The analysis showed that the selected static complexity drivers (for downstream echelon, downstream echelon and internal manufacturing) are not critical to the performance of the production plant. However, the dynamic complexity measures have negative impact on production plant performance. A possible explanation is that the decision makers can adapt to the static complexity factors by design of the supply chain. However, the uncertainty factor that arises with dynamic complexity can end up with performance issues.

Discussion papers are also guidelines for future research proposing new methods or new aspects to be used on dynamic complexity analysis. As discussed earlier, important characteristics of complex systems are self-organization and emergence. Many examples of these characteristics can be observed in biological systems like collective behavior of ant and bee colonies, Darwin's evolution theory. In manufacturing systems, like biological systems there are many causes motivating adaptation. Product demand variation can change with the technological enhancements, organizations need to adapt due to mergers and acquisitions, processes and equipment can change with the developments as well. Leitao & Barbosa (2010) proposes that biological complexity analysis techniques can be used in manufacturing systems. Ant colony optimization, particle swarm optimization can be techniques that can be adapted. On the other hand, to apply biology related methods, simulation tools can be useful. One of the most common and user friendly one is Netlogo.

On the other hand, Yang & Yang (2010) used Normal Accident Theory to drive insights about managing risk in supply chains. According to Normal Accident

Theory, occurrence of accident is inevitable if complexity increases and probability of an accident can be reduced by either reducing interactive complexity or reducing tight coupling. On the article, the effect of postponement (delaying the production of final product until the customer demand occurs) on risk management of supply chains has been discussed based on Normal Accident Theory. As a future research, article mentions the need of understanding the effect of complexity on performance metrics.

Likewise, Flowers & Cheng (2008) focuses on theoretically adapting the entropy metrics proposed in Frizelle & Woodcock (1995) to global manufacturing systems. By incorporating parameters like exchange rates, labor shortages to the metric, decision makers can compare facilities located globally and gain insight about the performance of them.

3.4 New Classification Criterion: Level of information

The assessment criteria used in the previous sections basically considers the time variable used in the study –static vs dynamic-, environment and method used in research. It can be seen that even though all of the articles concentrate on the system complexity, their aim of the measurement can be different. Some articles mainly focus on total amount of information in the system as complexity; others can spotlight the amount of useful information that creates value according to the target of the system. In order to make this distinction explicable, information classification of Hyvarinen (1970) can be helpful. This classification is explained below:

- Syntactic level shows the total amount of information in communication channels.
- Semantic level is related with the meaning of the information and understanding capabilities of the receiver.
- Pragmatic level indicates the utility of the information by the receiver; in other words, value of the information according to the target of the system.

Based on the above information level classification, complexity measures can be categorized in three types:

1. System complexity: According to syntactic level of information, these complexity measures attempt to explain the total amount of information in a system.
2. Perceived complexity: Similar to semantic level, this complexity type depends on the capability of the receiver. In the complexity definition, it has been noted that the complexity also arises because of the limitations of the human capacity. Therefore, in this type, aim is to understand how much complexity people experience in a system. For example, in a system, the total information flow can be high which leads to increased level of system complexity. However, decision makers invest in such sophisticated tools to process the information that the perceived complexity can be low. Or the system complexity can be low; but due to high level of uncertainty, perceived complexity can be high.
3. Value adding complexity: This complexity type has been inspired from pragmatic level of information. It assesses if the complexity creates value for the purpose of the system.

In Table 3.2, categorization of each paper based on this new criterion is provided. As the purpose of the Shannon's entropy is to measure the amount information, its usage simple provides the system complexity. However, in Table 3.2, it can be seen that most of the articles using Shannon's entropy offers measures in perceived complexity. For instance, the first article on using entropy for complexity (Frizelle & Woodcock (1995)) offers perceived complexity measurement, since it computes using queue lengths which are good indicators of experienced complexity by the users. Majority of the perceived complexity articles discuss the relationship between complexity and performance (like Deshmukh et al. (1998)) or use questionnaires with the experts in the system to understand how much they suffer from the complexity (like Perona & Miragliotta (2004)). Based on the results of the perceived complexity results, researchers can discuss the alternative decisions to increase performance for the system of interest. In the system complexity articles, either alternative complexity measures are discussed or no evidence has been presented about the performance of the systems. There is a limited literature on value adding complexity. These limited researches try to explain the type of complexity creating value for the system or, on the contrary, the amount of effort provided for the non-value adding activities.

Table 3.2 Classification of articles based on level of information

Article	**Type of complexity**	**Level of Information Criterion**		
		System Complexity	Perceived Complexity	Value Adding Complexity
Frizelle & Woodcock (1995)	Static & Dynamic		X	
Deshmukh et al. (1998)	Static		X	
Huatuco et al. (2001)	Dynamic			X
Milgate (2001)	Dynamic		X	
Sivadasan et al. (2002) & Sivadasan et al. (2006)	Dynamic			X
Wu et al. (2002)	Dynamic		X	
Makui & Sadjadi (2003)	Static		X	
Arteta & Giachetti (2004)	Static		X	
Perona & Miragliotta (2004)	Static		X	
Turner & Williams (2005)	Dynamic		X	
Makui & Madadi (2006)	Dynamic		X	
Battini et al. (2007)	Static	X		
Wu et al. (2007)	Dynamic		X	
Flowers & Cheng (2008)	Static & Dynamic	X		
Hu et al. (2008)	Static		X	
Kinra & Kotzab (2008)	Static		X	
Schaffer & Schleich (2008)	Static			X
Bozarth et al. (2009)	Static & Dynamic		X	
Leitao & Barbosa (2010)	Dynamic	X		
Yang&Yang (2010)	Dynamic		X	
Garbie & Shikdar (2011)	Static		X	
Hall et al. (2011)	Dynamic		X	
Huatuco et al. (2011)	Static		X	
Isık (2011)	Static & Dynamic		X	
Manuj & Sahin (2011)	Static & Dynamic		X	
Mattsson et al. (2011)	Static & Dynamic		X	
Wang et al. (2011)	Static	X		
Zhang (2011)	Static		X	
Gerschberger & Staberhofer (2012b) Gerschberger&Staberhofer (2012a)	Static		X	
Modrak & Marton (2012)	Static	X		
Modrak & Semanco (2012)	Static	X		
Rensburg (2012)	Static		X	
Zhang (2012)	Static		X	
Cheng et al. (2013)	Static	X		

CHAPTER FOUR
COMPLEXITY, ENTROPY & SYSTEM DYNAMICS

4.1 Starting Point of Complexity Theory

Scientific revolution started with Copernicus's publication which was about the model of the universe putting Sun at the center rather than Earth. And his studies are followed by many advances in various fields including astronomy, biology, chemistry, medicines, health, transportation, agriculture and mathematics. Scientific revolution ended with foundation of Royal Society in London which started a new era in science in a more organized and disciplinary way. Newton and Leibniz dominated this period which is late 17^{th} and early 18^{th} century. In Newton's Principia, he formulated laws of motions and universal gravity. The most important point is he has not only presented basic principles of physics, he has also formed the basis of scientific method. Observations, experiments, reasoning and recording became a common method for scientists. Newton also introduced the concept of "analysis and synthesis" to break the problem into pieces to simplify the observation and solution. On the other hand, Newton and Leibniz invented calculus as well. By the tools introduced by calculus -like integrals, differential equations-, inventions in nearly all areas on science were supported and accelerated. Calculus could be able to examine any surface that was not able to be handled by geometry. But the handicap was, geometry focused on straight lines and calculus was capable of smooth lines, on the other hand reality can contain unsmooth objects as well (Bunch & Hellemans, 2004; De Toni & Comello, 2010; Barranger, 2001).

For nearly 200 years, calculus predominated the scientific innovations in several fields. In 19^{th} century, thermodynamics introduced as a new concept to understand energy and 1865 the term "entropy" invented by Clausius –a German physicist and mathematician. Newtonian principles are about motion, but energy is the main focus of thermodynamics. First law of thermodynamics is about "conservation of energy" which means that energy can neither be destroyed nor created, but it can transfer. Total energy of an isolated system cannot change. The second law of thermodynamics is all about entropy. What entropy means in thermodynamics is the heat and also in other words “disorder”. Second law states that disorder of a closed system which has no interaction with the rest of the universe always increases. Since any closed system moves toward an equilibrium state, its entropy continues to increase and the highest value of entropy and worst level of disorder happen at the time of equilibrium state. Another important point here is the movement towards equilibrium via increase of entropy is irreversible. All natural processes are irreversible. An example of it can be thermal contact of two containers with different temperature ends up with an equilibrium temperature due to the flow of high temperature system to the low temperature one which is irreversible. Also, the combined entropy of the two systems increases. At the point of equilibrium temperature, entropy is at its maximum point.

In 1877, Boltzmann introduced a way to calculate the entropy (total disorder of a system) using the following formula:

$$S = K_B \ln P \tag{4.1}$$

In the formula, S is entropy, K_B is Boltzmann constant and P is the probability of system in a given state. Boltzmann used a probabilistic approach for the first time. Set of all possible states of a system is called “phase space”. Since we have an incomplete knowledge of system telling us the state can be in one of the V possible states, the probability of each state of V is equally possible according to Boltzmann assumption (where P=V). Therefore, probabilities of the states are uniformly distributed. However, the thermodynamic states may not have equal probabilities and Gibbs adapted the formula as follows:

$$S = -K_B \sum p_i \ln p_i \tag{4.2}$$

where p_i is the probability of any state I in the possible state list of V. Even though, thanks to Boltzmann constant, the entropy in thermodynamics gives a definite value, what we interested in other disciplines is the change of entropy.

Invention of thermodynamic laws is a prerequisite for Einstein's proof of energy and mass are two forms of the same thing in 1905. Twentieth century was dominated by the innovation of relativity theory. Its principal tool was again calculus.

Even though someone can think that physics has nothing to do with the information theory, in 1949, Shannon and Weaver introduced the entropy concept to cybernetics. Gibbs formula adapted to information theory as follows:

$$S = -\sum p_i \ln p_i \tag{4.3}$$

where p_i is the probability of the system in state i and entropy is calculated based on all possible states that the system can be in.

As mentioned above, calculus is interested in the smooth lines and linearity; however, this contradicts with the nature surrounds us. Discovery of the *fractals* showed the researchers calculus would not be helpful. Fractals are the shapes showing repeating patterns at every scale. Examples are Cantor set, Sierpinski triangle, Mandelbrot set, Menger sponge or Barnsley fern. Sierpinski triangle is shown in Figure 4.1. Even in most of the models proposed using calculus, there have been many assumptions that do not reflect the realistic world totally. To complement the necessity of an approach to deal with the unsmooth shapes and discontinuity that calculus cannot handle, chaos theory has been proposed. In 1961, Lorenz – a meteorologist- accidentally discovered this new mathematical system –chaos theory- on a computer model prepared to forecast the atmospheric behavior. He realized that small changes in the initial condition of the model ended up with extremely different forecasts of weather. He called this as "butterfly effect" making a metaphor as the butterfly flapping its wings in Amazon forest can end up with hurricane in America several weeks later. One can imagine that weather forecast can be more accurate in a small time frame but as the time extends the accuracy of the weather forecast drops substantially. Even in simple systems, chaotic behavior can emerge. For instance, Lorenz used three simple equations with three variables to predict weather, but due to sensitivity to initial conditions the results were chaotic. The importance of chaos theory is it offered solution for the nonlinear systems, it ended up the domination of calculus and reductionist approach.

In the last 20 years, research area “complexity theory” has been discovered. As mentioned on the earlier sections, still the definition and approaches are not clear enough. Chaos theory is a subfield of mathematics like calculus, but complexity is not mathematics but multidisciplinary field that can be part of biology, physics, social sciences, etc.

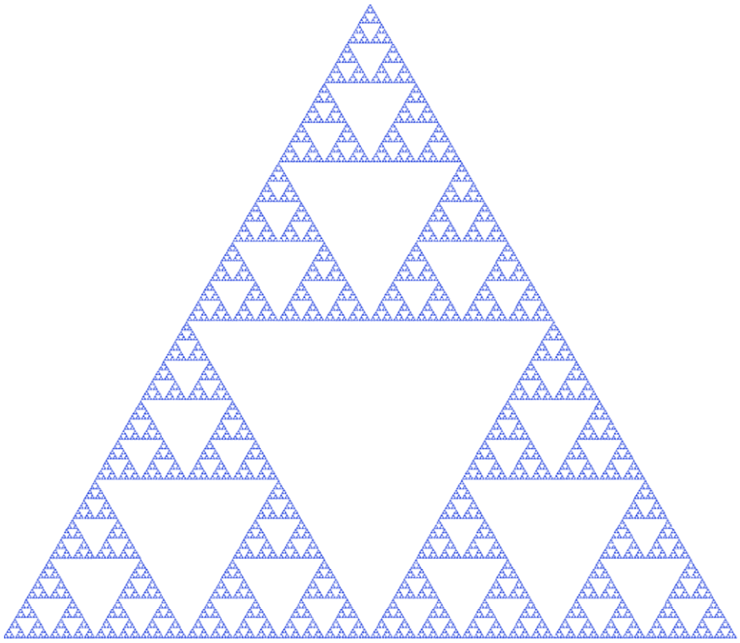

Figure 4.1 Sierpinski triangle

As it is confused some times, analyzing some principles of the complexity can give an idea about the similarities and distinctions of complexity and chaos:

- Complex systems contain many elements interacting with each other nonlinearly: All nonlinear systems can have a chaotic behavior at some part of their phase space. But as mentioned earlier, very few elements can cause chaos, but they don’t have to be complex.
- Elements of the complex system are highly interdependent: Interdependency of the elements is not a requirement for chaotic behavior. Basic example can be a container of gas. It is highly chaotic, because one cannot forecast the

movement of the molecules, but it is not complex. If some part of the gas has been removed, it is still the same gas.

- Complex systems have the emergence behavior: Human brain is one of the most complex system in the world. The behavior of the human being or the action of it cannot be understood analyzing each of the neurons individually. Due to their emergent behavior, systems can adapt to the changing conditions creating self-organization without interference from outside. Self-organization can be seen as the opposite of chaos or similarly to the word "order". Self-organization and emergence are the characteristic of the complex systems which support to system to fail into a chaotic behavior. Life and living things can be seen as a good example. Kauffman (1993) suggested that "living systems exist in the [ordered] regime near the edge of chaos, and natural selection achieves and sustains such a poised state". "Edge of chaos" principle allows the nature to modify itself to stay alive and evolve.
- Reductionist approach is not applicable to complex systems: Chaotic systems and complex systems are not appropriate for the reductionist approach. Fractals can be an example. They are chaotic systems and decomposing them will give you the same scene again. As it is in complexity, part can be seen in the whole, whole can be seen in the part.

4.2 Reasoning Behind Used Methods

It can be seen complexity theory is still a grey area and needs focus and explanation. Based on above mentioned characteristics, complexity is surviving at the "edge of chaos" on the balance of self-organization and chaos or in other words on the line between order and disorder. As discussed before, thermodynamics is all about energy and the relationship of heat and work which is disordered and ordered energy. Entropy measure is useful to understand our lack of knowledge about the system; therefore, how much complex our complex system of interest.

Based on Barranger (2001) and Tuan (2004), entropy and so does the complexity is a subjective matter and relates with our lack of knowledge due to the capabilities of human brain. Even using a very simple question like asking a colour of an object can cause confusion and, people can give different answers if they examine it under different lightings. If the questions and systems we are dealing with are more complex, incapacity of mental power can lead to issues in prediction and understanding. Decisions made today can lead to unforeseen results in the future which is called as ***policy resistance***. Our best solutions to fix a problem can cause failure in some other parts of the system. According to ***systems thinking***, "Everything is connected to everything else" which is the basis of unbreakable relationships of a complex system. ***System dynamics modeling*** is an effective tool to simulate a complex system. It is a multidisciplinary tool which is based on nonlinear dynamics and feedback control of mathematics, physics and engineering. It can be applied to technical systems as well as social sciences (Sterman, 2001). By simulating the interrelations by systems dynamic, consequences of decisions and getting insight about the workings of the system can be possible.

In this research, system dynamics modeling will be used to understand performance of the system in cases of business process changes and to generate input for entropy calculation.

CHAPTER FIVE
RETAIL SUPPLY CHAINS

There is a vast amount of literature on complexity of supply chains from manufacturer point of view. However, retail supply chains started to attract academics with the open problems on operations research and inventory management. It should also be noted that retail industry is starting point of the “bullwhip” effect and causing chaos on the rest of the supply chain due to its fluctuating nature. Therefore, understanding the complexity of it can help the practitioners on their decision making process.

Retailers operating in any sector (like FMCG, textile, home furnishing etc.) have similar planning processes and similar challenges (Agrawal & Smith, 2009). Possible challenges professional face with and can be basis for the complexity analysis are listed below:

- Multiple marketing channels: Retail operation can take place on a physical location –store- or on a virtual location –internet sales.
- Number of stores running: Size of the supply chain extends with the number of stores operating.
- Store formats: A single company can operate with different sized stores (like Tesco having hypermarkets, supermarkets, express stores), with different brands and concepts (Gap Inc company uses several brands with different concept and attracting different customers with different price points: The Gap stores, Old Navy, Banana Republic, Piper Lime).
- Nature of the item: Items that are on sale in stores can highly affect the supply chain management strategy due to their special characteristics:
    - perishability – e.g. food-,
    - seasonality –e.g. clothing, garden products, outdoor furniture-,
    - long procurement lead times –can be supplied from a different country and/or require special customs processes-.

- Number of SKUs/vendors: Number of SKUs managed in a supply chain is also important factor in inventory management. Also, number of suppliers to replenish the stock can affect the effort for managing stock.
- Items complementing/substituting each other: Gap of such items or changing price policy of one of them can lead to change in sales pattern of the other SKU.
- Different categories interacting with each other (i.e. home furniture and home textiles): They can behave similarly like complementing items. Range selection, availability and display in store can influence sales of each other.
- Physical characteristics of the items: Items can be heavy like furniture and require service to customer, or can require special processing like meat carcass or fish.
- Price structure (based on category nature): Pricing strategy influences the market share or promotional prices can affect the sales of all other categories.
- Building a new assortment and display: Changing the assortment and changing the facings and position of SKUs can change the sales potential of category.
- Selling branded products vs private label: Replenishment and setting assortment price points can be affected by the items selected from a brand or the private label.
- Sourcing through warehouse or directly to store: Supply chain costs, replenishment rates can be considered while making this decision. Warehouse and logistics between warehouses to stores can be owned by the retailer or can be provided by a third party. Sometimes, retail can also prefer the supplier to do its own shipment to stores directly.
- Selling directly from store or from warehouse or from supplier or from third party logistics: A retail company can offer its products to customers in the store. Depending on the characteristics of the item, it can be shipped to customer from warehouse. It can happen if the item is heavy like white goods, or shopping is done on the internet. Sometimes retailer can agree with the supplier to keep the stock on its own depot or supplier can do some modifications on the item after purchase. Most of the time this situation

happens in home furniture. Customer selects the furniture colour; however, it is not efficient to keep every colour in the store. Therefore; based on the selection, supplier sends the product to customer. Also, retailer can also prefer to keep and ship the goods using a third party logistics.

- Managing discontinued or leftover stock: Most of the time, when an item is delisted from the assortment list, there could be some stock left in the stores. Or, retailer can purchase some lines with high volume to use on promotions. However, after every promotion, there can be stock left in stores. In both situations, these items should be cleared by some mark down action or return to supplier. Mark down can take place in the store, or they can be collected on a outlet store, or they can be discounted in online stores.
- Managing slow selling stock though outlet, internet or catalog: Similar to leftover stock, items having low sales performance can be used in outlet, internet and catalog to stimulate the sales.

In most of the retail companies, organizational hierarchy consists of different departments to handle buying, assortment planning and supply chain planning (or sometimes called as merchandise planning) roles. Buying team (sometimes named as category planning team) generally seeks for new products and suppliers and tries to find the best price option. Assortment planning (sometimes this can be replaced by marketing team) works closely with the buying team to build up an assortment including the products and display locations for stores. During the assortment planning process, understanding the customer profile, offering variety of products with different price points to meet the customer demand is critical. Merchandise planning also plays role in range building by supporting the process with ideas to maximize the profitability. They can provide an analysis about supplier performance rates, past experience with the products listed (information like the product is selling good enough to be in the assortment or sold with a high percentage during mark down period).

Generally assortment building processes can take 12-16 months and they can happen on a rolling horizon basis. In Figure 5.1, assortment life cycle had been provided. Based on the assortment selection, unit buying plans are prepared. However; on the finance side, based on yearly strategy, sales targets and stock targets are prepared for the coming periods. With respect to sales and stock budget, merchandise planners prepare Open-To-Buy plans. One can recognize that unit buying plans should be consistent with the Open-to-buy plans and unit buying plans are detailed versions of the Open-to-buys. If there are inconsistencies, then assortment selection and yearly sales and stock budgets can be revisited. After approval of the assortment, purchase orders are raised by merchandise planning team. It should be noted that the ordering process can be extended to 5-6 months if the products are import lines or volumes need to be agreed with the supplier to take place in their production capacity. After assortment launch, replenishment of the assortment continues, and based on performance of the products on the assortment "Open-to-buy" plans should be revised weekly or monthly depending on the nature of the sector. Assortment in stores can change once or twice per year or more frequently based on the nature and fashion of the item. As it comes closer to assortment change, buying and merchandise planning team should perform stock clearance activities like organizing mark downs.

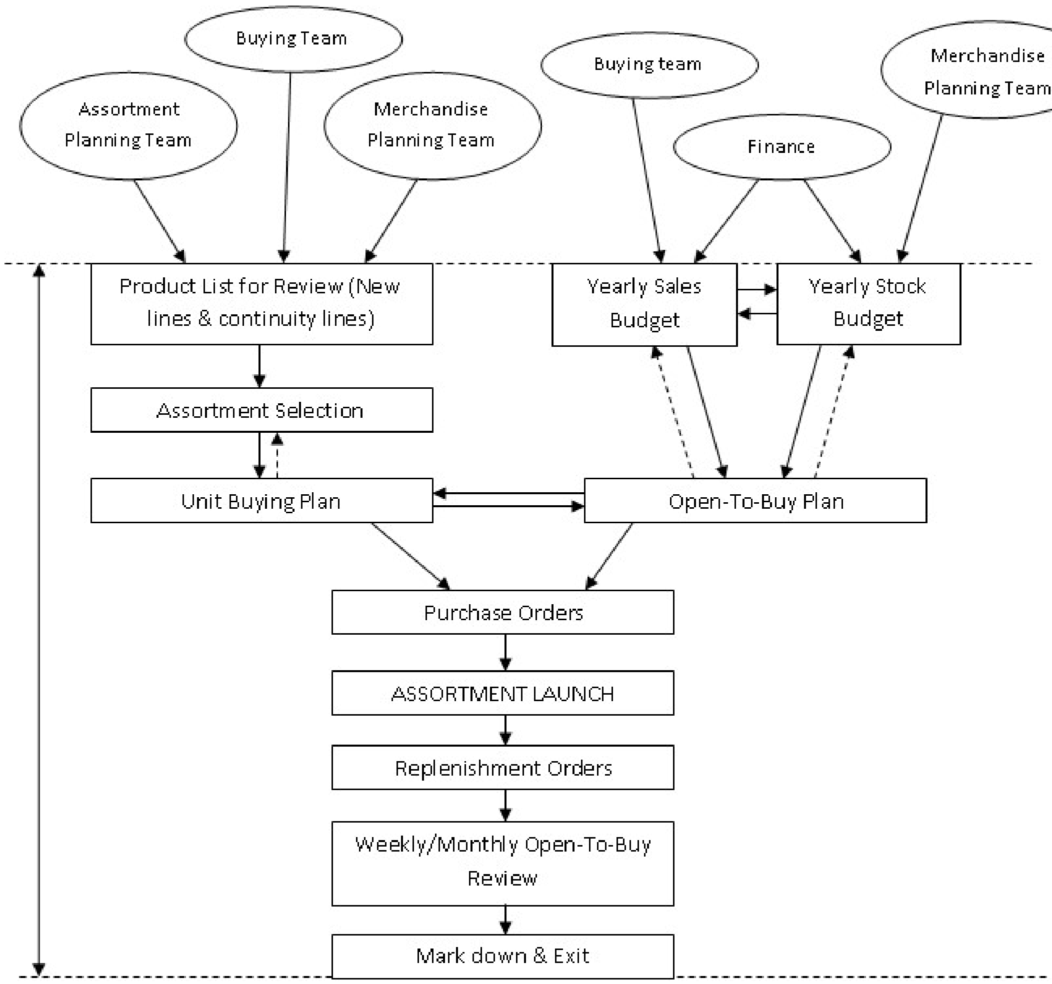

Figure 5.1 Assortment life cycle

CHAPTER SIX
RESEARCH APPROACH

6.1 Research Approach

This research is designed around quantitative measurement of complexity in retail supply chains and to understand if the complexity encountered is a "good" or a "bad" version. To gather insight about the impact of complexity on the system, performance measures have been assembled. In this chapter, the list of complexity and performance measures is described. The metrics presented in this chapter have been applied on comparative studies. These comparative scenarios are briefly explained in this chapter as well.

System dynamics modeling is the approach adopted in this dissertation. The application of system dynamics creates a framework to test the implications of the change of various factors in a supply chain by showing the complex interactions and numerous elements. Outputs of the system dynamics models have been evaluated using the introduced metrics.

In Chapter 7, system dynamics model used for representing the retail supply chain will be introduced. In Chapter 8, comparative scenarios will be quantitatively analyzed.

6.2 Complexity Measures

In Chapter 3, the use of entropy metrics in complexity literature has been presented and the reasoning behind the use of entropy has been explained in detail in Chapter 4. In this research, to understand the complexity 5 different measures are used.

Measures are adapted from Battini et al. (2007), Cheng et al. (2013) and Sivadasan et al. (2006). Selected measures can describe different level of information in the system, including syntactic, semantic and pragmatic version. On the other hand, both structural and operational complexity measures are considered.

Battini et al. (2007) and Cheng et al. (2013) adapted Shannon's entropy metric to measure the complexity of a supply chain network based on the transition probabilities. Transition probabilities have been computed using the inputs and outputs to an element in the network/system. Input & output flow can be quantified by the exchanged goods/values in a certain element. The flow can be shown with the below matrix

$$\begin{bmatrix} t_{11} & \cdots & t_{1N} \\ \vdots & \ddots & \vdots \\ t_{N1} & \cdots & t_{NN} \end{bmatrix} \tag{6.1}$$

As described earlier in Chapter 3, joint entropy $H_{O,I}$, output entropy H_O and input entropy H_I can be calculated by the below formulas where

$t_{..}$ represents the sum of all rows and columns,

$t_{.j}$ represents the column sum for element j,

$t_{i.}$ represents the row sum for element i.

$$H_{O,I} = -\sum_{i=1}^{N}\sum_{j=1}^{N} p_{O,I}(i,j) \cdot log p_{O,I}(i,j) = -\sum_{i=1}^{N}\sum_{j=1}^{N} \frac{t_{ij}}{t_{..}} log \frac{t_{ij}}{t_{..}} \tag{6.2}$$

$$H_O = -\sum_{i=1}^{N} p_O(i) \cdot log p_O(i) = -\sum_{i=1}^{N} \frac{t_{i.}}{t_{..}} log \frac{t_{i.}}{t_{..}} \tag{6.3}$$

$$H_I = -\sum_{j=1}^{N} p_I(j) \cdot log p_I(j) = -\sum_{j=1}^{N} \frac{t_{.j}}{t_{..}} log \frac{t_{.j}}{t_{..}} \tag{6.4}$$

Input entropy measure the uncertainties caused by the input flows to the elements, where output flows are unknown. Similarly, output entropy measure the uncertainties caused by the output flows from the elements, where input flows are unknown. Joint entropy is the uncertainty of an element based on the input and output flows. Average Mutual Information (AMI) shows the degree of information sharing among the members of system. As the AMI value get larger, the information sharing get higher which decreases the uncertainty in the system and leads to less complexity.

AMI is calculated using the below formulation.

$$AMI = H_O + H_I - H_{O,I} \tag{6.5}$$

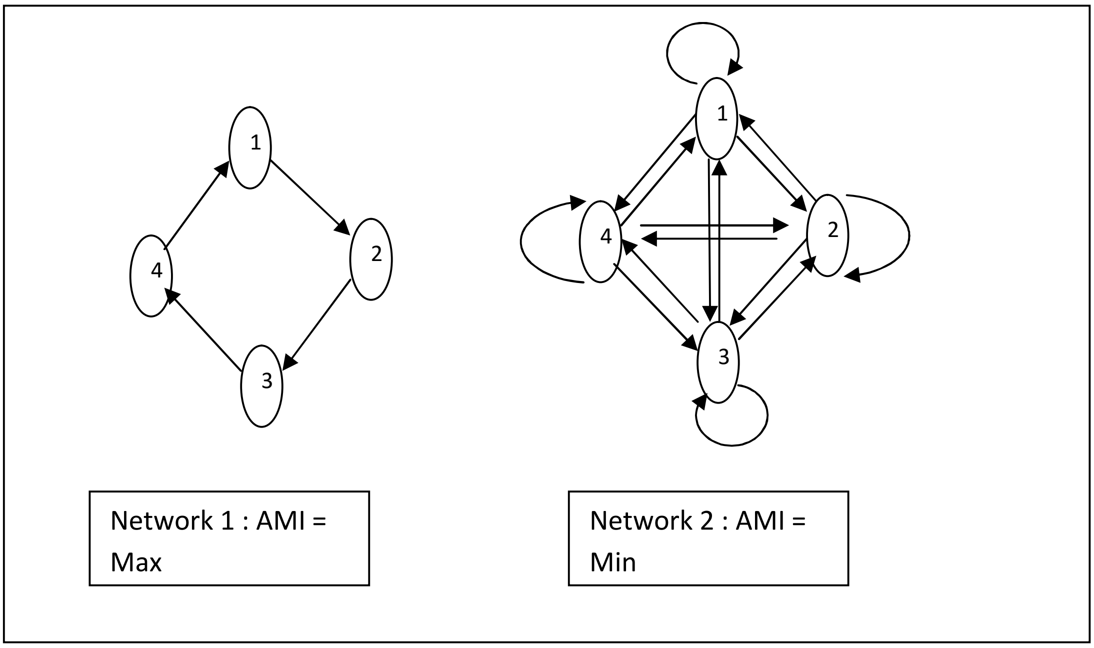

Figure 6.1 Network models showing minimum and maximum AMI

In Figure 6.1 Network 1, when a good leaves element 1, it can be clearly observed that it enters element 2. Uncertainty is minimal, leading to maximum value of AMI. The information sharing is clear and happens only with the nearby elements, thus the system is less complex. However, in network 2, if a particle leaves node 1, it can enter to any element in the system. Therefore, the information sharing is less since we cannot understand the system, unless we take information from all elements. The flow is unclear, uncertainty is high and AMI has its lowest value. In other words, complexity is high.

In Cheng et al. (2013), AMI is shown using Venn diagrams as in Figure 6.2. All possible connections of the input and output flows are shown in the first diagram as joint entropy. AMI is about the information sharing and it is represented as the intersection; therefore, it is degree of order. Degree of disorder is shown in the third diagram, $R_{O,I}$. As the $R_{O,I}$ increases, complexity increases in the supply chain.

Formulation of $R_{O,I}$ is shown below:

$$R_{O,I} = H_{O,I} - AMI \tag{6.6}$$

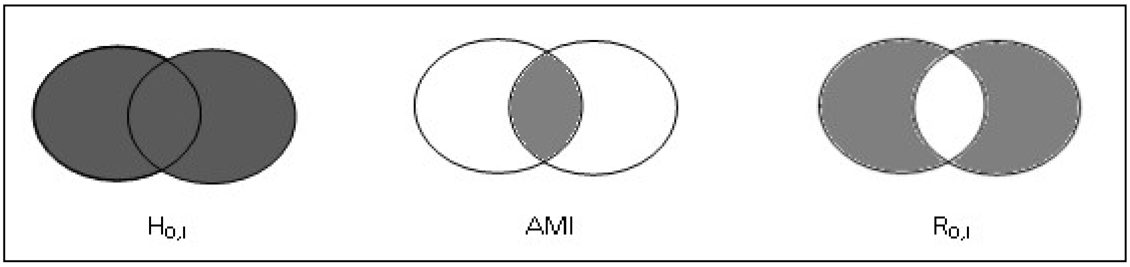

Figure 6.2 Venn diagram illustration of $H_{O,I}$, AMI, $R_{O,I}$.

Total system size is calculated by TST. System size can be incorporated into the complexity measures. As the information size increases with the TST, complexity impact will be amplified.

$$TST = \sum_{i=1}^{N} \sum_{j=1}^{N} t_{ij} = t_{..} \tag{6.7}$$

Another structural complexity metric used in Cheng et al. (2013) quantifies the complexity according to the network type used. Structural complexity should be independent of the system size. The initial flow matrix is converted to a 0-1 matrix showing only the number of arcs entering and leaving each element. Number of arcs input and output arcs to an element can single or multiple and it impacts the complexity of the network.

$$\begin{bmatrix} A_{11} & \cdots & A_{1N} \\ \vdots & \ddots & \vdots \\ A_{N1} & \cdots & A_{NN} \end{bmatrix} if\ t_{ij} > 0 \ \rightarrow A_{ij} = 1\ else\ A_{ij} = 0 \tag{6.8}$$

For each element in the system, {total number of input arcs}/{total number of output arcs} give the diversity type of the element. As diversity types increases in a supply chain, complexity is expected to increase since more information is required to describe the system. Formulation of diversity is shown below where e is an element of the supply chain network consisting of N elements in total:

$$Diversity = \frac{A_{.e}}{A_{e.}} \quad (6.9)$$

If there are x number of diversity types in the system, then probability of the existence of each type should be calculated in order to compute the complexity using Shannon's entropy. Calculation is shown in Table 6.1.

Table 6.1 Calculation of diversity type probabilities

Diversity Types	**Number of observing diversity type in the network**	**Probability of diversity type observance**
$Diversity_1$	# of $Diversity_1$	# of $Diversity_1$/N = p($Diversity_1$)
….		
$Diversity_x$	# of $Diversity_x$	# of $Diversity_x$/N = p($Diversity_x$)
TOTAL	**N**	**1**

Based on Shannon's entropy, complexity can be calculated using the below formula:

$$H(Diversity) = -\sum_{i=1}^{x} p(Diversity_i) * \log p(Diversity_i) \quad (6.10)$$

Final version of the complexity measure, that is adapted in this study, is from Sivadasan et al. (2006). It concentrates on the out-of-control states of the supply chain. In this dissertation, multiple variables are tracked. If these variables are outside the acceptable range, then the system will be accepted as out-of control. Because, organizations can offer different recovery plans in real life, the extent of out-of-control situations is critical as well. Therefore, metric considers the type of out-of-control states additionally. The reasons creating uncontrollable states are incorporated to the calculation as well. As the model of Sivadasan et al. (2006) developed for production environment, it included product type. But in this study, product type and observation frequency variables are eliminated. The adapted version of the metric that is used in this study is shown below:

$$H(OC) = -\sum_i (1 - P_i) \sum_j \sum_k p_{ijk} * \log p_{ijk} \quad (6.11)$$

where

i type of variable tracked

j reason of out-of-control state

k type of out of control state

P_i probability of tracked variable i is in controllable states

p_{ijk} probability of tracked variable i is in out-of-control state k due to reason j.

6.2.1 Categorization of Complexity Measures

In order to understand and interpret the complexity of the retail supply chains 5 measures are used and each one serves to a different level of information type and complexity type. In Chapter 3, complexity types have been classified based on time variable in the analysis, namely;

- Static complexity
- Dynamic complexity

Another classification is the level of information on the complexity measurement;

- System complexity
- Perceived complexity
- Value adding complexity

Briefly, used measures are;

1) ***$R_{O,I}$*TST***

As noted above, $R_{O,I}$ provides the degree of disorder. When multiplied with the system size TST, the effect of disorder is amplified. By simply using this measure, one cannot judge if the complexity is impacting the system negatively or the people in the system badly. Simply, a system using very sophisticated software to manage production, supply chain database or the B2B communication can be computed having huge complexity, but the support of the software can prevent the user on the system to suffer from it. So it can be a way to measure system complexity. As the research uses the outputs of a system dynamic model run over a long time period, it is dynamic complexity.

2) $R_{O,I}$

$R_{O,I}$, by itself can give an idea how the dynamics of the system is complicated or beyond the limits of understanding things simply. As noted in the earlier discussions, complexity is something caused also by the capabilities of the human brain. If the network structure becomes complicated and, if you are part of an element in the supply chain, then it can also get harder to capture the information without understanding the other elements in the system. Therefore, the perceived complexity get higher with the increase of $R_{O,I}$. Since the timely behavior of the system is included in the calculation due to usage of system dynamics, it can be noted as dynamic complexity.

3) AMI

AMI shows the information sharing on the network and it is inversely related with complexity. During a comparative study, it would be safer to control both $R_{O,\mathrm{I}}$ and AMI at the same time, since the value of the joint distribution can affect the values. Sometimes one metric cannot provide evidence about the complexity change in the test scenarios, but the other can show a significant change to guide us. Similar to $R_{O,I}$, it is perceived and dynamic complexity.

4) H(Diversity)

Diversity metric guides the researchers about showing the interconnections in a network. Since on the structure of the supply chain network is of interest, it measures static complexity. As the interconnections get intricate, the system gets less comprehendible. It is again an indicator of perceived complexity.

5) H(OC)

Out-of-control complexity metric shows the complications on the system due to failures. It also includes the variation of actions to recover. If the probability of going out of control, or the variation of reason to fail, or the type of failure increases, then the complexity gets higher. For example, if the sales value in the retailer gets 15% lower compared to the budgeted sales in all of the out-of-control periods, then you take the same action to make it higher every time. However, if in some out-of-control periods sales deviate 30% from the budget, this time you need to take more serious actions. Therefore, if in the same test period both 15% and 30% deviations occur, then different actions needs to be taken and different elements of the system should be incorporated into the solution. In 15% deviation, the sales decrease can only be recovered by some actions in the store operations. But if the sales deviate 30%, both store operation and stock planning team needs to take action. Consequently, the management of the supply chain gets harder, complexity increases and H(OC) value supports the idea. In real life, these recovery periods contain numerous non-value adding activities, like setting up emergency meetings, usage of communication tools more often (email announcements, overtime payments to employees, etc.). Thus, out-of-control complexity metric is inversely related with value adding complexity, in other words non-value adding complexity. It is also dynamic due to its usage of output data over a long time period.

The relationship and classification of metrics are shown in the Table 6.2.

Table 6.2 Complexity types and relationship

	Time variable		Information Level		
	Static	Dynamic	System	Perceived	Value Adding
$R_{O,I}*TST$		Positive	Positive		
$R_{O,I}$		Positive		Positive	
AMI		Negative		Negative	
H(Diversity)	Positive			Positive	
H(OC)		Positive			Negative

6.3 Performance Measures

In the dissertation, to observe the relationship of complexity with the system performance, some performance metrics appropriate for the retail supply chain have been used.

Measuring supply chain performance is challenging since most of the developed methods do not consider all relevant aspects of the supply chain in a single measure. In other words, they are not inclusive at all. For example, if the performance measure concentrates on operation costs at minimum, it can overlook the delays in customer deliveries or flexibility to meet fluctuations in demand. Therefore, to understand if the system is showing high performance, in other words high quality of service firstly organization's strategic goal should be understood. Then, parallel with the strategic goal; measurement should emphasize on the below three aspects (Beamon, 1999);

- Resource management; which is critical for profitability
- Output management; which ensures sufficient level of customer service
- Flexibility; which is needed to survive and adapt in uncertain nature of the competitive market.

In the retail supply chain of interest, strategic goals are to accomplish the sales target and to keep the stock position close to the budgeted value. In the comparison scenarios about retail supply chains, below measures are used;

- **Resource measures** are *supplier delivery performance*, *average stock holding* throughout the year in the retailer and *overstock* on the supplier.
    - **Supplier delivery performance:** It is measured by the percentage supplier actual delivery with respect to the order raised by the retailer. Since the sales data is not visible to all parties in the supply chain, due to forecast inaccuracies, supplier can get stock out or left with a huge amount of stock.
    - **Average Stock Holding:** In order to calculate stock turnover rate and deviation from the budget, average stock holding has been used.
    - **Overstock on Supplier:** Due to the bullwhip effect, suppliers can dedicate more stock than necessary for the retailer. In order to understand the performance of the retail supply chain as a whole, supplier delivery performance and the overstock on supplier can be considered together.
- **Output measures** are *Actualized sales* compared with the target values

- **Actualized sales percentage:** Stock holding, pricing strategies are planned as a consequence of the sales target. If there are issues due to stock holding, then store stock availability suffers, which can lead to drop in sales performance. Actualized sales percentage is calculated by the actual sales divided by the target sales performance.

- **Flexibility** can be measured by the extent *demand variability* can be satisfied by the retailer.
    - **Demand flexibility:** One can think that with the overstock dedicated to the retailer (due to bullwhip effect), the flexibility should be higher even if the visibility is low in the supply chain. However, it should be taken into account that, if there is no visibility, then each member considers its own costs and benefits and makes its own forecasting. There can be forecasting inaccuracies and due to competition in the market; suppliers can share the stock with other retails. Flexibility is calculated by the percentage capability of the available supplier stock to satisfy the customer demand of the retailer. Also, after setting an acceptable service level to customer, number of periods the supply chain can fulfill the customer demand can be used as flexibility indicator.

6.4 Test Scenarios

In this research, 4 different scenarios have been analyzed in terms of complexity and performance. Firstly, their system dynamic simulations had been prepared based on a real case data and the outputs have been summarized using complexity and performance measures explained in the above sections. Briefly, these scenarios are described below.

Scenario 1: Decentralized versus Centralized model

In this scenario, the impact of information visibility analyzed. In the decentralized model, suppliers and retailers make their own forecasting. When the sales data of the previous years has been analyzed; profitability decreased because of the stock reduction targets, subsequently hampered by the big discounts on the left over stock every year. To overcome profitability issue; retailer made a critical decision of increasing its sales by increasing the profitability and keeping less stock compared to previous years. The results of this decision either with information sharing or without sharing are shown in terms of complexity and performance in the succeeding sections.

Scenario 2: Stock management in case of low supplier service level

This scenario contains alternative ways to handle stock-out issues of the suppliers as a part of the stock management team. In a decentralized supply chain, if the supplier service rates are not adequate; then alternative decisions can be;

- Keeping safety stock in the stores by increasing the stock target
- Keeping safety stock in the warehouse by increasing the stock target
- Allocating the available stock of the supplier based on the sales performance of the stores.

Scenario 3: Cross-docking versus direct to store

Same decentralized model has been analyzed based on logistics strategy of the retailer. In the first model, all orders are sent to markets by cross-docking through a warehouse. In the second one, warehouse is eliminated; orders are directly shipped from supplier to markets. However, since the shipment costs for the supplier can be high; some orders are cancelled or increased up to a feasible value for sending.

Scenario 4: Category management decisions in a supply chain

In scenario 2, in case of low service level, alternative solutions that can be offered by the stock planning team have been analyzed. But, the category management team in the retailer can offer some strategic options on supplier management. Comparative models are:

- Original model of working with decentralized principle and low supplier service level
- Decreasing supplier number
- Shifting unsatisfied demand to any other supplier on the market

- Importing the stock in bulks as the retailer and keeping the imported stock in warehouse. It can be a way for the retailer to create its own private.

CHAPTER SEVEN
SYSTEM DYNAMICS

7.1 Using System Dynamics

Living in a highly changing world which is moving towards increase in complexity in many areas, decision making becomes more critical than ever. We can discover with a little investigation that most of the problems we face today are the consequences of a solution offered to another problem. But it can also be realized that generally nobody has foreseen these problems before implementing their solution. For example, invention of antibiotics at the beginning of 20th century was a successful and important milestone in the history of medicine. It saved many lives by curing many infectious diseases. Compared to evolutionary scale, the massive use of antibiotics by human being is very short term. Even in such a short period of time, adaptation of bacteria caused formidable examples of hard-to-treat multiple antibiotic resistant infections. These types of well-intentioned efforts to solve existing issues can lead to unforeseen results due to interaction of other people or nature, this phenomenon is named as *policy resistance* (Sterman, 2000). People sometimes can call the unexpected situations as side effects, but it is not that simple. Policy change decided by us can alter the state of the system, and since we are part of the system, other people or nature can react to change the state back into its initial position. Therefore, policy resistance emerges because of our tendency of using reductionist approach and seeing the system not as a whole.

As explained in the earlier sections, one of the most important characteristics of complexity is its nonlinear behavior which causes a small input to end up with large implications. Its components are decomposable; therefore, seeing the big picture would be important in case of planning any change in the running policies – *Systems thinking*. However, in most of the cases, our mental capability would not be sufficient to understand all interactions and the consequences. There could be many obstacles for researchers/decision makers to understand the big picture fully:

- Time delay for a result of an action to emerge can be long,

- cause and effect chain can be unclear or hard to track,
- reasoning skills of people investigating or within the system can be low,
- feedback taken from people can be inadequate or biased,
- people can show defensive reactions,
- cost of experimenting in real life can be too high.

System dynamics modeling is a practical way to overcome the above mentioned barriers. It is a method to induce learning in a complex system. It helps us to visualize sources of policy resistance and design new approaches to minimize it.

The interaction of the components on a system in case of any change is called as *feedback*. In system dynamics modeling, there are two types of feedback mechanisms (Sterman, 2000):

1. Positive (Self-reinforcing) loops: This type of loop responds to an action by increasing the effect of it. When the effect destabilizes the system, the feedback amplifies the magnitude of it.
2. Negative (Self-correcting or Balancing) loops: These loops balance the effect of an action to take it to its original state. Therefore, the impact of action and feedback are opposite.

In system dynamics, positive and negative feedback loops are simply described using causal loop diagrams. These diagrams are also helpful while converting the model into a simulation environment. To make it further useful in developing the simulation model, *Stock* and *Flow* elements are also incorporated. Stock and Flow are basically accumulation and dispersal of resources (Sterman, 2001).

Causal feedback loop showing stock and flow structures can easily be understood with a “Population” model in Figure 7.1 (http://systemsandus.com/2012/08/15/learn-to-read-clds/)

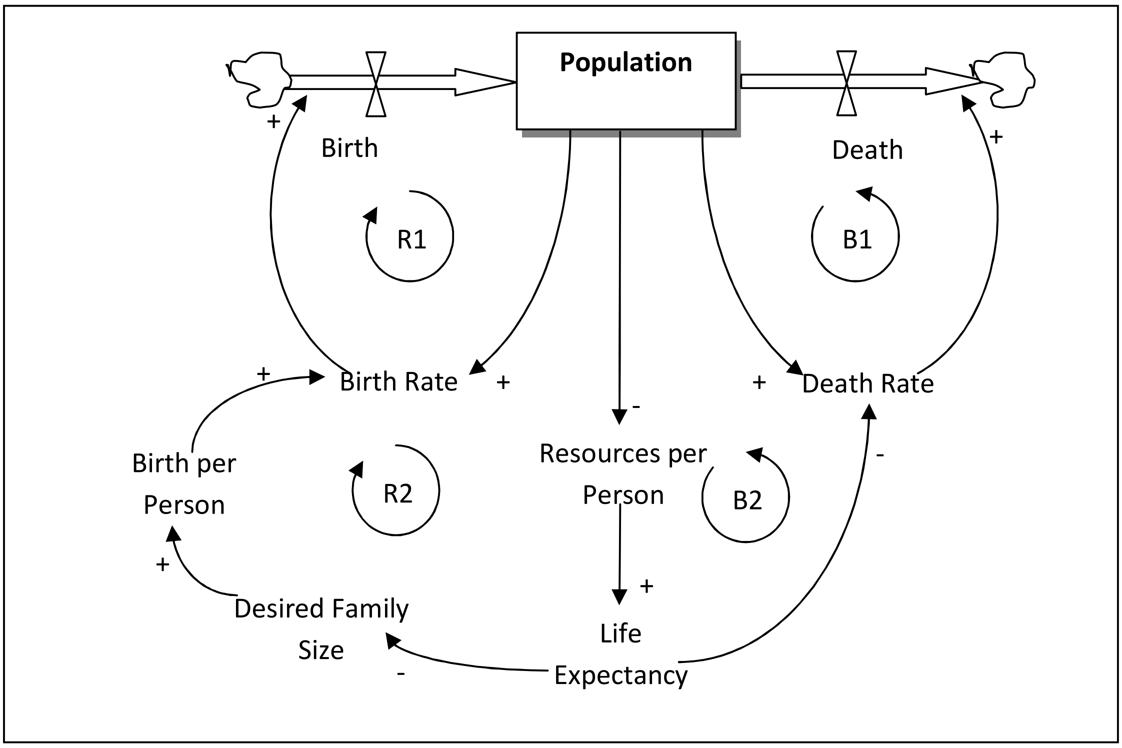

Figure 7.1 Causal loop diagram showing stock and flow structures of "Population model"

In the model Population is the accumulation of number of people in the society and shown as *Stock*. *Flows* feeding the population are births and deaths. Arrows with positive or negative signs show the causal relationships. R1 and R2 are self-reinforcing loops; whereas, B1 and B2 are the balancing loops. In R1, the increase in number of people in a population increases the birth rate as well since there will be more adult that can have babies. However, B1 shows the population balancing effect to keep the number of people in its original position. Self-correcting feedback loops show effect in the reverse direction of the action. More of something is balanced by an action to decrease it, or vice versa. If the number of people increases with births; death rate will also increase. If the population decreases, since there will be less people to die, death rate will decrease. On the other hand, if the population increases, resource per each person to consume will drop depending on the economic wealth of the population. Consequently, there will be less food, less water, less medicine, less money. Therefore, it will affect the average life expectancy negatively and increase the death rate. This causal relation has been shown in B2 as a balancing effect to the population. But at the same time, due to scarce resources, infant mortality rate can increase and to make the family survive in the future desired family size would increase. Therefore, the birth rate per person will increase and will lead to increased birth rate in the population. Therefore, besides the balancing effect of B2, there would be R2 reinforcing the population increase.

7.2 System Dynamics in Retail Supply Chains

In this research, system dynamics modeling is used to simulate the retail supply chain and to analyze the outputs to analyze and measure complexity. Different factors in a supply chain are analyzed in terms of their effect on complexity. As a system dynamics simulation tool STELLA is used. In this chapter, modeling details of the Scenario 1 will be provided. Other scenarios use the same models with minor changes.

7.2.1 Information Sharing in Retail Supply Chain

There is a growing trend for information sharing by creating external linkages in supply chains with other partners in order to increase visibility of their operations and activities. Shared information can be sales data, inventory position, forecasts, etc. and the sharing can be performed using sophisticated integrated systems or only by simple documentation or emails. But in the end, aim of this process is to improve the decision making process and to gain competitive advantage by making unclear or uncertain information visible. In general, Supply chain visibility can be defined as the determined level of sharing useful information with other members of the supply chain to create mutual benefit on the operations and to decrease costs (Barratt & Oke, 2007).

In traditional inventory theory, supply chains are considered as multi-echelon inventory systems. In these systems, uncertainties are caused by delays in deliveries, machine breakdowns, and order fluctuations. As mentioned in the earlier chapters, uncertainties increase complexity and complexity is always paid by a part of the system. For example, order fluctuations in the supply chains lead to increased costs either by increased level of buffer inventories or by overtime schedule charges (Yu et al., 2001; Mitleton, 2002).

In a supply chain, every member of the chain has to make their own forecasting in order to plan its production/service, inventory control, material requirements. Each member can do this forecast analyzing the downstream member's demand (retailer should forecast using customer demand data statistics). However, it has been observed that upstream members' demand fluctuation is greater than the fluctuation of downstream members' demand. This phenomenon is discovered by P&G executives and named as "bullwhip effect". To eliminate this effect, supply chain visibility (information sharing) can be used to decrease uncertainty in the upstream members (Yu et al., 2001).

In this study, retail supply chains will be analyzed based on their information sharing level described below:

- Decentralized Supply Chains: Each member of the supply chain make their own decision as if they are the single decision maker and optimize its own costs and benefits without visibility, this type of the systems are known as decentralized supply chains. There is no information sharing. Retailer uses customer demand information and supplier uses retailer's ordering data.
- Centralized Supply Chains: On Centralized supply chains, visibility is the major driver. Retailer and supplier use the customer's demand information to prepare their own inventory plans.

In the retail supply chain model of interest -which is decentralized-, causal loop diagram has shown in Figure 7.2. In the model, there are three *stock* components tracking stock position of supplier, warehouse and store. Depending on the supply chain of interest these *stock* components can increase. A supplier can increase its stock position either by production or import or buying from its supplier. Supplier stock can decrease by deliveries to retailers based on the incoming orders. In this model, deliveries from suppliers are shipped to warehouse and send to stores afterwards as cross-docking. Stores are points where stock can be bought by the customers. Sometimes warehouse does not operate as cross-docking and some stock can be captured in the warehouse as buffer. But in this example, stock is distributed immediately after its arrival from the supplier which is named as cross-docking.

Since suppliers and the retailer do not share information with each other, they make their own sales forecasts. Supplier decides its production or import quantities based on its own forecast, on the other hand retailer orders from supplier according to its own forecast, strategy or budget.

When there is sufficient stock in the stores, this would support the availability of the range of products on the shelves. As the range availability increases, customer satisfaction increases and it induces the sales as well. At the same time, increase in availability decreases the calculated order level since there will be less purchase required in the stores. This self-balancing loop is shown as B1.

Calculation of order level on the retailer is also affected by the stock holding strategy of the retailer. In general, stock holding is limited by some budget or inventory cover target. As the stock position raises above the target or the inventory cover, by self-balancing loop B2 calculated order level drops.

Due to bullwhip effect, sometimes supplier can also suffer from overstocks. It is an expected situation since supplier is not aware of the real customer data or the stock holding strategy of the retailer. In self-balancing loop B3, it is shown that in case of any overstock issue happening on the supplier side, they share the stock with other retailers to reduce it. The reduction of stock on supplier can sometimes lead to lower service levels in terms of satisfying the orders of the retailer in the figure. Therefore, actual stock shipped can be less than the order raised by the retailer.

If the retailer plans some promotional events to increase sales, this can trigger the order level from the supplier. In some situations, supplier cannot fulfill the requirement since the forecasting mechanisms are separate from each other.

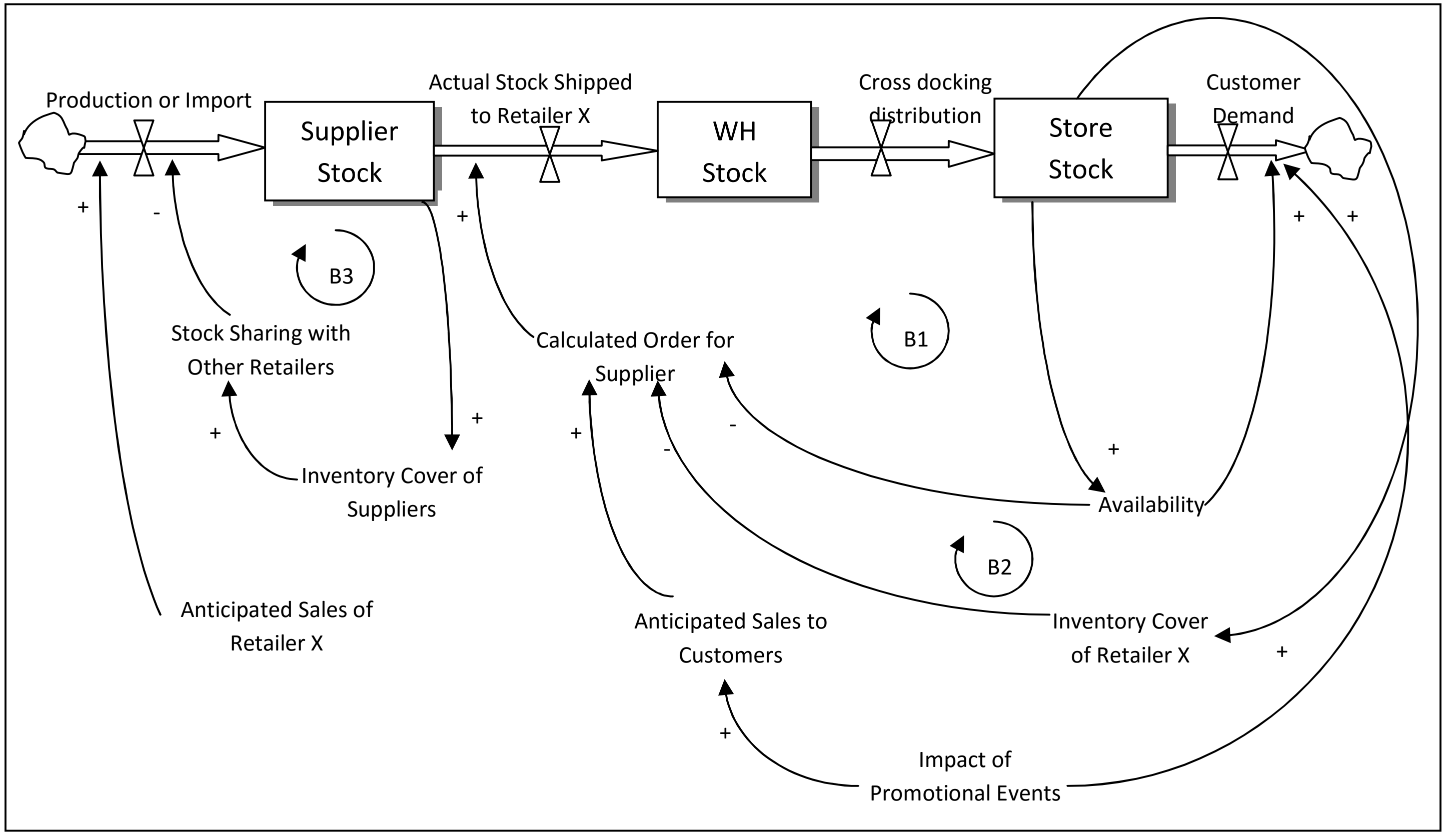

Figure 7.2 Decentralized retail supply chain model causal loop diagram

In Figure 7.3, same retail supply chain is converted to a centralized one. Information sharing has been agreed by the parties and retailer shares the sales data and expected weekly sales forecast with the supplier. According to the weekly sales trend, total purchase from supplier is agreed and supplier does not share the stock with the other retailers but dedicate to retailer. Based on the customer demand fluctuations orders can deviate between ordering periods, but the total purchase remains as in the original plan. Since stock sharing no more exists, B3 loop has been deleted. Supplier and retailer share the same sales plan therefore supplier is now aware of the promotional purchases and dedicates stock accordingly.

Based on the way of working, supplier is no longer has stock balancing loop B3 but information sharing reduces the bullwhip effect of the decentralized way of working.

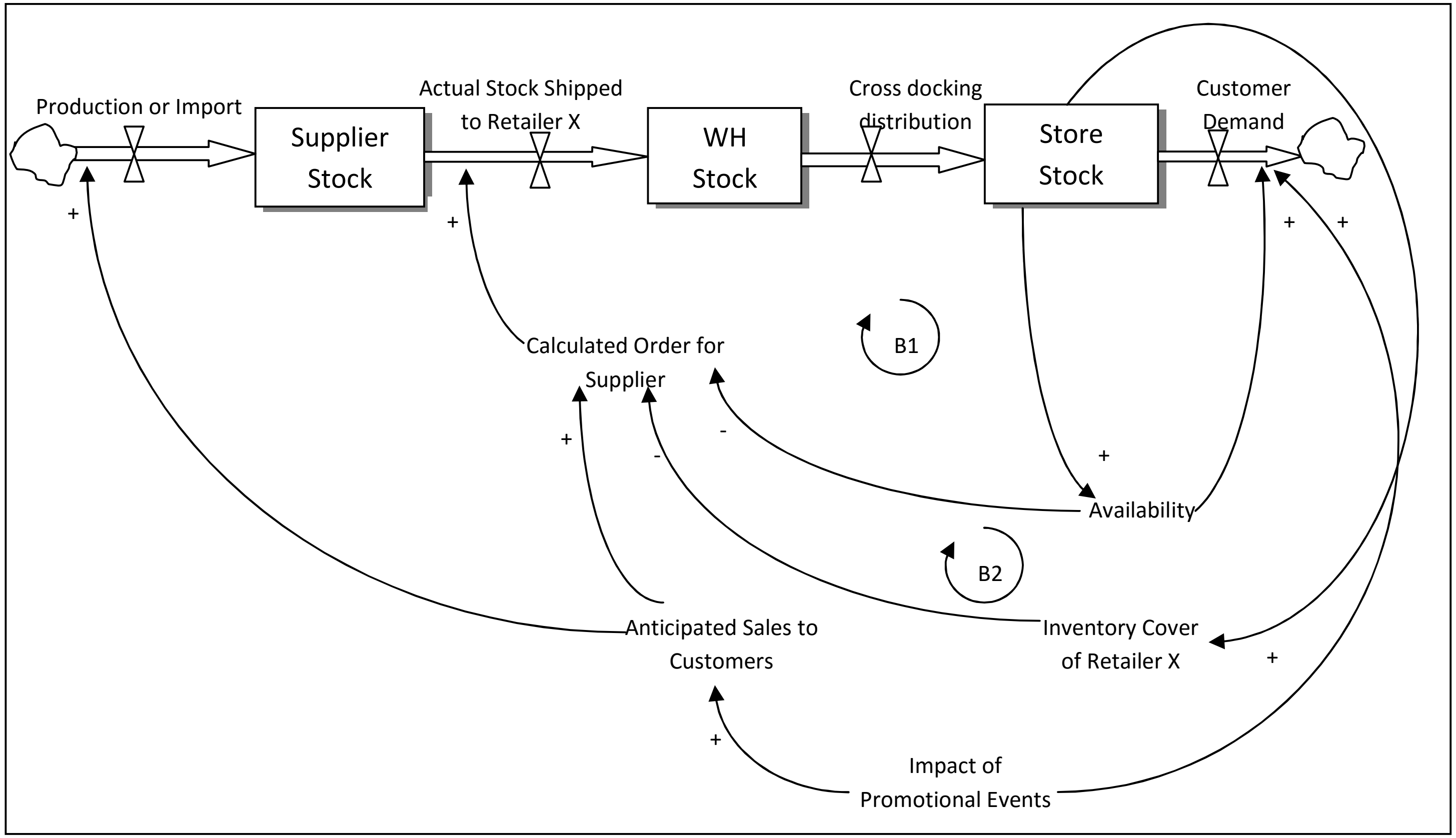

Figure 7.3 Centralized retail supply chain model causal loop diagram

CHAPTER EIGHT
COMPLEXITY & PERFORMANCE MEASUREMENT: A SYSTEM DYNAMICS SIMULATION APPROACH FOR RETAIL SUPPLY CHAINS

8.1 Scenario 1: Decentralized versus Centralized model

8.1.1 System Dynamic Model

System dynamic model details for the decentralized and the centralized model has been provided in Chapter 7. Causal loop diagrams for the models have been shown in the previous chapter as well. Based on the causal loop diagram, STELLA software has been used for programming. Model for the decentralized and the centralized model can be found in APPENDIX-1 and APPENDIX-2 respectively. Their flow models are the same as it can be seen from the pictures but the forecasting data has been modified so as to support the different decision making processes.

For the analysis, toys department of a retailer –Tesco Turkey- is selected. There are 3 store formats running in the Turkey market; hypermarket, supermarkets and express stores which are classified based on their layout. New store openings and closures can take place throughout a year based on the sales performance. In the Tesco Turkey, there were about 191 stores running on the selected years. Since the modeling of 191 stores and thousands of toys products in a simulation model cannot be feasible; data has been aggregated. Based on the sales values, hypermarkets are categorized into 3 categories; high performing stores (HYPER A), average performing stores (HYPER B) and low performing store (HYPER C). Total sales revenue for the previous year was 22.9million TL (Turkish Lira). Excluding the value added tax, revenue value was 19.4million TL. Total cost value was 15.1million TL and profit margin was 22.1%. Profit margin is calculated as net profit divided by revenue. Net profit is determined by subtracting cost of goods sold from the revenue excluding taxes. Store format based sales and stock can be found in Table 8.1.

Table 8.1 Toys department sales and stock values

STORE FORMAT	SKU	Sales	Sales Ex VAT	COGS	Sales % by Format	Margin	Total Stock	Stock % by Format
HYPER A	10	8,145,021	6,902,585	5,285,461	35.5%	23.4%	1,880,840	37.5%
HYPER B	16	6,766,949	5,734,829	4,434,321	29.5%	22.7%	1,547,159	30.9%
HYPER C	32	6,789,464	5,753,861	4,585,383	29.6%	20.3%	1,304,741	26.0%
SUPERMARKET	51	1,071,383	907,960	728,432	4.7%	19.8%	236,739	4.7%
EXPRESS STOR	82	151,190	128,127	100,370	0.7%	21.7%	41,354	0.8%
TOTAL	**191**	**22,924,007**	**19,427,362**	**15,133,966**	**100.0%**	**22.1%**	**5,010,834**	**100.0%**

Sales data of the previous 5 years had been analyzed. It can be seen in the Table 8.2 that revenue in the last 5 years increased gradually. Part of the sales increase is resulted from the store openings. 90% of the revenue comes from the top selling hypermarkets. In 2010, hypermarkets creating 90% of the revenue was 36, but in 2013 & 2014 this number increased up to 50s due to Tesco's aggressive plans to increase its market share. Moreover, it can also be seen that in 2013 and eventually in 2014 average revenue per store also increased significantly. When profit margin has analyzed, each year it decreased dramatically and ultimately it dropped approximately 15.3% from 37.4% to 22.1%. This is because of the financial issues, and company decided to increase its inventory turnover ratio (Annual cost of goods sold / Inventory). To achieve this, average stock holding throughout the year has decreased. Since there were left over stock from previous years or non-selling lines, liquidations took place more often. Even though this approach helped the business in financial figures about stock, profitability of the company impacted severely. In 2015, business decided to continue increasing the revenue by increasing the top selling hypermarket number. Also another important goal is to keep the average sales per store close to last year but to increase profit margin up to 29%. Profit increase can be achieved by a more serious stock and buying plans which eliminate the need for liquidation throughout the year. Since the store numbers are close in 2013 and 2014, the dramatic decrease in the average stock holding can be seen apparently in Table 8.3. But in 2015, the aim is to decrease it aggressively to 5million TL.

Table 8.2 Sales analysis of past 5 years and sales target for 2015

YEAR	Sales	Margin	Stores (90% of sales)	Avg Sales / Store	COGS
2010	14,411,670	37.4%	36	400,324	7,643,129
2011	17,830,259	34.7%	45	396,228	9,874,380
2012	18,605,385	28.6%	47	395,859	11,254,854
2013	20,965,555	24.2%	50	419,311	13,464,696
2014	22,924,007	22.1%	49	467,837	15,133,966
2015 Target	**23,790,159**	**29.1%**	**52**	**457,503**	**14,292,623**

Table 8.3 Average stock holding in TL(Average closing stock of 12 months)

YEAR	Average Stock Holding
2013	7,628,911
2014	6,324,032
2015 Target	**5,000,000**

In the STELLA models, retailer COGS forecast is 14.3million TL. In the decentralized model, suppliers are unaware of the strategic targets of the retailer and prepare their forecast based on the orders of the previous year with 10% of growth target. In the centralized model, retailer shares the COGS target of 14.3million TL with the suppliers based on their last year performance. There are 12 suppliers and their 2014 sales in the retailer have been provided in the Table 8.4.

Table 8.4 Supplier based sales of Tesco Turkey

SUPPLIER	SKU	Sales	Sales Ex VAT	COGS	COGS % by Supplier	Margin
VARDEM OYUNCAK V	750	6,806,321	5,768,139	4,308,823	28.5%	25.3%
TESCO STORES HON	563	5,862,478	4,968,263	3,934,029	26.0%	20.8%
MAMITOYS ELIF OZ	163	2,789,705	2,364,185	1,811,998	12.0%	23.4%
HASBRO INTERTOY	195	2,722,211	2,306,987	1,958,471	12.9%	15.1%
MATTEL OYUNCAKCI	326	2,269,245	1,923,113	1,561,371	10.3%	18.8%
ABC OYUNCAK SANA	7	567,843	481,229	379,874	2.5%	21.1%
TAN ITRIYAT SAN.	68	380,332	322,319	210,794	1.4%	34.6%
ADORE OYUNCAK VE	60	341,131	289,097	261,778	1.7%	9.4%
SAMATLI OYUNCAK	90	319,235	270,542	236,342	1.6%	12.6%
PILSAN PLASTIK V	35	312,766	265,060	181,025	1.2%	31.7%
ESER OYUN ALATLE	30	308,573	261,505	156,110	1.0%	40.3%
BALONEVI SAN.VE	63	244,167	206,924	133,352	0.9%	35.6%
TOTAL	**2,350**	**22,924,007**	**19,427,362**	**15,133,966**	**100.0%**	**22.1%**

Retailer orders from suppliers once every 2 weeks. Therefore, tracking of the retailer stock to the target of 5million TL takes place just the moment orders are sent to the suppliers. In other words, at the start of 1^{st}, 3^{rd}, 5^{th}, 7^{th},etc week stock will be compared with the target value. On the other weeks, based on the sales expectations, stock can be higher.

In the decentralized model, supplier allocates stock for 4 weeks to the Tesco Turkey retailer. If the orders raised to that supplier are less than the allocated stock, supplier sells the left over stock to other retailers. In the centralized model, suppliers split their total forecast to 4 pieces and take stock to their own warehouse once every 13 weeks.

Since the stock target is 5million TL, all store layouts are modified so as to accommodate with the new expectation. Unnecessary stock holding physical units have been removed. On the simulation, it will not be possible to track 2350 Stock Keeping Units (SKUs or products), thus availability will approximately calculated based on the stock target. If the stock is less than 5million; the availability would be low and customers would not able to find what they are looking for. In the STELLA model, low availability impacts the sales.

In the simulation, variation factor embedded into the customer sales. In all of the simulations used in this research, same customer demand variation is used in order not to cause any complexity due to the demand fluctuations and to compare the systems under the same circumstances. System is simulated for full year consisting of 52 weeks.

All the equations used in the STELLA programming are shown in APPENDIX-3 for decentralized model, in APPENDIX-4 for centralized model. It can be seen that in both of the models, everything is the same except supplier forecast numbers and the stock sharing rule (every 4 weeks supplier sends the leftover stock to other retailers in the decentralized model).

8.1.2 Complexity and Performance Measurement Results

Complexity metrics and performance measures listed in Chapter 6 has been used in order to describe the system. Network flow has been converted to a matrix form in order to calculate $R_{O,I}$ and AMI. The matrix is provided in APPENDIX-5. In order to calculate the static complexity H(Diversity), it is also converted to 0-1 matrix. It can be seen in APPENDIX-6. In the entire calculations, logarithm with base 2 is used. AMI for decentralized model is calculated as

$$AMI = H_O + H_I - H_{O,I} = 3.26 + 3.40 - 4.34 \approx 2.32 \qquad (8.1)$$

$R_{O,I}$ is;

$$R_{O,I} = H_{O,I} - \ AMI = 4.34 - 2.32 \approx 2.03 \qquad (8.2)$$

Total system size is;

$$TST = \sum_{i=1}^{N} \sum_{j=1}^{N} t_{ij} = t_{..} = 75{,}163{,}620 \qquad (8.3)$$

Complexity metric $R_{O,I}$*TST is 152,278,387.

To calculate the H(Diversity), based on the 0-1matrix, diversity of each element has been evaluated in Table 8.5. According to the diversity types, H(Diversity) is calculated in Table 8.6.

Table 8.5 Diversity types in the decentralized network model

	Input Arcs	Output Arcs	Diversity (input arcs / output arcs)
Supplier Forecasting	0	12	0
Supplier: ABC	1	2	0.5
Supplier: Artsana	1	2	0.5
Supplier: Balonevi	1	2	0.5
Supplier: Eser	1	2	0.5
Supplier: Giochi	1	2	0.5
Supplier: Hasbro	1	2	0.5
Supplier: Hedef	1	2	0.5
Supplier: Mamitoys	1	2	0.5
Supplier: Mattel	1	2	0.5
Supplier: Samatli	1	2	0.5
Supplier: Tan Itriyat	1	2	0.5
Supplier: Vardem	1	2	0.5
Other Supplier	12	0	DIV
Retailer Forecasting	12	1	12
Warehouse	1	5	0.2
Hyper A	1	1	1
Hyper B	1	1	1
Hyper C	1	1	1
Supermarket	1	1	1
Express	1	1	1
Customers	5	0	DIV

Table 8.6 Diversity types in the decentralized model

Diversity Types	Number of observing diversity type in	Probability of Diversity type observance
0	1	0.045
0.2	1	0.045
0.5	12	0.545
1	5	0.227
12	1	0.045
DIV	2	0.091
TOTAL	**22**	**1.000**

Based on the calculation below H(Diversity) is 41.48.

$$H(Diversity) = -\sum_{i=1}^{6} p(Diversity_i) * \log p(Diversity_i) = 41.48 \quad (8.5)$$

H(OC) is calculated based on the probability of the out-of-control states. In the models, which are provided in the scenarios, there are two variables that are tracked; Stock and COGS according to the targets. For each of them, three out-of-control levels are decided based on the severity amount of failure. As discussed earlier, these levels should be decided carefully, since it impacts the complexity figures significantly. Levels can be categorized according to the recovery approach chosen to fix it, as each failure level can be perceived differently by the people in the system.

Flow matrix for centralized model and simulation output of decentralized and centralized models can be found in APPENDIX-7, APPENDIX-8 and APPENDIX-9 respectively. In the model output, supplier and retail forecasts have been provided. In decentralized model, supplier forecasted much higher than the retailer forecast. In the centralized model, supplier allocated stock for Tesco Turkey based on the sales target information shared by the retailer. But due to low sales in some periods, retailer forecast has been reduced accordingly. “WH goods in” shows the actual goods received into the warehouse. If there is a difference between the “WH goods in” and the “Retailer forecast”, it means that the supplier couldn’t send the stock required since it is out-of-stock. “Over/Short stock” gives the stock deviation with respect to the stock target. “COGS” is derived from the actual COGS with variation factor in the simulation. It is compared to the COGS target in the performance measures. Other than the variation embedded into the simulation, it is also affected by the stock availability. “Total stock” is the stock position at the start of the week. Average stock is calculated based on the stock position on the order weeks (week 1,3,5,…,53). “Stock shared with the other retailers” provides the over stock that is sold to the other retailers if there is left over stock in the warehouse of the supplier.

As per the STELLA output for the decentralized and centralized models, the numbers computed for the complexity and performance have been summarized in the Table 8.7. Complexity figures are also shown in Figure 8.1.

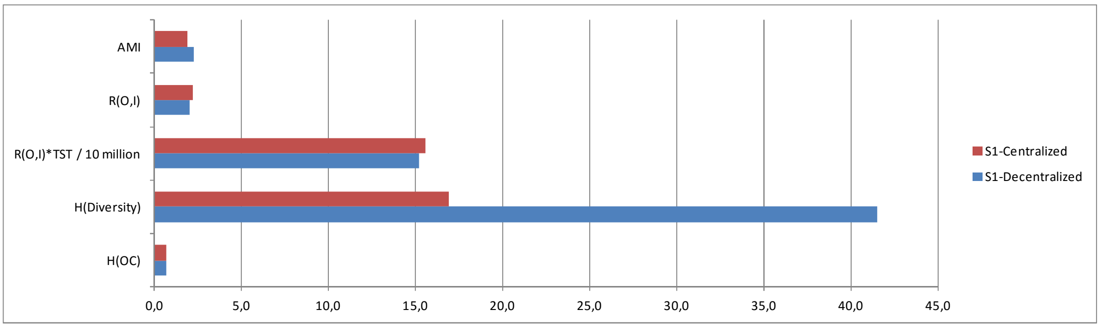

Figure 8.1 Results of complexity metrics for Scenario 1

Demand flexibility calculations for the models are shown in Table 8.8 and Table 8.9. In the decentralized model, supplier brings stock to its warehouse once every four weeks. Based on the COGS data of last 5 years, average COGS and standard deviation has been calculated. Based on standard normal distribution, probability of fulfilling the demand fully has been calculated for each 4 week period. When the probability of all weeks has been multiplied, it can be seen that meeting the demand of the customers fully based on supplier forecast is only 49.7%. In other words, decentralized retail supply chain in this example can fulfill the demand of customer throughout the year by at most 49.7%. This probability can drop if the retailer doesn't replenish the stores with the right stock amount on time. If the threshold value for this probability is set to 85%, it can be said that other than the weeks through 33 to 36, the supply chain meet the demand of the customer at least by 85% in 48 weeks. As the demand flexibility drops, it indicates that supply chain can be affected by the stock availability and sales can be affected by the low availability.

In order to calculate H(OC), observations of out-of-control and in-control states have been noted as in Table 8.10 and Table 8.11 and based on the probability distribution, complexity of the supply chain has been evaluated.

Table 8.7 Comparison results for Scenario 1

Performance Measure Type	Measure	Detail	S1-Decentralized	S1-Centralized
Resource	Supplier Delivery Performance	% of the Order satisfied by the Suppliers	98.6%	100.0%
	Average Stock Holding	Average value of the stock through 52 weeks	5,008,810	5,015,533
	OverStock on Supplier	Total Over Stock Risk at the End of the year	2,745,714	338,041
Output	Actualized Sales	% of Sales Actualized compared to Target	97.1%	97.1%
Flexibility	Demand Flexibility	Proportion of the demand that can be met fully by the supply chain based on average past 5 years data	49.7%	82.0%
		Number of the weeks demand can be met 85% or more by the supply chain based on average past 5 years data	48	52

Complexity Measures	Type	Measure	S1-Decentralized	S1-Centralized
	Dynamic - Perceived	AMI	2.32	1.92
	Dynamic - Perceived	R(O,I)	2.03	2.23
	Dynamic - System	R(O,I)*TST	152,278,387	156,120,872
	Static - Perceived	H(Diversity)	41.48	16.95
	Dynamic - Value Adding	H(OC)	0.69	0.69

Table 8.8 Demand flexibility for decentralized model

S1-Decentralized				
Wk	**Supplier Forecast**	**Average 4 Weeks COGS**	**Standard Dev. For 4 weeks**	**49.7%**
1	977,157	666,406	98,000	100%
5	888,599	658,069	98,000	99%
9	895,520	665,139	98,000	99%
13	1,182,494	892,746	98,000	100%
17	1,294,299	1,152,356	98,000	93%
21	1,655,382	1,462,213	98,000	98%
25	1,120,190	852,945	98,000	100%
29	1,231,844	707,582	98,000	100%
33	1,228,569	1,189,457	98,000	66%
37	1,071,480	815,051	98,000	100%
41	2,178,965	1,739,130	98,000	100%
45	1,860,036	1,237,040	98,000	100%
49	1,062,828	955,158	98,000	86%

Table 8.9 Demand flexibility for centralized model

S1-Centralized				
Wk	**Supplier Forecast**	**Average 13 Weeks Sales**	**Standard Dev. For 13 weeks**	**82.0%**
1	2,340,474	2,127,703	176,672	89%
14	4,208,834	3,826,213	176,672	98%
27	3,172,981	2,884,528	176,672	95%
40	4,570,335	4,154,850	176,672	99%

Table 8.10 Observation data and probabilities of variable under track for decentralized model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	21	
	Out-of-control 1	100,000	200,000	5	1
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%	16	
	Out-of-control 1	10%	30%	27	
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000		0.78
	Out-of-control 1	100,000	200,000	1.00	1.00
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%		0.31
	Out-of-control 1	10%	30%	0.75	
	Out-of-control 2	30%	50%	0.19	
	Out-of-control 3	Other		0.06	

Table 8.11 Observation data and probabilities of variable under track for centralized model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	22	
	Out-of-control 1	100,000	200,000	5	
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%	16	
	Out-of-control 1	10%	30%	27	
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000		0.81
	Out-of-control 1	100,000	200,000	1.00	
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%		0.31
	Out-of-control 1	10%	30%	0.75	
	Out-of-control 2	30%	50%	0.19	
	Out-of-control 3	Other		0.06	

8.1.3 Discussion

Based on the measures, following results has been derived;

- Even though, stock left over in the decentralized model is considerably high– which is 2.7million TL-, supplier delivery performance is lower compared to centralized model. Being unaware of the plans of the retailer, suppliers can allocate stock on wrong periods –bullwhip effect also amplify the impact-, consequently they can both suffer from low delivery performance and high leftover stock.
- Since the actualized sales are lower than the target values, in the centralized model, suppliers ended up with 338,000 TL of over stock.
- Due to tight connection between supplier and retailer, demand flexibility is extremely successful in the centralized model. Proportion of meeting the demand fully throughout the year is 82% and in 52 weeks there is at least 85% chance of meeting is demand fully.
- System size (TST) decreased in the centralized model due to reducing the effect of bullwhip and keeping less stock in the supplier warehouses, however system complexity ($R_{O,I}$*TST) has increased. It is directly related with the increase of the $R_{O,I}$. It can be concluded that even though stock position of the system decreased dramatically, the data sharing between the parties increased the complexity of the system. While the system complexity increased, the performance and flexibility improved as well. But data sharing should be a critical decision; in some systems this improvement can bring associated costs like overtime of workers, improving the IT system of the company.
- Both AMI and $R_{O,I}$ indicated an increase of perceived complexity which is because of the centralized forecasting for retailer and suppliers. This increased the communication which does not exist in the decentralized system. For the people working in the centralized model can feel the complications in the ways of working due to synchronizing the stock in all parties. But with support of IT tools, the complexity experienced can be reduced.

- Static complexity of the centralized model is lower. The reason of the substantial decrease is due to cancellation of stock sharing in the centralized model. Also, the reduction of two forecasting mechanisms (supplier forecast and retail forecast) into a single form (centralized forecasting) reduced the static complexity.
- There is no major stock and sales deviation difference in the simulation results, which ended up with the same value added complexity –H(OC)- value. As it can be seen from the performance results that average stock and actualized COGS values are very close. In Table 8.10 and Table 8.11, the sales and stock deviation levels are very similar. Sales deviations are mostly related with the low customer demand and are not sourced due to stock availability. Stock deviations from target are almost ignorable.

8.2 Scenario 2: Stock management in case of low supplier service level

8.2.1 System Dynamic Model

In this scenario, toys department working with 12 suppliers suffer from low service level. Toys products in Turkey market are mainly dominated by the import products; therefore, due to import regulation changes, whole market can suffer from stock-out issues from time to time. Under these circumstances, stock management team can take actions to overcome the situation with the lowest impact on the sales.

Alternative decisions can be;

1. Keeping safety stock in the stores by increasing the stock target
2. Keeping safety stock in the warehouse by increasing the stock target
3. Allocating the available stock of the supplier based on the sales performance of the stores.

Decentralized model is adapted in this scenario to the alternative models. In order to create stock-out examples, variation factors added into the system for all of the alternatives like customer sales.

In the first model, stock target of 5million TL replaced with 5.5million TL and orders are placed accordingly. Stock allocations to the stores are made according to the stock proportions provided in Table 8.1. Availability is again calculated based on 5million TL of worth of stock. STELLA simulation is exactly same with the Decentralized model in Scenario 1 and only the stock target has been adapted.

In the second model, stock target is again increased up to 5.5million TL but this time cross-docking strategy has been altered with keeping 0.5million TL safety stock in the warehouse. If the actual goods-in is lower than retail forecast, then the missing portion is distributed to stores from the safety stock. STELLA model and equations are provided in APPENDIX-10 and APPENDIX-11.

Last model is about keeping the stock target in 5million TL but alternatively changing the allocation strategy. If the supplier service level is low and actual receiving is not adequate to satisfy the retailer forecast, then the received products are distributed to stores based on a prioritization. Stores are prioritized based on highest sales potential to the lowest. Availability calculation has been adapted to the change as well. Store format stock targets are given based on the stock proportion given in Table 8.1 multiplied with 5million TL. If the store format stock is lower than this value, then availability decreases and this impacts the sales performance of the stores. STELLA model and equations are provided in APPENDIX-12 and APPENDIX-13.

8.2.2 Complexity and Performance Measurement Results

Network flow matrices for the models in Scenario 2 can be found in APPENDIX-14, APPENDIX-15 and APPENDIX-16. Additionally, simulation outputs of the models are available on APPENDIX-17, APPENDIX-18 and APPENDIX-19.

According to the simulation outputs; complexity and performance measures have been computed and shown in Table 8.12. In Figure 8.2, complexity metric results shown in a chart for comparison.

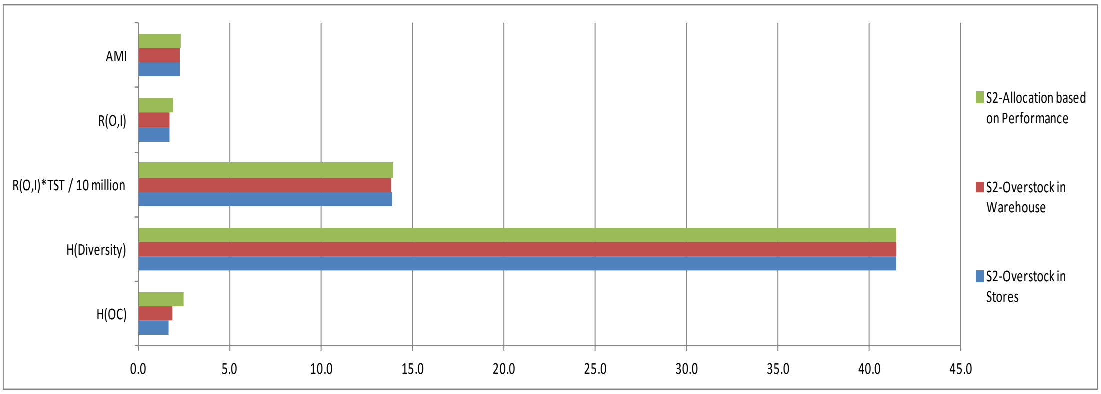

Figure 8.2 Results of complexity metrics for Scenario 2

As mentioned earlier, in the STELLA model the same supplier forecast in Scenario 1 is used, but to create stock-out problem in this scenario variation factors added to the models to decrease the goods-in for the suppliers. Even though, suppliers forecasted to sell 16.6million TL of stock to retailer, they could hardly buy a stock of 14.7million TL ready to be sold. In order to test the models under the same circumstances, same supplier stock used, which resulted with the same demand flexibility figure. In Table 8.13, demand flexibility values are provided for all models.

Table 8.12 Comparison results for Scenario 2

Performance Measure Type	**Measure**	**Detail**	**S2-Overstock in Stores**	**S2-Overstock in Warehouse**	**S2-Allocation based on Performance**
Resource	Supplier Delivery Performance	% of the Order satisfied by the Suppliers	67.0%	67.9%	80.9%
	Average Stock Holding	Average value of the stock through 52 weeks	5,327,829	5,335,970	4,973,487
	OverStock on Supplier	Total Over Stock Risk at the End of the year	259,685	286,162	1,748,157
Output	Actualized Sales	% of Sales Actualized compared to Target	97.1%	96.9%	89.5%
Flexibility	Demand Flexibility	Proportion of the demand that can be met fully by the supply chain based on average past 5 years data	0.0%	0.0%	0.0%
		Number of the weeks demand can be met 85% or more by the supply chain based on average past 5 years data	28	28	28

Complexity Measures	**Type**	**Measure**	**S2-Overstock in Stores**	**S2-Overstock in Warehouse**	**S2-Allocation based on Performance**
	Dynamic - Perceived	AMI	2.30	2.30	2.31
	Dynamic - Perceived	R(O,I)	1.71	1.72	1.91
	Dynamic - System	R(O,I)*TST	138,889,539	138,104,156	139,315,666
	Static - Perceived	H(Diversity)	41.48	41.48	41.48
	Dynamic - Value Adding	H(OC)	1.67	1.88	2.49

For H(OC) complexity, out-of-control values and probabilities have been given in Table 8.14, Table 8.15 and Table 8.16 for each model.

Table 8.13 Demand flexibility of Scenario 2 models

S2-Overstock in Stores				
Wk	**Supplier Forecast**	**Average 4 Weeks COGS**	**Standard Dev. For 4 weeks**	**0.0%**
1	918,528	666,406	98,000	99%
5	844,169	658,069	98,000	97%
9	599,998	665,139	98,000	25%
13	922,345	892,746	98,000	62%
17	1,151,926	1,152,356	98,000	50%
21	1,291,198	1,462,213	98,000	4%
25	728,124	852,945	98,000	10%
29	1,231,844	707,582	98,000	100%
33	1,056,569	1,189,457	98,000	9%
37	1,071,480	815,051	98,000	100%
41	2,178,965	1,739,130	98,000	100%
45	1,599,631	1,237,040	98,000	100%
49	1,062,828	955,158	98,000	86%

Table 8.14 Observation data and probabilities of variable under track for "Keeping safety stock in stores" model

Observations		**Lower Bound**	**Upper Bound**	**Customer**	**Supplier**
Stock Deviation	In Control	0	100,000	14	
	Out-of-control 1	100,000	200,000	3	2
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other		4	4
Sales Deviation	In Control	0%	10%	15	
	Out-of-control 1	10%	30%	26	2
	Out-of-control 2	30%	50%	6	
	Out-of-control 3	Other		3	

Probabilities		**Lower Bound**	**Upper Bound**	**Customer**	**Supplier**
Stock Deviation	In Control	0	100,000		0.52
	Out-of-control 1	100,000	200,000	0.43	0.33
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other		0.57	0.67
Sales Deviation	In Control	0%	10%		0.29
	Out-of-control 1	10%	30%	0.74	1.00
	Out-of-control 2	30%	50%	0.17	
	Out-of-control 3	Other		0.09	

Table 8.15 Observation data and probabilities of variable under track for "Keeping safety stock in warehouse" model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	14	
	Out-of-control 1	100,000	200,000	3	2
	Out-of-control 2	200,000	300,000		1
	Out-of-control 3	Other		4	3
Sales Deviation	In Control	0%	10%	15	
	Out-of-control 1	10%	30%	27	1
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000		0.52
	Out-of-control 1	100,000	200,000	0.43	0.33
	Out-of-control 2	200,000	300,000		0.17
	Out-of-control 3	Other		0.57	0.50
Sales Deviation	In Control	0%	10%		0.29
	Out-of-control 1	10%	30%	0.75	
	Out-of-control 2	30%	50%	0.19	
	Out-of-control 3	Other		0.06	

Table 8.16 Observation data and probabilities of variable under track for "Allocating stock based on store performance" model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	14	
	Out-of-control 1	100,000	200,000	6	2
	Out-of-control 2	200,000	300,000	2	
	Out-of-control 3	Other		1	2
Sales Deviation	In Control	0%	10%	15	
	Out-of-control 1	10%	30%	23	4
	Out-of-control 2	30%	50%	5	2
	Out-of-control 3	Other		3	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000		0.52
	Out-of-control 1	100,000	200,000	0.67	0.50
	Out-of-control 2	200,000	300,000	0.22	
	Out-of-control 3	Other		0.11	0.50
Sales Deviation	In Control	0%	10%		0.29
	Out-of-control 1	10%	30%	0.74	0.67
	Out-of-control 2	30%	50%	0.16	0.33
	Out-of-control 3	Other		0.10	

8.2.3 Discussion

Based on the measures, following results has been derived;

- In this scenario, even though suppliers' forecasts are the same as the Scenario-1 Decentralized model, their actual intakes are 88% of their forecasts. Although, the retail supply chain in this analysis consists of suppliers, warehouse, stores and customers; in practice, suppliers can also be affected by their upper echelons that are not included in this study. In toys business, majority of the suppliers are importers from China. Due to geographical distance and strict import regulations; shipment of the products can be delayed to the suppliers. If market conditions of supplying the products are unsafe, stock management strategies can be adapted on the retailer side. In this scenario, three examples of adapted strategies are tested.
- In the first two models, stock budgets are adapted to the risky conditions and safety stock of 500,000TL is kept. Due to the sudden change in the strategy, supplier delivery performance is much lower (67.9%) compared the latter model (80.9) in which the stock target kept the same.
- Even though the stock target is set to 5.5million TL in the first two models, average stock holding is about 5.3million TL due to insufficient stock in the supplier. In the last model, average stock holding is close to the target but in some periods, it drops approximately to 4.4million TL which affects the sales extremely.
- The overstocks of the suppliers in the first two models are even close to the performance of centralized model, whereas, on the last one due to drawbacks of decentralized way of working, left over stock is high. This is tragic from the point of the last model, because retailer stock has reduced to 4.4million in some weeks due to stock shortage; but on the other weeks, suppliers struggle with the overstock and share it with the other retailers.
- Sales performance is the highest in the first version since the stock availability is the highest because of the buffer stock sitting in the stores. In the second scenario, shipment of the buffer to stores can take some time;

therefore, sale performance is affected by 0.2%. In the last one since the stock position is much lower, sales are affected dramatically.

- Since the supplier stock position is not adequate, demand flexibility is very low compared to Scenario 1 in all of the models. In only 28 weeks, supplier stock would be 85% sufficient to meet the customer demand fully.
- System size is the bigger in first model than the second one. Even though the stock target is the same in both models, system size is higher since the buffer stock is allocated to stores. System complexity is higher in first model, which is impacted by the system size. In other words, the information transmitted is higher in the first model and this increased the system complexity.
- In the last model, system size is much lower compared to the first and the second one. The reason of the difference is because the stock target which is lower in the last model, as a result the intake of the retailer is lower as well. Even though the system size is the lowest in the third model, system complexity is the highest since the $R_{O,I}$ is high.
- Perceived complexity (according to the results of AMI and $R_{O,I}$) are approximately the same in the first two models; whereas it is higher in the third one which also impacted the system complexity significantly. When the stock position in the retailer is high because of the stock target increase, managing the availability in stores will be easier. But rise of the stock increases the complexity of the retailer. But the increase of complexity in retailer is ignorable compared to the impact of the left overstock in the supplier depots in the last model. From the supplier perspective, they need to struggle with the overstock and search for the third parties to sell the stock.
- System complexity is also impacted by the leftover stock. The increase in the flow of the stock to the other retailers boosted the system complexity as well.
- As the system structure is same in all of the models, static complexity is the same.
- Sales and stock value deviations are close in the first and the second model, but due to delays in shipment from warehouse, H(OC) is slightly higher. In other words, non-value adding complexity is higher in the second model. In

the third model, since the stock target is lower, sales and stock values fluctuated more, leading to the worst non-value adding complexity.

- Looking into the complexity and performance values, it can be concluded that third model created the worst performance results and, system, perceived and non-value adding complexity values are also the highest of all models in scenario 2. The complexity generated from allocating the stock based on store performance in case of stock shortage affecting the system condition badly and it should be a not preferable approach with respect to the other approaches.
- Unlike Scenario 1, the complexity increase in Scenario 2 is not a manageable one and costs associated with it impacted the performance measures.
- In the first and second model, the decision maker can consider the increase in system complexity. Holding the stock in warehouse and sending the stock when required to the stores (Model 2) can influence the performance measures slightly negative, but the complexity of managing store operation with high buffer stock (Model 1) can impact the store staff seriously.

8.3 Scenario 3: Cross-docking versus Direct-to-store Shipment

8.3.1 System Dynamic Model

In Scenario 3, the basic assumption of cross-docking in the earlier scenarios has been analyzed. Logistics strategy of the supply chain revised so that deliveries from suppliers directly shipped to stores. First model is exactly the same model of Scenario 1 – Decentralized supply chain.

In the second model, warehouse -which is used for cross-docking- is eliminated. In practice, if the order requests are low, then suppliers are not willing to ship the orders directly to stores since the logistic costs can be higher than the order cost itself. In STELLA model, if the order value is lower than 5,000TL, order is cancelled by the supplier. But if it is between 5,000TL and 10,000TL, then order is rounded up to 10,000TL. If it is higher than 10,000TL, supplier accepts the order as it is.

STELLA model and the equation used are provided in APPENDIX-20 and APPENDIX-21.

8.3.2 Complexity and Performance Measurement Results

As the cross-docking model is already explained in Scenario 1, network flow matrix of only direct-to-store shipment model is presented in APPENDIX-22. Additionally, simulation output of the model is available on APPENDIX-23.

According to the simulation outputs; complexity and performance measures have been computed and shown in Table 8.17. In Figure 8.3, complexity metric results shown in a chart for comparison.

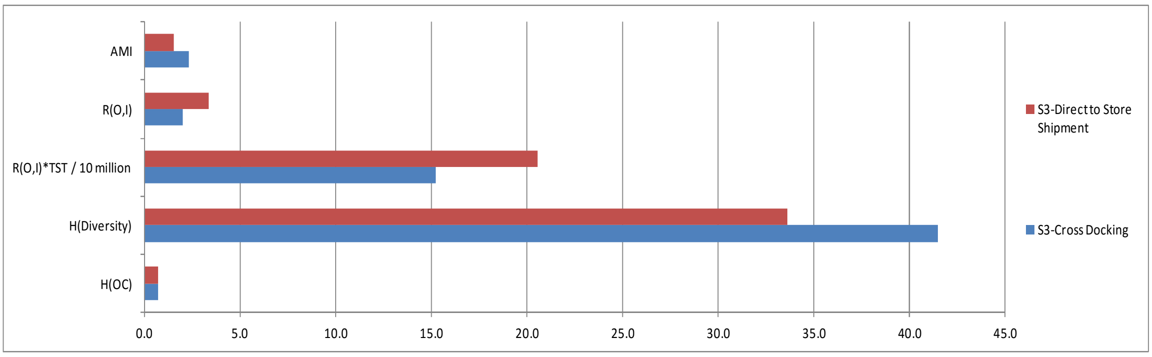

Figure 8.3 Results of complexity metrics for Scenario 3

Demand flexibility values of both models are the same as the model of Decentralized Supply Chain since the supplier forecasts are exactly the same.

For H(OC) complexity, out-of-control values and probabilities have been given in Table 8.18 for direct-to-store shipment model.

Table 8.17 Comparison results for Scenario 3

Performance Measure Type	**Measure**	**Detail**	**S3-Cross Docking**	**S3-Direct to Store Shipment**
Resource	Supplier Delivery Performance	% of the Order satisfied by the Suppliers	98.6%	98.1%
	Average Stock Holding	Average value of the stock through 52 weeks	5,008,810	5,009,629
	OverStock on Supplier	Total Over Stock Risk at the End of the year	2,745,714	2,744,467
Output	Actualized Sales	% of Sales Actualized compared to Target	97.1%	97.1%
Flexibility	Demand Flexibility	Proportion of the demand that can be met fully by the supply chain based on average past 5 years data	49.7%	49.7%
		Number of the weeks demand can be met 85% or more by the supply chain based on average past 5 years data	48	48

Complexity Measures	**Type**	**Measure**	**S3-Cross Docking**	**S3-Direct to Store Shipment**
	Dynamic - Perceived	AMI	2.32	1.54
	Dynamic - Perceived	R(O,I)	2.03	3.36
	Dynamic - System	R(O,I)*TST	152,278,387	205,763,568
	Static - Perceived	H(Diversity)	41.48	33.61
	Dynamic - Value Adding	H(OC)	0.69	0.69

Table 8.18 Observation data and probabilities of variable under track for "Direct-to-store shipment" model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	23	
	Out-of-control 1	100,000	200,000	4	
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%	16	
	Out-of-control 1	10%	30%	27	
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000		0.85
	Out-of-control 1	100,000	200,000	1.00	
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%		0.31
	Out-of-control 1	10%	30%	0.75	
	Out-of-control 2	30%	50%	0.19	
	Out-of-control 3	Other		0.06	

8.3.3 Discussion

Based on the measures, following results has been derived;

- Supplier delivery performance is slightly lower in direct-to-store shipment model, because of the cancelled orders which are lower than 5,000TL; whereas, the average stock holding is insignificantly higher due to the orders that are rounded up. If the geographical places of the stores are distributed in distant locations, then the transfer costs can be higher and suppliers will be reluctant to send the orders are even higher than 5,000 TL. In that case, implications on sales and stock can be substantial.
- Since the cancelled orders are insignificant, the left over stock does not vary much in two models.

- In both of the models, demand flexibilities are the same, since the same goods-in values are used for the suppliers.
- System size is smaller in the direct-to-store shipment model since the warehouse is eliminated and one echelon in the supply chain is cancelled. Even though, system size is lower; system complexity is higher in the direct-to-store shipment model. System complexity increase because of the drastic increase in the $R_{O,I}$ value. Impact of the distributed shipments rather than a single warehouse consolidating all shipments in system complexity is higher than the impact of system size.
- Perceived complexity of direct-to-store shipment is higher than cross-docking model. The distributed shipments from suppliers to stores increased the complexity of the system. In practice, for the suppliers preparing several shipments to geographically distributed locations is not preferable compared to shipping to a warehouse. For the store operation, receiving operation is also cumbersome task because item counting, system entry can be a tedious work or it can be open to fraud in terms of security. If the warehouse integration is implemented in an efficient way, then cross-docking can actually decrease the work both in the supplier and store operations.
- Static complexity decreased in direct-to-store shipment model, since one of the echelons has been eliminated.
- Because of the similar deviation in stock and sales performance, the non-value adding complexity result is the same.
- Retail supply chains struggling with the decision of using a warehouse should consider the impact of complexity on cost and performance measures. Dynamic system and perceived complexity metrics indicated apparently that managing direct-to-store can be poor way of working. For the case that is represented in this research provided the similar performance output for both models; therefore, cost trade-off between below cases should be investigated:
    - Cost of building/hiring a warehouse
    - Cost of transportation, order preparation in supplier side and goods acceptance operation in stores.

8.4 Scenario 4: Category Management Decisions in a Supply Chain

8.4.1 System Dynamic Model

In this scenario the impacts of some strategic decisions taken by the category management have been analyzed in terms of complexity and performance. The problem in this scenario is again low supplier service level, but some mid- or long-term actions are discussed.

First model is created with the same model used for “Scenario 2 - Keeping safety stock in stores” but eliminating the safety stock and making stock target again back to its original position of 5million TL. The output of this model is used for the comparison basis for the other models.

In the second model, supplier number is decreased from 12 to 11. Second biggest supplier is eliminated and top selling supplier is providing the orders of the eliminated one. Variation factor for the supplier service level is same with the original one. In order to decrease the communication workload, retailers can decide working with less number of suppliers. STELLA flow model and equations are provided in APPENDIX-24 and APPENDIX-25.

In the third model, second model is used but in order to make the biggest supplier a more trustable one, supplier service level variation factor effect on this supplier is cancelled. The biggest supplier gets all of the stock according to its yearly forecast and on time. However, the supplier and retailer still operate as decentralized. STELLA flow model and equations are provided in APPENDIX-26 and APPENDIX-27.

In the original model supplier service levels of 12 suppliers are equal and very low in some weeks; however, in practice retailer can communicate with new suppliers and gather the missing part of the order from them. In the fourth model, original STELLA model is adapted by adding a dummy supplier offering the short stock. STELLA flow model and equations can be seen in APPENDIX-28 and APPENDIX-29.

Retailers can provide products under their own brand, which is called as private label. In the original model, Tesco brand is shown as a supplier and supplier manufactures/imports the products labeled as Tesco. But in practice, keeping private label stock can be risky for the supplier since it cannot be sold by the other retailers due to legal prohibitions. In the fifth model, retailer imports the private label stock directly only two times in a year and dedicates a warehouse location for keeping the bulky stock. STELLA flow model and equations can be seen in APPENDIX-30 and APPENDIX-31. In this model, since the retailer makes its own import, import forecast is based on the retailer sales forecast; therefore, it is lower than the forecast of the decentralized model Tesco supplier. Since there would be bulk stock in the import warehouse, the missing part of the orders due to low supplier service level is fulfilled by the private label products.

8.4.2 Complexity and Performance Measurement Results

Network flow matrix and simulation output of all models for the comparison basis are shown in APPENDIX-32 to APPENDIX-41 respectively. Results of the complexity and performance metrics are shown in Table 8.19. Complexity comparison is also presented in Figure 8.4.

Demand flexibility of the “original model”, “supplier number reduction” and “using a dummy supplier” model are the same and equal to the value of Scenario 2 models because the same supplier stock in-take values are used. In the third model, since the stock in-take of the biggest supplier is improved, demand flexibility has enhanced. Also, in the “Private label” model, since there is a bulk intake of import products, again the demand flexibility is impacted positively. Demand flexibility for the third and the fifth model are demonstrated in below Table 8.20 and 8.21.

In order to calculate Out-of-control entropy –H(OC)-, sales and stock deviations are tracked and can be seen in Table 8.22 – 8.26.

Table 8.19 Comparison results for Scenario 4

Performance Measure Type	Measure	Detail	S4-Original Model	S4-Supplier Number Reduction	S4-Supplier Number Reduction with Performance Improvement	S4-Using a Dummy Supplier	S4-Private Label
Resource	Supplier Delivery Performance	% of the Order satisfied by the Suppliers	76,0%	76,0%	91,9%	100,0%	83,7%
	Average Stock Holding	Average value of the stock through 52 weeks	4.908.576	4.908.576	4.976.312	5.015.533	4.951.175
	OverStock on Supplier	Total Over Stock Risk at the End of the year	951.124	951.124	1.882.981	1.864.591	1.175.351
Output	Actualized Sales	% of Sales Actualized compared to Target	95,7%	95,7%	96,8%	97,1%	96,6%
Flexibility	Demand Flexibility	Proportion of the demand that can be met fully by the supply chain based on average past 5 years data	0,0%	0,0%	9,2%	0,0%	0,0%
		Number of the weeks demand can be met 85% or more by the supply chain based on average past 5 years data	28	28	32	28	36

Complexity Measures	Type	Measure	S4-Original Model	S4-Supplier Number Reduction	S4-Supplier Number Reduction with Performance Improvement	S4-Using a Dummy Supplier	S4-Private Label
	Dynamic - Perceived	AMI	2,31	2,31	2,32	2,32	2,33
	Dynamic - Perceived	R(O,I)	1,83	1,61	1,70	2,07	1,89
	Dynamic - System	R(O,I)*TST	140.466.407	123.431.105	128.057.656	155.950.338	138.465.196
	Static - Perceived	H(Diversity)	41,48	40,58	40,58	43,51	42,54
	Dynamic - Value Adding	H(OC)	1,67	1,67	1,19	0,69	1,24

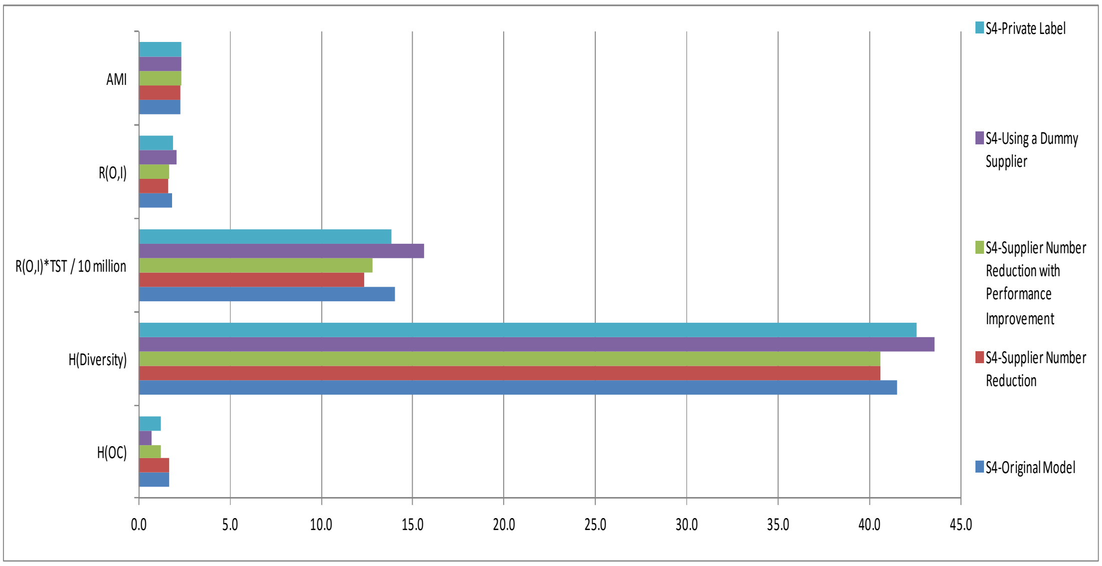

Figure 8.4 Results of complexity metrics for Scenario 4

Table 8.20 Demand flexibility for "Supplier number reduction with performance improvement" model

S4-Supplier Number Reduction with Performance Improvement				
Wk	**Supplier Forecast**	**Average 4 Weeks COGS**	**Standard Dev. For 4 weeks**	**9.2%**
1	950,481	666,406	98,000	100%
5	868,383	658,069	98,000	98%
9	761,058	665,139	98,000	84%
13	1,064,126	892,746	98,000	96%
17	1,229,519	1,152,356	98,000	78%
21	1,489,678	1,462,213	98,000	61%
25	941,800	852,945	98,000	82%
29	1,231,844	707,582	98,000	100%
33	1,150,309	1,189,457	98,000	34%
37	1,071,480	815,051	98,000	100%
41	2,178,965	1,739,130	98,000	100%
45	1,741,552	1,237,040	98,000	100%
49	1,062,828	955,158	98,000	86%

Table 8.21 Demand flexibility for "Private label" model

S4-Private Label				
Wk	Supplier Forecast	Average 4 Weeks COGS	Standard Dev. For 4 weeks	0.0%
1	2,382,530	666,406	98,000	100%
5	2,172,217	658,069	98,000	100%
9	1,812,113	665,139	98,000	100%
13	1,847,766	892,746	98,000	100%
17	1,726,321	1,152,356	98,000	100%
21	1,367,176	1,462,213	98,000	17%
25	538,811	852,945	98,000	0%
29	2,153,204	707,582	98,000	100%
33	1,868,358	1,189,457	98,000	100%
37	1,437,131	815,051	98,000	100%
41	2,014,677	1,739,130	98,000	100%
45	1,183,727	1,237,040	98,000	29%
49	786,493	955,158	98,000	4%

Table 8.22 Observation data and probabilities of variable under track for "Original model" model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	15	
	Out-of-control 1	100,000	200,000	6	1
	Out-of-control 2	200,000	300,000	1	
	Out-of-control 3	Other		2	2
Sales Deviation	In Control	0%	10%	16	
	Out-of-control 1	10%	30%	25	2
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	0.56	
	Out-of-control 1	100,000	200,000	0.67	0.33
	Out-of-control 2	200,000	300,000	0.11	
	Out-of-control 3	Other		0.22	0.67
Sales Deviation	In Control	0%	10%	0.31	
	Out-of-control 1	10%	30%	0.74	1.00
	Out-of-control 2	30%	50%	0.21	
	Out-of-control 3	Other		0.06	

Table 8.23 Observation data and probabilities of variable under track for "Supplier number reduction" model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	15	
	Out-of-control 1	100,000	200,000	6	1
	Out-of-control 2	200,000	300,000	1	
	Out-of-control 3	Other		2	2
Sales Deviation	In Control	0%	10%	16	
	Out-of-control 1	10%	30%	25	2
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	0.56	
	Out-of-control 1	100,000	200,000	0.67	0.33
	Out-of-control 2	200,000	300,000	0.11	
	Out-of-control 3	Other		0.22	0.67
Sales Deviation	In Control	0%	10%	0.31	
	Out-of-control 1	10%	30%	0.74	1.00
	Out-of-control 2	30%	50%	0.21	
	Out-of-control 3	Other		0.06	

Table 8.24 Observation data and probabilities of variable under track for "Supplier number reduction with performance improvement" model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	19	
	Out-of-control 1	100,000	200,000	5	1
	Out-of-control 2	200,000	300,000	1	
	Out-of-control 3	Other			1
Sales Deviation	In Control	0%	10%	16	
	Out-of-control 1	10%	30%	26	1
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	0.70	
	Out-of-control 1	100,000	200,000	0.83	0.50
	Out-of-control 2	200,000	300,000	0.17	
	Out-of-control 3	Other			0.50
Sales Deviation	In Control	0%	10%	0.31	
	Out-of-control 1	10%	30%	0.74	1.00
	Out-of-control 2	30%	50%	0.20	
	Out-of-control 3	Other		0.06	

Table 8.25 Observation data and probabilities of variable under track for “Using a dummy supplier” model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	22	
	Out-of-control 1	100,000	200,000	5	
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%	16	
	Out-of-control 1	10%	30%	27	
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	0.81	
	Out-of-control 1	100,000	200,000	1.00	
	Out-of-control 2	200,000	300,000		
	Out-of-control 3	Other			
Sales Deviation	In Control	0%	10%	0.31	
	Out-of-control 1	10%	30%	0.75	
	Out-of-control 2	30%	50%	0.19	
	Out-of-control 3	Other		0.06	

Table 8.26 Observation data and probabilities of variable under track for “Private label” model

Observations		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	17	
	Out-of-control 1	100,000	200,000	4	3
	Out-of-control 2	200,000	300,000		1
	Out-of-control 3	Other			2
Sales Deviation	In Control	0%	10%	17	
	Out-of-control 1	10%	30%	25	1
	Out-of-control 2	30%	50%	7	
	Out-of-control 3	Other		2	

Probabilities		Lower Bound	Upper Bound	Customer	Supplier
Stock Deviation	In Control	0	100,000	0.63	
	Out-of-control 1	100,000	200,000	1.00	0.50
	Out-of-control 2	200,000	300,000		0.17
	Out-of-control 3	Other			0.33
Sales Deviation	In Control	0%	10%	0.33	
	Out-of-control 1	10%	30%	0.74	1.00
	Out-of-control 2	30%	50%	0.21	
	Out-of-control 3	Other		0.06	

8.4.3 Discussion

Based on the measures, following results has been derived;

- Performance measures of the "original model" and "Supplier number reduction" are the same since supplier stock in-take are equal and only difference is the supplier number. But it can be seen that if the stock intake of the biggest supplier –which also owns the orders of the cancelled supplier- improves according to their forecast as in the 3rd model; sales, stock, supplier performance measures apparently increases.
- If the retailer operates in a more flexible way and seeks for additional supplier in case of stock shortage in its suppliers, then supply chain performance metrics provide the best results in terms of sales and average stock as shown in "Using a dummy supplier" model.
- In the "Private label" model, due to bulk stock buying twice in a year, retailer is able to cover the stock shortage with the private label stock in stores which improves the average stock holding and sales compared to the average stock holding.
- Demand flexibility increases in the "Supplier number reduction with performance improvement" and "private label" models. In the 3rd model, intake performance of the biggest supplier increases; whereas, in the 5th model, private label stock dedicated warehouse improves the demand flexibility.
- System size (TST) of the "Original" model and the "supplier number reduction" model are the same. In the "supplier number reduction with performance improvement" model, with the in-take improvement in the biggest supplier, supplier delivery performance increases, this in turn reduces the retail forecast. In the "original model", the insufficient order fulfillment makes the retailer repetitively request the short stock; therefore, the retail forecast is high in the stock-out models. "Using the dummy supplier" model sorts out the insufficient stock problem using alternative suppliers. With the reduction of the stock shortage, retail forecast decreases, which reduces the system size. But the system size is larger than the "supplier number reduction with performance improvement" model. Even though the supplier delivery

performance is high in the "supplier number reduction with performance improvement" model, in the "Using the dummy supplier" model the missing part of the retailer order is compensated by the dummy supplier, which increases the stock flow and successively raises the stock flow to stores and sales. "Private label" model has the smallest system size, because the stock buying as import is directly planned by the retailer forecast which eliminates the bullwhip effect.

- Even though the system size of the "original" model and the "supplier number reduction" model are the same, system complexity of the models are significantly different and the second model gives the lowest value in this scenario. The reason of the low system complexity is the low stock position and the less supplier number compared to all other models. These factors reduces the amount of information in the system. If the supplier stock intake increases as in the 3rd model, system complexity increases. Since the left over stock is high and dummy supplier added to the supply chain, "using a dummy supplier" model generates the highest system complexity.
- Perceived complexity is similarly lowest in the "supplier number reduction" model and increases in the 3rd model with the stock intake increase. But still the supplier number reduction impact keeps the perceived complexity lower than the "original" model.
- Perceived complexity of the "using a dummy supplier" model is the highest of all due to a number of reasons;
    - Adding a new element to the system as dummy supplier
    - Increased left over stock in the original suppliers
    - Feedback mechanism of the retailer forecast to the dummy supplier after calculating missing stock

As it can be understood, the flexible way of working in a retailer category management creates complexity. The communication with the new suppliers to seek for new products and stock to increase availability can support the retail business to keep up with the performance targets but it can be a tedious work for the buying team as well.

- In the "private label" model, the perceived complexity is slightly elevated with respect to "original model". Better stock availability in stores with higher sales with the help of keeping bulk stock in the import warehouse, impacted the perceived complexity by increasing it. Again the left over stock in the suppliers increased and this increased the perceived complexity on their side as well.
- Static complexity has decreased with the supplier reduction in 2nd and 3rd model. In the 5th model, Tesco supplier converts to a private label warehouse and allocation from the import warehouse depends on the order delivery performance of the other retailer. Therefore this feedback mechanism increases the static complexity with respect to the "original" model. In the 4th model, in addition to the 12 supplier, a dummy supplier has been added in order to meet the missing part of the orders, which increases the static complexity to its highest position in Scenario 4 models.
- Value added complexity metric H(OC) indicates results in parallel with the performance metrics. Performance results of the 1st and the 2nd models are the same; also the non-value adding complexity is equal on these models. With increasing the supplier delivery performance of the biggest supplier, non-value adding complexity decreases. Best performing model in terms of average stock, supplier delivery performance and sales is a "using a dummy supplier" model gives the lowest non-value adding complexity value in scenario 4.

CHAPTER NINE
CONCLUSION

Complexity will be observed as a trending topic in the coming years due to incredible progress in science and technology. Currently there is growing interest on this topic; however, even there is no generic and agreed definition of the term. This research started with providing the key properties of the complexity and gathered a definition accordingly.

In this research, the aim is to provide a starting point for analyzing complexity in retail supply chains. There has been a vast amount of literature that provided guidance to measure complexity in manufacturing systems and supply chains from manufacturer point of view. These researches listed and assessed in Chapter 3. However, it has been observed that the studies measuring complexity evaluate different levels information of the systems. Based on the information level, complexity has been classified into three categories; system, perceived and value adding complexity. In order to understand if the complexity observed in the retail supply chain is useful or raised because of the issues to be fixed; both complexity and performance measures have been applied. 5 different complexity metrics gathered from existing literature evaluating different information levels. One metric is static complexity metric and others computed complexity as dynamic. Performance measures explore the retail supply chain from various aspects including resource management, output management and flexibility.

Most common issues in a retail supply chain has been selected and tested under four scenarios;

- Scenario 1: Decentralized and Centralized model → to understand effect of data visibility
- Scenario 2: Stock management in case of low supplier service level → to tackle stock shortage affecting the whole supply chain by short term solutions.

- Scenario 3: Cross docking versus direct to store deliveries → to evaluate a logistics problem
- Scenario 4: Category management decisions in a supply chain → to observe the impact of strategic options on supplier management mostly decided by the category team.

For each of the scenario, complexity and performance measures had been evaluated. So as to highlight the below features, system dynamics modeling has been used;

- observe dynamic behavior,
- present complex interactions between elements of the system
- test the implications of various factors
- simulate scenarios under the same circumstances.

Also, the models do not only depend on the flow of stock, but also the decision making process. Retail forecasting, supplier forecasting are represented as components of the system.

Outputs of the system dynamic models are used as data for the complexity and performance metrics. It has been noticed that there is not always one way relation with complexity and performance. Also using a single type of complexity metric cannot always guide us about understanding the system and the issues. The analysis leaded to multi-perspective evaluation. For example, in the first scenario, data visibility improved the performance of the retail supply chain substantially, but the dynamic-system and dynamic-perceived complexity figures increased as well. Therefore, if the additional costs of centralized management are tolerated, then switching to centralized model can be feasible. The complexity observed in this scenario is the impact of data sharing and is useful for the system.

On the other hand, in the second scenario, all the dynamic complexity metrics of the “Allocation based on performance model” are higher compared to other two models. Nonetheless, the sales performance is dramatically affected by the decision in a negative way. Analyzing the complexity metrics in detail, it can be seen that holding high stock in stores or in warehouse increases the complexity of the retailer, but in my model, due to bullwhip effect, supplier complexity is even higher in the last model due to forecasting problems. Therefore, complexity metrics can be useful for addressing the point of issue in the systems.

As a conclusion, practitioners usually make decisions based on performance, but complexity can lead us to spotlight potential cost generating areas. As the applicability of it is undemanding, the use of it considering the big picture –systems thinking-, can reduce problems that emerge unexpectedly in the future. Based on the effect of the problematic areas on the complexity metric, the issues can be prioritized easily.

As future research, following topics can be investigated.

- It can be seen from the literature review that there is a dominant influence of information theory (usage of entropy metric) in complexity researches. Other developed metrics are quite inadaptable to different areas other than the area they are used for. Alternative generic metrics needs to be investigated.
- Retail supply chain complexity is an undiscovered topic, where several other scenarios summarized in Chapter 5 can be analyzed.
- Chaotic scenarios can be created using system dynamics simulation for retail supply chain and the relationship of the chaos and complexity can be studied.
- Cost impact of complexity has not been measured in this study, even though it has been noted in many articles that there is strong relationship with cost and complexity. This relation needs to be exemplified.

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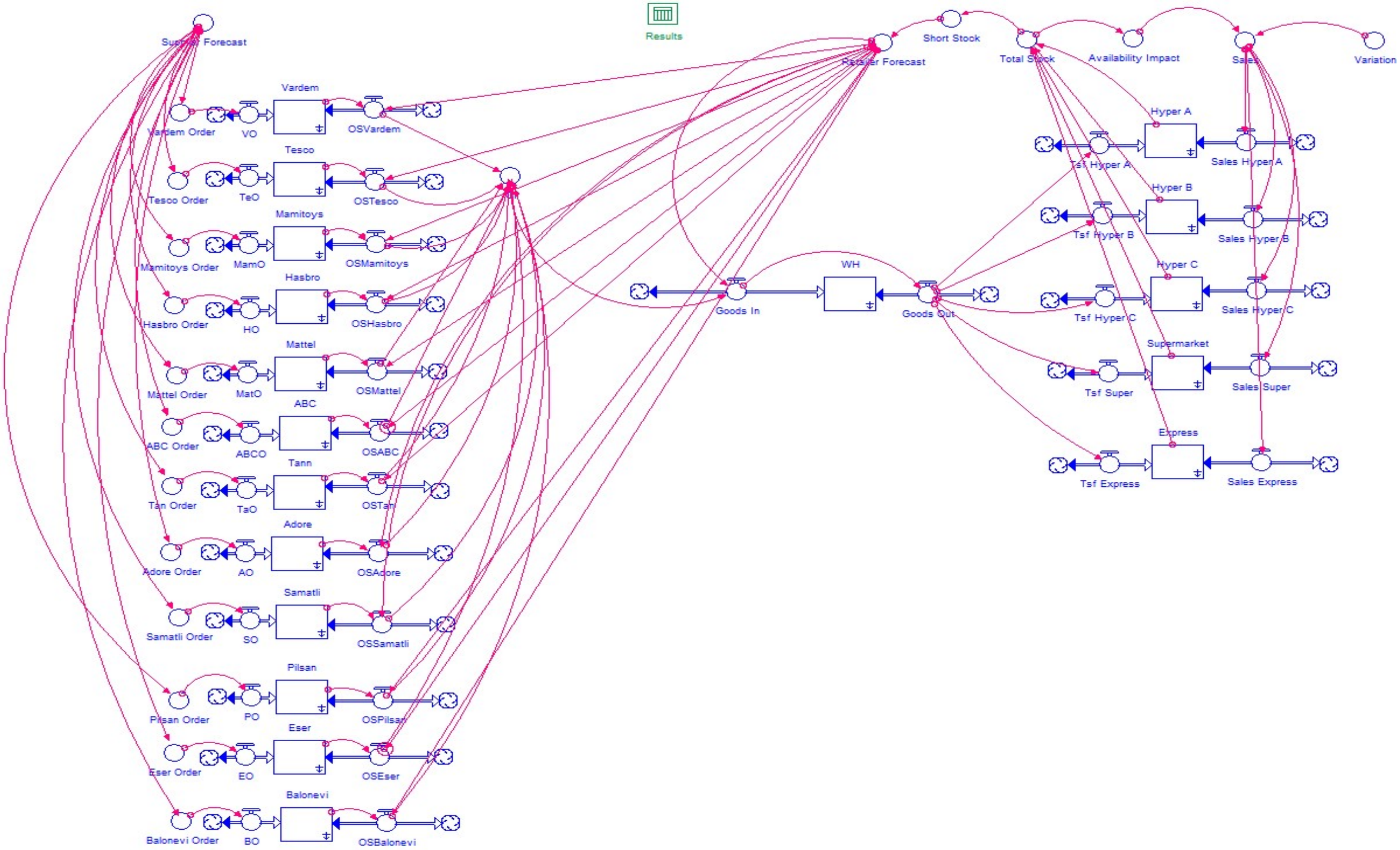
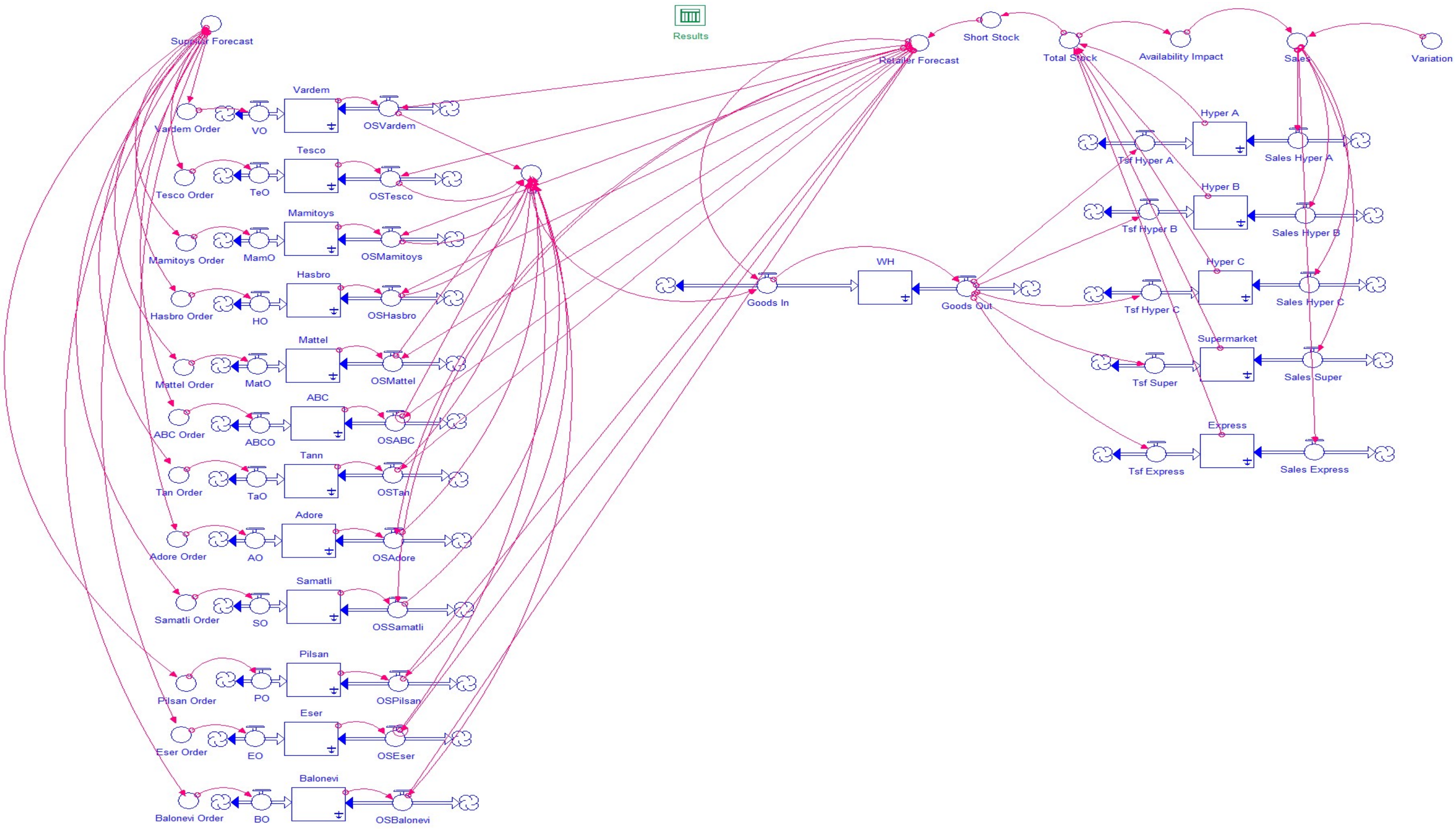
APPENDIX 1 : STELLA Model for “Scenario 1 - Decentralized Model”



APPENDIX 2 : STELLA Model for "Scenario 1 - Centralized Model"



APPENDIX 3 : STELLA Model Equations for "Scenario 1 - Decentralized Model"

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Goods_Out*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = Goods_Out*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = Goods_Out*0.295
OUTFLOWS:
```

```
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = Goods_Out*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Goods_Out*0.047
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE Retailer_Forecast*0.014
Tesco(t) = Tesco(t - dt) + (TeO - OSTesco) * dt
INIT Tesco = 0
INFLOWS:
TeO = Tesco_Order
OUTFLOWS:
OSTesco = IF MOD(TIME,4)=0 THEN Tesco ELSE
IF Tesco<Retailer_Forecast*0.260 THEN Tesco ELSE Retailer_Forecast*0.260
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
```

```
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.285 THEN Vardem ELSE Retailer_Forecast*0.285
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
INIT WH = 0
INFLOWS:
Goods_In = IF GI<Retailer_Forecast THEN GI ELSE Retailer_Forecast
OUTFLOWS:
Goods_Out = Goods_In
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact = if 5000000-Total_Stock<0 then 1 else
Total_Stock/5000000
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
GI =
OSVardem+OSTesco+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+
OSPilsan+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
```

```
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Supplier_Forecast = IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
```

```
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0
Tan_Order = Supplier_Forecast*0.014
Tesco_Order = Supplier_Forecast*0.260
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
Vardem_Order = Supplier_Forecast*0.285
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
```

```
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE
0
```

APPENDIX 4 : STELLA Model Equations for "Scenario 1 - Centralized Model"

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE
Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE
Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Goods_Out*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE
Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = Goods_Out*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = Goods_Out*0.295
OUTFLOWS:
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
```

```
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = Goods_Out*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE
Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE
Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE
Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Goods_Out*0.047
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE
Retailer_Forecast*0.014
Tesco(t) = Tesco(t - dt) + (TeO - OSTesco) * dt
INIT Tesco = 0
INFLOWS:
TeO = Tesco_Order
OUTFLOWS:
OSTesco = IF Tesco<Retailer_Forecast*0.260 THEN Tesco ELSE
Retailer_Forecast*0.260
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
```

```
OUTFLOWS:
OSVardem = IF Vardem<Retailer_Forecast*0.285 THEN Vardem ELSE
Retailer_Forecast*0.285
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
INIT WH = 0
INFLOWS:
Goods_In = IF GI<Retailer_Forecast THEN GI ELSE Retailer_Forecast
OUTFLOWS:
Goods_Out = Goods_In
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact = if 5000000-Total_Stock<0 then 1 else
Total_Stock/5000000
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
GI =
OSVardem+OSTesco+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+
OSPilsan+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0,Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
```

```
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Supplier_Forecast = IF TIME=0 THEN 2340474 ELSE
IF TIME=13 THEN 4208834 ELSE
IF TIME=26 THEN 3172981 ELSE
IF TIME=39 THEN 4570335 ELSE
0
Tan_Order = Supplier_Forecast*0.014
Tesco_Order = Supplier_Forecast*0.260
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
```

```
Vardem_Order = Supplier_Forecast*0.285
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE 0
```

APPENDIX 5 : Network Matrix for "Scenario 1 - Decentralized Model"

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266.358	416.184	166.474	283.005	149.826	4.328.314	233.063	199.768	1.997.684	1.714.678	2.147.510	4.744.498	0	0	0	0	0	0	0	0	0	**16.647.363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	43.931	222.426	0	0	0	0	0	0	0	**266.358**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	68.643	347.541	0	0	0	0	0	0	0	**416.184**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	27.457	139.016	0	0	0	0	0	0	0	**166.474**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	46.677	236.328	0	0	0	0	0	0	0	**283.005**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	24.711	125.115	0	0	0	0	0	0	0	**149.826**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	713.886	3.614.429	0	0	0	0	0	0	0	**4.328.314**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	38.440	194.623	0	0	0	0	0	0	0	**233.063**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	32.949	166.820	0	0	0	0	0	0	0	**199.768**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	329.486	1.668.198	0	0	0	0	0	0	0	**1.997.684**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	282.809	1.431.870	0	0	0	0	0	0	0	**1.714.678**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	354.197	1.793.313	0	0	0	0	0	0	0	**2.147.510**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	782.528	3.961.970	0	0	0	0	0	0	0	**4.744.498**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14.091.929	0	0	0	0	0	0	**14.091.929**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.935.085	4.100.986	4.114.888	653.378	97.312	0	**13.901.649**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.925.737	**4.925.737**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.093.218	**4.093.218**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.107.094	**4.107.094**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	652.140	**652.140**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97.127	**97.127**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266.358**	**416.184**	**166.474**	**283.005**	**149.826**	**4.328.314**	**233.063**	**199.768**	**1.997.684**	**1.714.678**	**2.147.510**	**4.744.498**	**2.745.714**	**13.901.649**	**14.091.929**	**4.935.085**	**4.100.986**	**4.114.888**	**653.378**	**97.312**	**13.875.316**	

APPENDIX 6 : 0-1 Matrix to Calculate H(Diversity) for “Scenario 1 - Decentralized Model”

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	**12**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	**2**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	**5**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**1**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**12**	**12**	**1**	**1**	**1**	**1**	**1**	**1**	**5**	

APPENDIX 7 : Network Matrix for “Scenario 1 - Centralized Model”

	Centralized Forecasting	**Supplier: Samatli**	**Supplier: ABC**	**Supplier: Eser**	**Supplier: Adore**	**Supplier: Balonevi**	**Supplier: Tesco**	**Supplier: Tan**	**Supplier: Pilsan**	**Supplier: Mamitoys**	**Supplier: Mattel**	**Supplier: Hasbro**	**Supplier: Vardem**	**Warehouse**	**Hyper A**	**Hyper B**	**Hyper C**	**Supermarket**	**Express**	**Customers**	**SUM**
Centralized Forecasting	0	228.682	357.316	142.926	242.975	128.634	3.716.082	200.097	171.511	1.715.115	1.472.140	1.843.749	4.073.398	13.954.583	0	0	0	0	0	0	**28.247.207**
Supplier: Samatli	223.273	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**223.273**
Supplier: ABC	348.865	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**348.865**
Supplier: Eser	139.546	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**139.546**
Supplier: Adore	237.228	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**237.228**
Supplier: Balonevi	125.591	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**125.591**
Supplier: Tesco	3.628.192	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3.628.192**
Supplier: Tan	195.364	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**195.364**
Supplier: Pilsan	167.455	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**167.455**
Supplier: Mamitoys	1.674.550	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.674.550**
Supplier: Mattel	1.437.322	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.437.322**
Supplier: Hasbro	1.800.141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.800.141**
Supplier: Vardem	3.977.056	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3.977.056**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.953.877	4.116.602	4.130.557	655.865	97.682	0	**13.954.583**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.928.839	**4.928.839**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.095.796	**4.095.796**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4.109.680	**4.109.680**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	652.551	**652.551**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97.188	**97.188**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**13.954.583**	**228.682**	**357.316**	**142.926**	**242.975**	**128.634**	**3.716.082**	**200.097**	**171.511**	**1.715.115**	**1.472.140**	**1.843.749**	**4.073.398**	**13.954.583**	**4.953.877**	**4.116.602**	**4.130.557**	**655.865**	**97.682**	**13.884.054**	

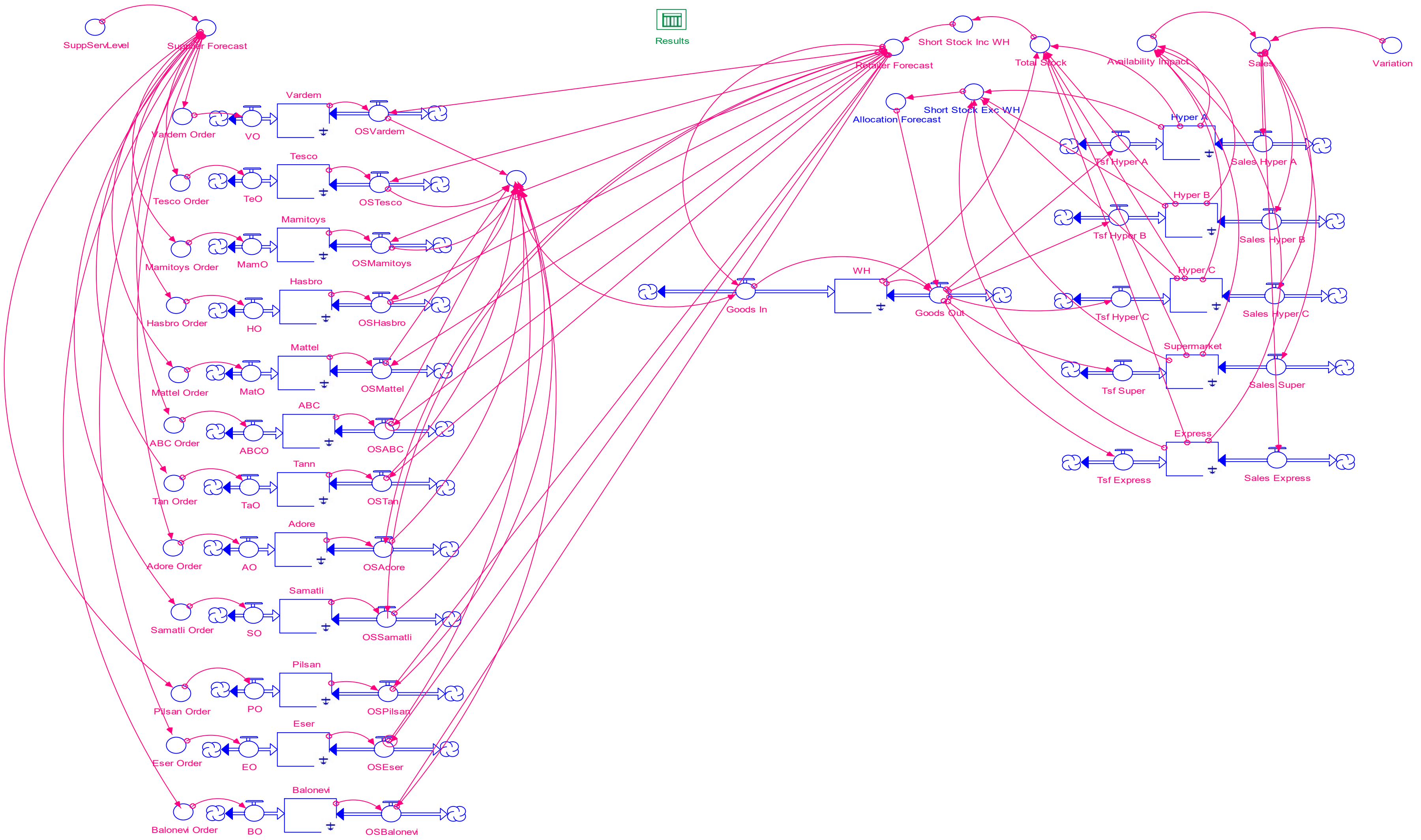
APPENDIX 8 : STELLA Output of "Scenario 1 - Decentralized Model"

Time	Supplier Forecast	Retailer Forecast	WH Goods In	Over/Short Stock	COGS	Total Stock	Stock Shared with Other Retailers
AVERAGE				8.810		5.008.810	
TOTAL	16.647.363	14.091.929	13.901.649		13.875.316		2.745.714
0	977.157	-	-	10.833	-	5.010.833	-
1	-	382.191	382.191	10.833	177.269	5.010.833	-
2	-	-	-	215.755	90.804	5.215.755	-
3	-	215.072	215.072	124.951	146.616	5.124.951	-
4	888.599	-	-	193.407	174.297	5.193.407	379.894
5	-	284.982	284.982	19.110	75.648	5.019.110	-
6	-	-	-	228.444	213.743	5.228.444	-
7	-	405.084	405.084	14.701	61.199	5.014.701	-
8	895.520	-	-	358.586	219.426	5.358.586	198.533
9	-	291.567	291.567	139.160	241.495	5.139.160	-
10	-	-	-	189.232	243.622	5.189.232	-
11	-	355.316	355.316	- 54.390	222.977	4.945.610	-
12	1.182.494	-	-	77.949	147.527	5.077.949	248.637
13	-	397.606	397.606	- 69.578	91.319	4.930.422	-
14	-	-	-	236.709	158.980	5.236.709	-
15	-	576.264	576.264	77.729	246.720	5.077.729	-
16	1.294.299	-	-	407.273	377.382	5.407.273	208.624
17	-	618.672	618.672	29.891	342.865	5.029.891	-
18	-	-	-	305.698	382.629	5.305.698	-
19	-	695.960	675.627	- 76.931	266.963	4.923.069	-
20	1.655.382	-	-	331.733	394.933	5.331.733	-
21	-	642.269	642.269	- 63.200	326.636	4.936.800	-
22	-	-	-	252.433	361.931	5.252.433	-
23	-	1.138.863	1.013.113	- 109.498	592.503	4.890.502	-
24	1.120.190	-	-	311.111	436.336	5.311.111	-
25	-	627.910	627.910	- 125.225	305.608	4.874.775	-
26	-	-	-	197.077	197.556	5.197.077	-
27	-	436.034	436.034	- 479	187.625	4.999.521	-
28	1.231.844	-	-	247.930	174.902	5.247.930	56.246
29	-	328.345	328.345	73.028	199.052	5.073.028	-
30	-	-	-	202.321	100.891	5.202.321	-
31	-	275.537	275.537	101.430	194.124	5.101.430	-
32	1.228.569	-	-	182.843	167.163	5.182.843	627.962
33	-	881.976	881.976	15.680	596.472	5.015.680	-
34	-	-	-	301.184	232.584	5.301.184	-
35	-	342.147	342.147	68.600	240.015	5.068.600	-
36	1.071.480	-	-	170.732	173.671	5.170.732	4.446
37	-	440.437	440.437	- 2.939	193.557	4.997.061	-
38	-	-	-	243.941	275.188	5.243.941	-
39	-	490.305	490.305	- 31.247	252.755	4.968.753	-
40	2.178.965	-	-	206.303	212.553	5.206.303	140.738
41	-	725.388	725.388	- 6.250	315.560	4.993.750	-
42	-	-	-	403.578	447.283	5.403.578	-
43	-	1.237.611	1.237.611	- 43.705	472.633	4.956.295	-
44	1.860.036	-	-	721.273	603.915	5.721.273	215.966
45	-	565.053	565.053	117.358	386.486	5.117.358	-
46	-	-	-	295.925	247.905	5.295.925	-
47	-	630.314	630.314	48.020	288.615	5.048.020	-
48	1.062.828	-	-	389.719	353.459	5.389.719	664.669
49	-	547.851	547.851	36.260	303.558	5.036.260	-
50	-	-	-	280.553	373.163	5.280.553	-
51	-	559.173	514.977	- 92.610	208.872	4.907.390	-
52	-	-	-	213.495	176.329	5.213.495	-
Final	-	-		37.166	-	5.037.166	-

APPENDIX 9 : STELLA Output of "Scenario 1 - Centralized Model"

Time	Supplier Forecast	Retailer Forecast	WH Goods In	Over/Short Stock	COGS	Total Stock	Stock Shared with Other Retailers
AVERAGE				15.533		5.015.533	
TOTAL	14.292.624	13.954.583	13.954.583		13.884.055		338.041
0	2.340.474	-	-	10.833	-	5.010.833	-
1	-	382.191	382.191	10.833	177.269	5.010.833	-
2	-	-	-	215.755	90.804	5.215.755	-
3	-	215.072	215.072	124.951	146.616	5.124.951	-
4	-	-	-	193.407	174.297	5.193.407	-
5	-	284.982	284.982	19.110	75.648	5.019.110	-
6	-	-	-	228.444	213.743	5.228.444	-
7	-	405.084	405.084	14.701	61.199	5.014.701	-
8	-	-	-	358.586	219.426	5.358.586	-
9	-	291.567	291.567	139.160	241.495	5.139.160	-
10	-	-	-	189.232	243.622	5.189.232	-
11	-	355.316	355.316	- 54.390	222.977	4.945.610	-
12	-	-	-	77.949	147.527	5.077.949	-
13	4.208.834	397.606	397.606	- 69.578	91.319	4.930.422	-
14	-	-	-	236.709	158.980	5.236.709	-
15	-	576.264	576.264	77.729	246.720	5.077.729	-
16	-	-	-	407.273	377.382	5.407.273	-
17	-	618.672	618.672	29.891	342.865	5.029.891	-
18	-	-	-	305.698	382.629	5.305.698	-
19	-	695.960	695.960	- 76.931	266.963	4.923.069	-
20	-	-	-	352.066	394.933	5.352.066	-
21	-	621.936	621.936	- 42.867	327.982	4.957.133	-
22	-	-	-	251.087	361.931	5.251.087	-
23	-	1.140.209	1.140.209	- 110.844	592.340	4.889.156	-
24	-	-	-	437.025	436.336	5.437.025	-
25	-	501.996	501.996	689	313.459	5.000.689	-
26	3.172.981	-	-	189.226	197.556	5.189.226	-
27	-	443.885	443.885	- 8.330	187.330	4.991.670	-
28	-	-	-	248.225	174.902	5.248.225	-
29	-	328.050	328.050	73.323	199.052	5.073.323	-
30	-	-	-	202.321	100.891	5.202.321	-
31	-	275.537	275.537	101.430	194.124	5.101.430	-
32	-	-	-	182.843	167.163	5.182.843	-
33	-	881.976	881.976	15.680	596.472	5.015.680	-
34	-	-	-	301.184	232.584	5.301.184	-
35	-	342.147	342.147	68.600	240.015	5.068.600	-
36	-	-	-	170.732	173.671	5.170.732	-
37	-	440.437	440.437	- 2.939	193.557	4.997.061	-
38	-	-	-	243.941	275.188	5.243.941	-
39	4.570.335	490.305	490.305	- 31.247	252.755	4.968.753	-
40	-	-	-	206.303	212.553	5.206.303	-
41	-	725.388	725.388	- 6.250	315.560	4.993.750	-
42	-	-	-	403.578	447.283	5.403.578	-
43	-	1.237.611	1.237.611	- 43.705	472.633	4.956.295	-
44	-	-	-	721.273	603.915	5.721.273	-
45	-	565.053	565.053	117.358	386.486	5.117.358	-
46	-	-	-	295.925	247.905	5.295.925	-
47	-	630.314	630.314	48.020	288.615	5.048.020	-
48	-	-	-	389.719	353.459	5.389.719	-
49	-	547.851	547.851	36.260	303.558	5.036.260	-
50	-	-	-	280.553	373.163	5.280.553	-
51	-	559.173	559.173	- 92.610	208.872	4.907.390	-
52	-	-	-	257.691	176.329	5.257.691	338.041
Final	-	-		81.362	-	5.081.362	-

APPENDIX 10 : STELLA Model for "Scenario 2 - Keeping safety stock in warehouse"



APPENDIX 11 : STELLA Model Equations for "Scenario 2 - Keeping safety stock in warehouse"

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Goods_Out*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = Goods_Out*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = Goods_Out*0.295
OUTFLOWS:
```

```
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = Goods_Out*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Goods_Out*0.047
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE Retailer_Forecast*0.014
Tesco(t) = Tesco(t - dt) + (TeO - OSTesco) * dt
INIT Tesco = 0
INFLOWS:
TeO = Tesco_Order
OUTFLOWS:
OSTesco = IF MOD(TIME,4)=0 THEN Tesco ELSE
IF Tesco<Retailer_Forecast*0.260 THEN Tesco ELSE Retailer_Forecast*0.260
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
```

```
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.285 THEN Vardem ELSE Retailer_Forecast*0.285
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
INIT WH = 0
INFLOWS:
Goods_In = IF GI<Retailer_Forecast THEN GI ELSE Retailer_Forecast
OUTFLOWS:
Goods_Out = MIN(Allocation_Forecast,WH+Goods_In)
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Allocation_Forecast = MAX(0, Short_Stock_Exc_WH + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Availability_Impact = if 5000000-Hyper_A-Hyper_B-Hyper_C-Supermarket-
Express<0 then 1 else (Hyper_A+Hyper_B+Hyper_C+Supermarket+Express)/5000000
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
GI =
OSVardem+OSTesco+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+
OSPilsan+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock_Inc_WH + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
```

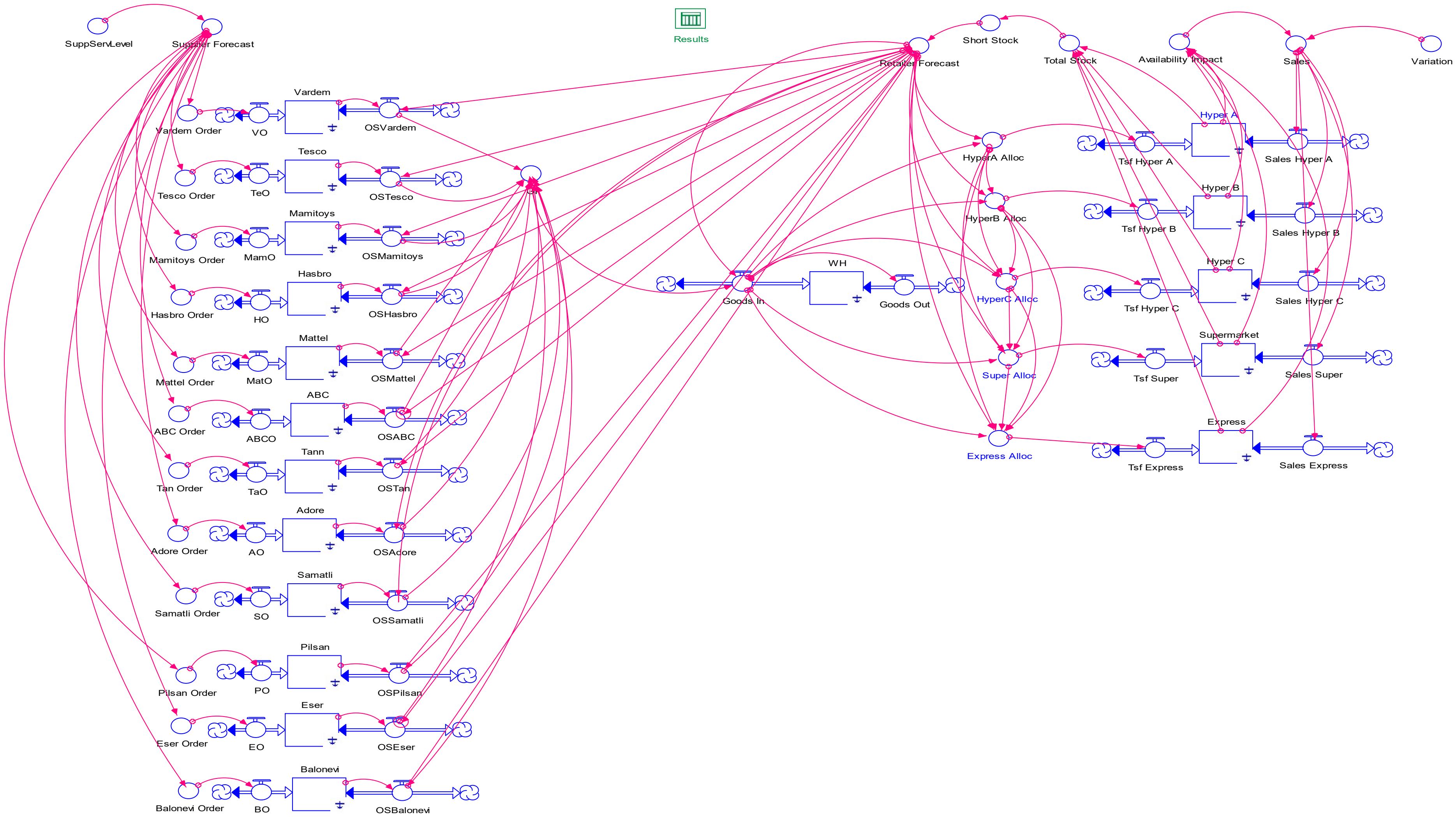
```
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
```

```
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock_Exc_WH = IF Hyper_A+Hyper_B+Hyper_C+Supermarket+Express<5000000
THEN 5000000-(Hyper_A+Hyper_B+Hyper_C+Supermarket+Express) ELSE 5000000-
(Hyper_A+Hyper_B+Hyper_C+Supermarket+Express)
Short_Stock_Inc_WH = IF Total_Stock<5500000 THEN 5500000-Total_Stock ELSE
5500000-Total_Stock
Supplier_Forecast = SuppServLevel * (
IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0)
SuppServLevel = IF TIME=0 THEN 0.94 ELSE
IF TIME=1 THEN 0.93 ELSE
IF TIME=2 THEN 0.38 ELSE
IF TIME=3 THEN 0.97 ELSE
IF TIME=4 THEN 0.95 ELSE
IF TIME=5 THEN 0.89 ELSE
IF TIME=6 THEN 0.38 ELSE
IF TIME=7 THEN 0.48 ELSE
IF TIME=8 THEN 0.67 ELSE
IF TIME=9 THEN 0.35 ELSE
IF TIME=10 THEN 1 ELSE
IF TIME=11 THEN 1 ELSE
IF TIME=12 THEN 0.78 ELSE
IF TIME=13 THEN 1 ELSE
IF TIME=14 THEN 0.49 ELSE
IF TIME=15 THEN 0.33 ELSE
IF TIME=16 THEN 0.89 ELSE
IF TIME=17 THEN 0.56 ELSE
```

```
IF TIME=18 THEN 0.96 ELSE
IF TIME=19 THEN 1 ELSE
IF TIME=20 THEN 0.78 ELSE
IF TIME=21 THEN 0.91 ELSE
IF TIME=22 THEN 0.31 ELSE
IF TIME=23 THEN 0.77 ELSE
IF TIME=24 THEN 0.65 ELSE
IF TIME=25 THEN 0.52 ELSE
IF TIME=26 THEN 0.91 ELSE
IF TIME=27 THEN 0.52 ELSE
IF TIME=28 THEN 1 ELSE
IF TIME=29 THEN 0.78 ELSE
IF TIME=30 THEN 0.88 ELSE
IF TIME=31 THEN 0.45 ELSE
IF TIME=32 THEN 0.86 ELSE
IF TIME=33 THEN 0.33 ELSE
IF TIME=34 THEN 0.62 ELSE
IF TIME=35 THEN 0.72 ELSE
IF TIME=36 THEN 1 ELSE
IF TIME=37 THEN 0.71 ELSE
IF TIME=38 THEN 0.33 ELSE
IF TIME=39 THEN 0.85 ELSE
IF TIME=40 THEN 1 ELSE
IF TIME=41 THEN 0.8 ELSE
IF TIME=42 THEN 1 ELSE
IF TIME=43 THEN 0.31 ELSE
IF TIME=44 THEN 0.86 ELSE
IF TIME=45 THEN 1 ELSE
IF TIME=46 THEN 0.43 ELSE
IF TIME=47 THEN 0.34 ELSE
IF TIME=48 THEN 1 ELSE
IF TIME=49 THEN 1 ELSE
IF TIME=50 THEN 1 ELSE
IF TIME=51 THEN 0.32 ELSE
IF TIME=52 THEN 0.5 ELSE
IF TIME=53 THEN 0.91 ELSE
0
Tan_Order = Supplier_Forecast*0.014
Tesco_Order = Supplier_Forecast*0.260
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express+WH
Vardem_Order = Supplier_Forecast*0.285
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
```

```
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE
0
```

APPENDIX 12 : STELLA Model for "Scenario 2 - Allocating Stock Based on Store Performance"



APPENDIX 13 : STELLA Model Equations for "Scenario 2 - Allocating Stock Based on Store Performance"

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Express_Alloc
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = HyperA_Alloc
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = HyperB_Alloc
OUTFLOWS:
```

```
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = HyperC_Alloc
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Super_Alloc
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE Retailer_Forecast*0.014
Tesco(t) = Tesco(t - dt) + (TeO - OSTesco) * dt
INIT Tesco = 0
INFLOWS:
TeO = Tesco_Order
OUTFLOWS:
OSTesco = IF MOD(TIME,4)=0 THEN Tesco ELSE
IF Tesco<Retailer_Forecast*0.260 THEN Tesco ELSE Retailer_Forecast*0.260
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
```

```
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.285 THEN Vardem ELSE Retailer_Forecast*0.285
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
INIT WH = 0
INFLOWS:
Goods_In = IF GI<Retailer_Forecast THEN GI ELSE Retailer_Forecast
OUTFLOWS:
Goods_Out = Goods_In
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact =
MIN(1,Hyper_A/(5000000*0.375))*0.375+MIN(1,Hyper_B/(5000000*0.309))*0.309+MI
N(1,Hyper_C/(5000000*0.260))*0.260+MIN(1,Supermarket/(5000000*0.047))*0.047+
MIN(1,Express/(5000000*0.008))*0.008
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
Express_Alloc = IF Goods_In-HyperA_Alloc-HyperB_Alloc-HyperC_Alloc-
Super_Alloc<Retailer_Forecast*0.007 THEN Goods_In-HyperA_Alloc-HyperB_Alloc-
HyperC_Alloc-Super_Alloc ELSE Retailer_Forecast*0.007
GI =
OSVardem+OSTesco+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+
OSPilsan+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
HyperA_Alloc = IF Goods_In<Retailer_Forecast*0.355 THEN Goods_In ELSE
Retailer_Forecast*0.355
HyperB_Alloc = IF Goods_In-HyperA_Alloc<Retailer_Forecast*0.295 THEN
Goods_In-HyperA_Alloc ELSE Retailer_Forecast*0.295
HyperC_Alloc = IF Goods_In-HyperA_Alloc-HyperB_Alloc<Retailer_Forecast*0.296
THEN Goods_In-HyperA_Alloc-HyperB_Alloc ELSE Retailer_Forecast*0.296
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
```

```
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
```

```
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Super_Alloc = IF Goods_In-HyperA_Alloc-HyperB_Alloc-
HyperC_Alloc<Retailer_Forecast*0.047 THEN Goods_In-HyperA_Alloc-
HyperB_Alloc-HyperC_Alloc ELSE Retailer_Forecast*0.047
Supplier_Forecast = SuppServLevel * (
IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0)
SuppServLevel = IF TIME=0 THEN 0.94 ELSE
IF TIME=1 THEN 0.93 ELSE
IF TIME=2 THEN 0.38 ELSE
IF TIME=3 THEN 0.97 ELSE
IF TIME=4 THEN 0.95 ELSE
IF TIME=5 THEN 0.89 ELSE
IF TIME=6 THEN 0.38 ELSE
IF TIME=7 THEN 0.48 ELSE
IF TIME=8 THEN 0.67 ELSE
IF TIME=9 THEN 0.35 ELSE
IF TIME=10 THEN 1 ELSE
IF TIME=11 THEN 1 ELSE
IF TIME=12 THEN 0.78 ELSE
IF TIME=13 THEN 1 ELSE
IF TIME=14 THEN 0.49 ELSE
IF TIME=15 THEN 0.33 ELSE
IF TIME=16 THEN 0.89 ELSE
IF TIME=17 THEN 0.56 ELSE
IF TIME=18 THEN 0.96 ELSE
IF TIME=19 THEN 1 ELSE
IF TIME=20 THEN 0.78 ELSE
IF TIME=21 THEN 0.91 ELSE
IF TIME=22 THEN 0.31 ELSE
IF TIME=23 THEN 0.77 ELSE
IF TIME=24 THEN 0.65 ELSE
IF TIME=25 THEN 0.52 ELSE
IF TIME=26 THEN 0.91 ELSE
IF TIME=27 THEN 0.52 ELSE
IF TIME=28 THEN 1 ELSE
IF TIME=29 THEN 0.78 ELSE
IF TIME=30 THEN 0.88 ELSE
IF TIME=31 THEN 0.45 ELSE
IF TIME=32 THEN 0.86 ELSE
IF TIME=33 THEN 0.33 ELSE
```

```
IF TIME=34 THEN 0.62 ELSE
IF TIME=35 THEN 0.72 ELSE
IF TIME=36 THEN 1 ELSE
IF TIME=37 THEN 0.71 ELSE
IF TIME=38 THEN 0.33 ELSE
IF TIME=39 THEN 0.85 ELSE
IF TIME=40 THEN 1 ELSE
IF TIME=41 THEN 0.8 ELSE
IF TIME=42 THEN 1 ELSE
IF TIME=43 THEN 0.31 ELSE
IF TIME=44 THEN 0.86 ELSE
IF TIME=45 THEN 1 ELSE
IF TIME=46 THEN 0.43 ELSE
IF TIME=47 THEN 0.34 ELSE
IF TIME=48 THEN 1 ELSE
IF TIME=49 THEN 1 ELSE
IF TIME=50 THEN 1 ELSE
IF TIME=51 THEN 0.32 ELSE
IF TIME=52 THEN 0.5 ELSE
IF TIME=53 THEN 0.91 ELSE
0
Tan_Order = Supplier_Forecast*0.014
Tesco_Order = Supplier_Forecast*0.260
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
Vardem_Order = Supplier_Forecast*0.285
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
```

```
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE
0
```

APPENDIX 14 : Network Matrix for "Scenario 2 - Keeping Safety Stock in Stores"

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	4,328,314	233,063	199,768	1,997,684	1,714,678	2,147,510	4,744,498	0	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	4,155	230,367	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	6,492	359,948	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	2,597	143,979	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	4,415	244,765	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	2,337	129,581	0	0	0	0	0	0	0	**131,918**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	67,518	3,743,459	0	0	0	0	0	0	0	**3,810,977**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	3,636	201,571	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	3,116	172,775	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	31,162	1,727,750	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	26,748	1,482,986	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	33,499	1,857,332	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	74,010	4,103,407	0	0	0	0	0	0	0	**4,177,417**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21,505,452	0	0	0	0	0	0	**21,505,452**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,111,262	4,247,386	4,261,784	676,702	100,785	0	**14,397,920**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,925,813	**4,925,813**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,093,281	**4,093,281**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,107,157	**4,107,157**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	652,150	**652,150**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97,129	**97,129**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**4,328,314**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**4,744,498**	**259,685**	**14,397,920**	**21,505,452**	**5,111,262**	**4,247,386**	**4,261,784**	**676,702**	**100,785**	**13,875,529**	

APPENDIX 15 : Network Matrix for “Scenario 2 - Keeping Safety Stock in Warehouse”

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	4,328,314	233,063	199,768	1,997,684	1,714,678	2,147,510	4,744,498	0	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	4,579	229,943	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	7,154	359,286	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	2,862	143,714	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	4,865	244,315	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	2,575	129,343	0	0	0	0	0	0	0	**131,918**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	74,402	3,736,575	0	0	0	0	0	0	0	**3,810,977**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	4,006	201,200	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	3,434	172,457	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	34,339	1,724,573	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	29,475	1,480,259	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	36,915	1,853,916	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	81,556	4,095,861	0	0	0	0	0	0	0	**4,177,417**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21,158,601	0	0	0	0	0	0	**21,158,601**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,940,052	4,105,114	4,119,029	654,035	97,409	0	**13,915,639**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,915,014	**4,915,014**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,084,308	**4,084,308**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,098,153	**4,098,153**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	650,720	**650,720**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96,916	**96,916**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**4,328,314**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**4,744,498**	**286,162**	**14,371,443**	**21,158,601**	**4,940,052**	**4,105,114**	**4,119,029**	**654,035**	**97,409**	**13,845,111**	

APPENDIX 16 : Network Matrix for "Scenario 2 - Allocating Stock Based on Store Performance"

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	4,328,314	233,063	199,768	1,997,684	1,714,678	2,147,510	4,744,498	0	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	27,971	206,551	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	43,704	322,736	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	17,482	129,094	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	29,719	219,461	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	15,733	116,185	0	0	0	0	0	0	0	**131,918**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	454,521	3,356,456	0	0	0	0	0	0	0	**3,810,977**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	24,474	180,732	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	20,978	154,913	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	209,779	1,549,134	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	180,060	1,329,673	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	225,512	1,665,319	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	498,225	3,679,193	0	0	0	0	0	0	0	**4,177,418**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,953,540	0	0	0	0	0	0	**15,953,540**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,108,648	3,960,642	3,295,241	474,280	70,637	0	**12,909,448**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,541,632	**4,541,632**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,774,032	**3,774,032**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,786,825	**3,786,825**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	601,286	**601,286**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	89,553	**89,553**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**4,328,314**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**4,744,498**	**1,748,157**	**12,909,448**	**15,953,540**	**5,108,648**	**3,960,642**	**3,295,241**	**474,280**	**70,637**	**12,793,328**	

APPENDIX 17 : STELLA Output of “Scenario 2 - Keeping Safety Stock in Stores”

AVERAGE					- 172,171		5,327,829	
TOTAL	16,647,363	14,657,605	21,505,452	14,397,920		13,875,529		259,685
Time	Supplier Forecast	Actual Supplier Stock Receiving	Retailer Forecast	WH Goods In	Over/Short Stock	COGS	Total Stock	Stock Shared with Other Retailers
0	977,157	918,528	489,167	-	- 489,167	-	5,010,833	-
1	-	-	882,191	882,191	- 489,167	177,269	5,010,833	-
2	-	-	-	-	215,755	90,804	5,715,755	-
3	-	-	215,072	36,337	124,951	146,616	5,624,951	-
4	888,599	844,169	-	-	14,672	174,297	5,514,672	-
5	-	-	463,717	463,717	- 159,625	75,648	5,340,375	-
6	-	-	-	-	228,444	213,743	5,728,444	-
7	-	-	405,084	380,452	14,701	61,199	5,514,701	-
8	895,520	599,998	-	-	333,954	219,426	5,833,954	-
9	-	-	316,199	316,199	114,528	241,495	5,614,528	-
10	-	-	-	-	189,232	243,622	5,689,232	-
11	-	-	355,316	283,799	- 54,390	225,429	5,445,610	-
12	1,182,494	922,345	-	-	3,980	147,527	5,503,980	-
13	-	-	471,575	471,575	- 143,547	92,608	5,356,453	-
14	-	-	-	-	235,420	158,980	5,735,420	-
15	-	-	577,553	450,770	76,440	246,720	5,576,440	-
16	1,294,299	1,151,926	-	-	280,490	377,382	5,780,490	-
17	-	-	745,455	745,455	- 96,892	342,865	5,403,108	-
18	-	-	-	-	305,698	382,629	5,805,698	-
19	-	-	695,960	406,471	- 76,931	271,135	5,423,069	-
20	1,655,382	1,291,198	-	-	58,405	394,933	5,558,405	-
21	-	-	915,597	915,597	- 336,528	330,818	5,163,472	-
22	-	-	-	-	248,251	361,931	5,748,251	-
23	-	-	1,143,045	375,601	- 113,680	605,769	5,386,320	-
24	1,120,190	728,124	343,848	-	- 343,848	436,336	5,156,152	-
25	-	-	1,282,869	728,124	- 780,184	295,894	4,719,816	-
26	-	-	347,954	-	- 347,954	197,556	5,152,046	-
27	-	-	981,065	-	- 545,510	185,935	4,954,490	-
28	1,231,844	1,231,844	731,445	-	- 731,445	166,806	4,768,555	-
29	-	-	1,299,624	1,231,844	- 898,251	183,197	4,601,749	-
30	-	-	-	-	150,396	100,891	5,650,396	-
31	-	-	327,462	-	49,505	194,124	5,549,505	-
32	1,228,569	1,056,569	144,619	-	- 144,619	167,163	5,355,381	-
33	-	-	1,209,438	1,056,569	- 311,782	596,472	5,188,218	-
34	-	-	-	-	148,315	232,584	5,648,315	-
35	-	-	495,016	-	- 84,269	240,015	5,415,731	-
36	1,071,480	1,071,480	324,284	-	- 324,284	173,671	5,175,716	-
37	-	-	935,453	935,453	- 497,955	193,671	5,002,045	-
38	-	-	-	-	243,827	275,188	5,743,827	-
39	-	-	490,419	136,027	- 31,361	254,345	5,468,639	-
40	2,178,965	2,178,965	149,679	-	- 149,679	212,553	5,350,321	-
41	-	-	1,081,370	1,081,370	- 362,232	315,955	5,137,768	-
42	-	-	-	-	403,183	447,283	5,903,183	-
43	-	-	1,238,006	1,097,595	- 44,100	476,801	5,455,900	-
44	1,860,036	1,599,631	-	-	576,694	603,915	6,076,694	-
45	-	-	709,632	709,632	- 27,221	386,486	5,472,779	-
46	-	-	-	-	295,925	247,905	5,795,925	-
47	-	-	630,314	630,314	48,020	288,615	5,548,020	-
48	1,062,828	1,062,828	-	-	389,719	353,459	5,889,719	259,685
49	-	-	547,851	547,851	36,260	303,558	5,536,260	-
50	-	-	-	-	280,553	373,163	5,780,553	-
51	-	-	559,173	514,977	- 92,610	212,814	5,407,390	-
52	-	-	-	-	209,553	176,329	5,709,553	-
Final	-	-	-		33,224	-	5,533,224	-

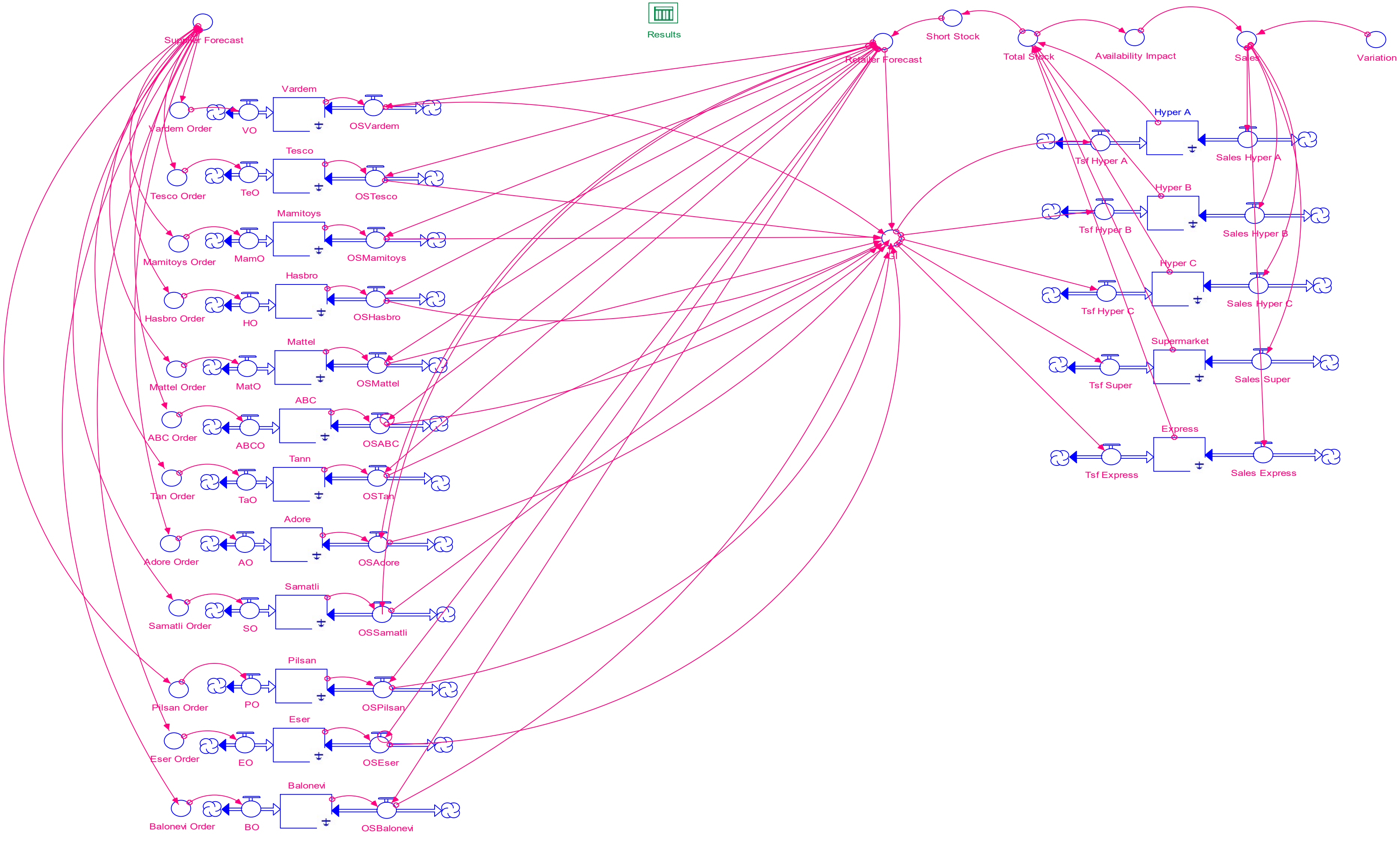
APPENDIX 18 : STELLA Output of "Scenario 2 - Keeping Safety Stock in Warehouse"

Time	Supplier Forecast	Actual Supplier Stock Receiving	Retailer Forecast	WH Goods In	Over/Short Stock	COGS	Total Stock	WH Stock	Stock Shared with Other Retailers
AVERAGE					- 164,030		5,335,970	346,612	
TOTAL	16,647,363	14,657,605	21,158,601	14,371,443		13,845,111			286,162
0	977,157	918,528	489,167	-	- 489,167	-	5,010,833	-	-
1	-	-	882,191	882,191	- 489,167	177,269	5,010,833	-	-
2	-	-	-	-	215,755	90,804	5,715,755	500,000	-
3	-	-	215,072	36,337	124,951	146,616	5,624,951	500,000	-
4	888,599	844,169	-	-	14,672	174,297	5,514,672	321,265	-
5	-	-	463,717	463,717	- 159,625	75,648	5,340,375	321,265	-
6	-	-	-	-	228,444	213,743	5,728,444	500,000	-
7	-	-	405,084	380,452	14,701	61,199	5,514,701	500,000	-
8	895,520	599,998	-	-	333,954	219,426	5,833,954	475,368	-
9	-	-	316,199	316,199	114,528	241,495	5,614,528	475,368	-
10	-	-	-	-	189,232	243,622	5,689,232	500,000	-
11	-	-	355,316	283,799	- 54,390	222,977	5,445,610	500,000	-
12	1,182,494	922,345	-	-	6,432	147,527	5,506,432	428,483	-
13	-	-	469,123	469,123	- 141,095	91,319	5,358,905	428,483	-
14	-	-	-	-	236,709	158,980	5,736,709	500,000	-
15	-	-	576,264	453,223	77,729	246,720	5,577,729	500,000	-
16	1,294,299	1,151,926	-	-	284,231	377,382	5,784,231	376,958	-
17	-	-	741,714	741,714	- 93,151	342,865	5,406,849	376,958	-
18	-	-	-	-	305,698	382,629	5,805,698	500,000	-
19	-	-	695,960	410,212	- 76,931	266,963	5,423,069	500,000	-
20	1,655,382	1,291,198	-	-	66,318	394,933	5,566,318	214,252	-
21	-	-	907,684	907,684	- 328,615	327,982	5,171,385	214,252	-
22	-	-	-	-	251,087	361,931	5,751,087	500,000	-
23	-	-	1,140,209	383,514	- 110,844	592,340	5,389,156	500,000	-
24	1,120,190	728,124	319,670	-	- 319,670	436,336	5,180,330	-	-
25	-	-	1,258,691	728,124	- 756,006	297,410	4,743,994	-	-
26	-	-	325,292	-	- 325,292	197,556	5,174,708	-	-
27	-	-	958,403	-	- 522,848	186,786	4,977,152	-	-
28	1,231,844	1,231,844	709,633	-	- 709,633	167,569	4,790,367	-	-
29	-	-	1,278,575	1,231,844	- 877,202	184,035	4,622,798	-	-
30	-	-	-	-	170,606	100,891	5,670,606	453,269	-
31	-	-	307,252	-	69,715	194,124	5,569,715	453,269	-
32	1,228,569	1,056,569	124,409	-	- 124,409	167,163	5,375,591	192,748	-
33	-	-	1,189,228	1,056,569	- 291,572	596,472	5,208,428	192,748	-
34	-	-	-	-	168,526	232,584	5,668,526	367,342	-
35	-	-	474,805	-	- 64,058	240,015	5,435,942	367,342	-
36	1,071,480	1,071,480	304,073	-	- 304,073	173,671	5,195,927	25,195	-
37	-	-	915,242	915,242	- 477,744	193,557	5,022,256	25,195	-
38	-	-	-	-	243,941	275,188	5,743,941	500,000	-
39	-	-	490,305	156,238	- 31,247	252,755	5,468,753	500,000	-
40	2,178,965	2,178,965	127,765	-	- 127,765	212,553	5,372,235	165,933	-
41	-	-	1,059,456	1,059,456	- 340,318	315,560	5,159,682	165,933	-
42	-	-	-	-	403,578	447,283	5,903,578	500,000	-
43	-	-	1,237,611	1,119,509	- 43,705	472,633	5,456,295	500,000	-
44	1,860,036	1,599,631	-	-	603,171	603,915	6,103,171	381,898	-
45	-	-	683,155	683,155	- 744	386,486	5,499,256	381,898	-
46	-	-	-	-	295,925	247,905	5,795,925	500,000	-
47	-	-	630,314	630,314	48,020	288,615	5,548,020	500,000	-
48	1,062,828	1,062,828	-	-	389,719	353,459	5,889,719	500,000	286,162
49	-	-	547,851	547,851	36,260	303,558	5,536,260	500,000	-
50	-	-	-	-	280,553	373,163	5,780,553	500,000	-
51	-	-	559,173	514,977	- 92,610	208,872	5,407,390	500,000	-
52	-	-	-	-	213,495	176,329	5,713,495	455,804	-
Final	-	-	-		37,166	-	5,537,166	455,804	-

APPENDIX 19 : STELLA Output of "Scenario 2 - Allocating Stock Based on Store Performance"

AVERAGE					- 26,513		4,973,487	
TOTAL	16,647,363	14,657,605	15,953,540	12,909,448		12,793,328		1,748,157
Time	Supplier Forecast	Actual Supplier Stock Receiving	Retailer Forecast	WH Goods In	Over/Short Stock	COGS	Total Stock	Stock Shared with Other Retailers
0	977,157	918,528	-	-	10,833	-	5,010,833	-
1	-	-	382,191	382,191	10,833	177,092	5,010,833	-
2	-	-	-	-	215,932	90,713	5,215,932	-
3	-	-	214,804	214,804	125,219	146,469	5,125,219	-
4	888,599	844,169	-	-	193,554	174,123	5,193,554	321,533
5	-	-	284,661	284,661	19,431	75,572	5,019,431	-
6	-	-	-	-	228,520	213,529	5,228,520	-
7	-	-	404,795	404,795	14,990	61,138	5,014,990	-
8	895,520	599,998	-	-	358,647	219,207	5,358,647	154,713
9	-	-	291,286	291,286	139,441	241,254	5,139,441	-
10	-	-	-	-	189,473	243,378	5,189,473	-
11	-	-	354,831	308,712	- 53,905	222,958	4,946,095	-
12	1,182,494	922,345	-	-	31,849	146,943	5,031,849	-
13	-	-	443,122	443,122	- 115,094	90,476	4,884,906	-
14	-	-	-	-	237,552	158,754	5,237,552	-
15	-	-	575,195	479,223	78,798	245,984	5,078,798	-
16	1,294,299	1,151,926	-	-	312,037	375,254	5,312,037	-
17	-	-	711,780	711,780	- 63,217	334,949	4,936,783	-
18	-	-	-	-	313,614	380,478	5,313,614	-
19	-	-	685,893	440,146	- 66,864	264,806	4,933,136	-
20	1,655,382	1,291,198	-	-	108,476	378,393	5,108,476	-
21	-	-	848,986	848,986	- 269,917	308,201	4,730,083	-
22	-	-	-	-	270,868	350,888	5,270,868	-
23	-	-	1,109,384	442,212	- 80,019	572,406	4,919,981	-
24	1,120,190	728,124	210,214	-	- 210,214	391,646	4,789,786	-
25	-	-	1,104,544	728,124	- 601,859	265,517	4,398,141	-
26	-	-	139,253	-	- 139,253	170,074	4,860,747	-
27	-	-	744,882	-	- 309,327	159,306	4,690,673	-
28	1,231,844	1,231,844	468,633	-	- 468,633	146,483	4,531,367	-
29	-	-	1,016,489	1,016,489	- 615,116	162,948	4,384,884	-
30	-	-	-	-	238,425	89,523	5,238,425	-
31	-	-	228,065	215,355	148,902	171,035	5,148,902	-
32	1,228,569	1,056,569	-	-	193,222	147,523	5,193,222	-
33	-	-	851,957	851,957	45,699	520,233	5,045,699	-
34	-	-	-	-	377,423	208,257	5,377,423	-
35	-	-	241,581	204,612	169,166	211,412	5,169,166	-
36	1,071,480	1,071,480	-	-	162,367	152,057	5,162,367	-
37	-	-	427,188	427,188	10,310	167,506	5,010,310	-
38	-	-	-	-	269,992	243,013	5,269,992	-
39	-	-	432,079	432,079	26,979	220,280	5,026,979	-
40	2,178,965	2,178,965	-	-	238,778	187,237	5,238,778	212,214
41	-	-	667,596	667,596	51,542	274,182	5,051,542	-
42	-	-	-	-	444,956	400,464	5,444,956	-
43	-	-	1,149,414	1,149,414	44,493	413,526	5,044,493	-
44	1,860,036	1,599,631	-	-	780,380	554,880	5,780,380	361,955
45	-	-	456,912	456,912	225,499	340,094	5,225,499	-
46	-	-	-	-	342,317	220,175	5,342,317	-
47	-	-	556,191	556,191	122,143	251,883	5,122,143	-
48	1,062,828	1,062,828	-	-	426,451	316,003	5,426,451	586,528
49	-	-	473,663	473,663	110,448	264,675	5,110,448	-
50	-	-	-	-	319,436	330,824	5,319,436	-
51	-	-	477,951	477,951	- 11,388	183,740	4,988,612	-
52	-	-	-	-	282,823	155,871	5,282,823	111,214
Final	-	-	-		126,953	-	5,126,953	-

APPENDIX 20 : STELLA Model for "Scenario 3 – Direct to Store Shipment"



APPENDIX 21 : STELLA Model Equations for “Scenario 3 – Direct to Store Shipment”

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN  (IF MAX(ABC,5000)=5000 THEN 0 ELSE
MAX(ABC,10000)) ELSE  (IF MAX(Retailer_Forecast*0.025,5000)=5000 THEN 0 ELSE
MAX(Retailer_Forecast*0.025,10000))
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN  (IF MAX(Adore,5000)=5000 THEN 0 ELSE
MAX(Adore,10000)) ELSE  (IF MAX(Retailer_Forecast*0.017,5000)=5000 THEN 0
ELSE MAX(Retailer_Forecast*0.017,10000))
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN  (IF MAX(Balonevi,5000)=5000 THEN 0
ELSE MAX(Balonevi,10000)) ELSE  (IF MAX(Retailer_Forecast*0.009,5000)=5000
THEN 0 ELSE MAX(Retailer_Forecast*0.009,10000))
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN  (IF MAX(Eser,5000)=5000 THEN 0 ELSE
MAX(Eser,10000)) ELSE  (IF MAX(Retailer_Forecast*0.010,5000)=5000 THEN 0
ELSE MAX(Retailer_Forecast*0.010,10000))
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = GI*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN  (IF MAX(Hasbro,5000)=5000 THEN 0
ELSE MAX(Hasbro,10000)) ELSE  (IF MAX(Retailer_Forecast*0.129,5000)=5000
THEN 0 ELSE MAX(Retailer_Forecast*0.129,10000))
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
```

```
INFLOWS:
Tsf_Hyper_A = GI*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = GI*0.295
OUTFLOWS:
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = GI*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN  (IF MAX(Mamitoys,5000)=5000 THEN 0
ELSE MAX(Mamitoys,10000)) ELSE  (IF MAX(Retailer_Forecast*0.120,5000)=5000
THEN 0 ELSE MAX(Retailer_Forecast*0.120,10000))
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN  (IF MAX(Mattel,5000)=5000 THEN 0
ELSE MAX(Mattel,10000)) ELSE  (IF MAX(Retailer_Forecast*0.103,5000)=5000
THEN 0 ELSE MAX(Retailer_Forecast*0.103,10000))
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN  (IF MAX(Pilsan,5000)=5000 THEN 0
ELSE MAX(Pilsan,10000)) ELSE  (IF MAX(Retailer_Forecast*0.012,5000)=5000
THEN 0 ELSE MAX(Retailer_Forecast*0.012,10000))
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN  (IF MAX(Samatli,5000)=5000 THEN 0
ELSE MAX(Samatli,10000)) ELSE  (IF MAX(Retailer_Forecast*0.016,5000)=5000
THEN 0 ELSE MAX(Retailer_Forecast*0.016,10000))
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = GI*0.047
OUTFLOWS:
```

```
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN  (IF MAX(Tann,5000)=5000 THEN 0 ELSE
MAX(Tann,10000)) ELSE  (IF MAX(Retailer_Forecast*0.014,5000)=5000 THEN 0
ELSE MAX(Retailer_Forecast*0.014,10000))
Tesco(t) = Tesco(t - dt) + (TeO - OSTesco) * dt
INIT Tesco = 0
INFLOWS:
TeO = Tesco_Order
OUTFLOWS:
OSTesco = IF MOD(TIME,4)=0 THEN Tesco ELSE
IF Tesco<Retailer_Forecast*0.260 THEN (IF MAX(Tesco,5000)=5000 THEN 0 ELSE
MAX(Tesco,10000)) ELSE  (IF MAX(Retailer_Forecast*0.260,5000)=5000 THEN 0
ELSE MAX(Retailer_Forecast*0.260,10000))
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.285 THEN (IF MAX(Vardem,5000)=5000 THEN 0 ELSE
MAX(Vardem,10000)) ELSE  (IF MAX(Retailer_Forecast*0.285,5000)=5000 THEN 0
ELSE MAX(Retailer_Forecast*0.285,10000))
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact = if 5000000-Total_Stock<0 then 1 else
Total_Stock/5000000
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
GI = IF Retailer_Forecast=0 THEN 0 ELSE
OSABC+OSAdore+OSBalonevi+OSEser+OSHasbro+OSMamitoys+OSMattel+OSPilsan+OSSama
tli+OSTan+OSTesco+OSVardem
Hasbro_Order = Supplier_Forecast*0.129
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
```

```
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
```

```
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Supplier_Forecast = IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0
Tan_Order = Supplier_Forecast*0.014
Tesco_Order = Supplier_Forecast*0.260
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
Vardem_Order = Supplier_Forecast*0.285
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
```

```
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE
0
```

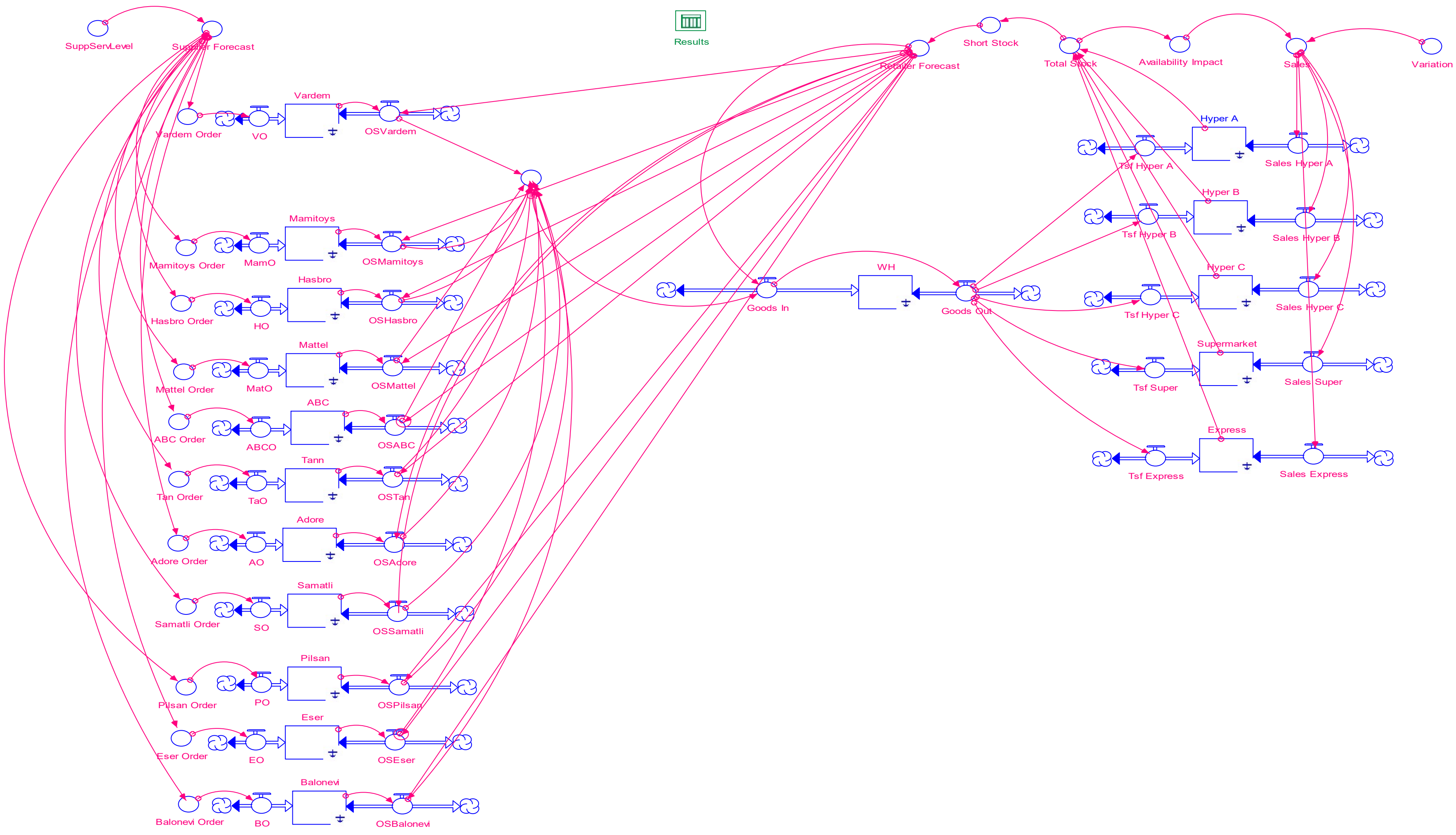
APPENDIX 22 : Network matrix for “Scenario 3 – Direct to Store Shipment”

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	4,328,314	233,063	199,768	1,997,684	1,714,678	2,147,510	4,744,498	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	23,337	0	86,272	71,691	71,934	11,422	1,701	0	**266,358**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	50,415	0	129,848	107,902	108,268	17,191	2,560	0	**416,184**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	54,684	0	39,685	32,978	33,090	5,254	783	0	**166,474**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	23,275	0	92,204	76,621	76,880	12,207	1,818	0	**283,005**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	59,826	0	31,950	26,550	26,640	4,230	630	0	**149,826**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	706,939	0	1,285,588	1,068,306	1,071,927	170,205	25,350	0	**4,328,314**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	29,790	0	72,162	59,966	60,169	9,554	1,423	0	**233,063**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	64,201	0	48,126	39,992	40,128	6,372	949	0	**199,768**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	326,280	0	593,348	493,064	494,736	78,556	11,700	0	**1,997,684**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	280,057	0	509,291	423,213	424,648	67,427	10,042	0	**1,714,678**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	350,750	0	637,850	530,044	531,841	84,448	12,577	0	**2,147,510**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	774,914	0	1,409,203	1,171,027	1,174,997	186,570	27,787	0	**4,744,498**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,994,520	4,150,376	4,164,445	661,246	98,483	0	**14,069,070**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,927,870	**4,927,870**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,094,991	**4,094,991**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,108,872	**4,108,872**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	652,422	**652,422**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97,169	**97,169**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**4,328,314**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**4,744,498**	**2,744,467**	**0**	**9,930,048**	**8,251,730**	**8,279,702**	**1,314,682**	**195,804**	**13,881,325**	

APPENDIX 23 : STELLA Output of "Scenario 3 – Direct to Store Shipment"

AVERAGE				9,629		5,009,629	
TOTAL	16,647,363	14,069,070	13,902,896		13,877,303		2,744,467
Time	Supplier Forecast	Retailer Forecast	Total DTS Goods In	Over/Short Stock	Sales	Total Stock	Stock Shared with Other Retailers
0	977,157	-	-	10,833	-	5,010,833	-
1	-	382,191	382,825	10,833	177,269	5,010,833	-
2	-	-	-	216,389	90,804	5,216,389	-
3	-	214,438	202,351	125,585	146,616	5,125,585	-
4	888,599	-	-	181,320	174,297	5,181,320	391,981
5	-	297,069	286,471	7,023	75,648	5,007,023	-
6	-	-	-	217,846	213,743	5,217,846	-
7	-	415,682	413,259	4,103	61,199	5,004,103	-
8	895,520	-	-	356,163	219,426	5,356,163	188,869
9	-	293,990	273,709	136,737	241,495	5,136,737	-
10	-	-	-	168,951	243,622	5,168,951	-
11	-	375,597	376,911	- 74,671	222,062	4,925,329	-
12	1,182,494	-	-	80,177	147,527	5,080,177	244,900
13	-	395,378	394,654	- 67,350	91,361	4,932,650	-
14	-	-	-	235,944	158,980	5,235,944	-
15	-	577,029	592,021	76,964	246,720	5,076,964	-
16	1,294,299	-	-	422,265	377,382	5,422,265	195,819
17	-	603,680	616,856	44,883	342,865	5,044,883	-
18	-	-	-	318,874	382,629	5,318,874	-
19	-	682,785	671,843	- 63,756	267,678	4,936,245	-
20	1,655,382	-	-	340,410	394,933	5,340,410	5,600
21	-	633,592	645,080	- 54,523	327,211	4,945,477	-
22	-	-	-	263,347	361,931	5,263,347	-
23	-	1,127,949	1,008,985	- 98,584	593,825	4,901,416	-
24	1,120,190	-	-	316,576	436,336	5,316,576	1,317
25	-	622,445	634,476	- 119,760	305,951	4,880,240	-
26	-	-	-	208,765	197,556	5,208,765	-
27	-	424,346	421,247	11,209	187,643	5,011,209	-
28	1,231,844	-	-	244,813	174,902	5,244,813	64,467
29	-	331,462	327,321	69,911	199,052	5,069,911	-
30	-	-	-	198,180	100,891	5,198,180	-
31	-	279,678	260,871	97,289	194,124	5,097,289	-
32	1,228,569	-	-	164,036	167,163	5,164,036	643,652
33	-	900,783	903,668	- 3,127	596,099	4,996,873	-
34	-	-	-	304,442	232,584	5,304,442	-
35	-	338,889	324,024	71,858	240,015	5,071,858	-
36	1,071,480	-	-	155,867	173,671	5,155,867	877
37	-	455,302	459,788	- 17,804	192,981	4,982,196	-
38	-	-	-	249,003	275,188	5,249,003	-
39	-	485,243	477,394	- 26,185	253,013	4,973,815	-
40	2,178,965	-	-	198,196	212,553	5,198,196	134,298
41	-	733,495	740,757	- 14,357	315,048	4,985,643	-
42	-	-	-	411,352	447,283	5,411,352	-
43	-	1,229,837	1,228,260	- 35,931	473,375	4,964,069	-
44	1,860,036	-	-	718,954	603,915	5,718,954	209,949
45	-	567,372	583,117	115,039	386,486	5,115,039	-
46	-	-	-	311,670	247,905	5,311,670	-
47	-	614,569	627,080	63,765	288,615	5,063,765	-
48	1,062,828	-	-	402,230	353,459	5,402,230	649,839
49	-	535,340	543,583	48,771	303,558	5,048,771	-
50	-	-	-	288,797	373,163	5,288,797	-
51	-	550,930	506,344	- 84,367	209,223	4,915,634	-
52	-	-	-	212,755	176,329	5,212,755	12,901
Final	-	-	-	36,426	-	5,036,426	-

APPENDIX 24 : STELLA Model for "Scenario 4 – Supplier Number Reduction"



APPENDIX 25 : STELLA Model Equations for "Scenario 4 : Supplier Number Reduction"

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Goods_Out*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = Goods_Out*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = Goods_Out*0.295
OUTFLOWS:
```

```
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = Goods_Out*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Goods_Out*0.047
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE Retailer_Forecast*0.014
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.545 THEN Vardem ELSE Retailer_Forecast*0.545
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
```

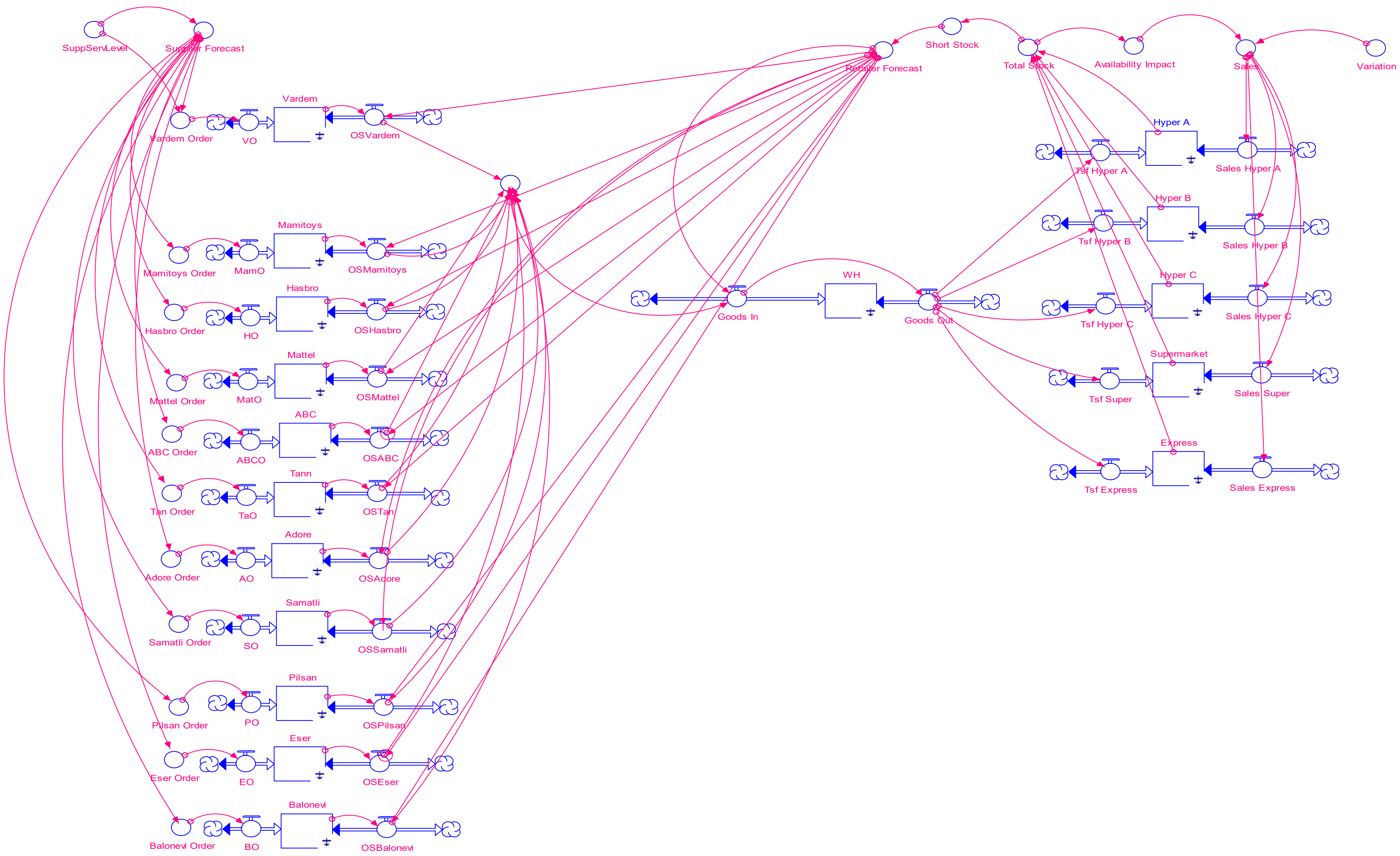
```
INIT WH = 0
INFLOWS:
Goods_In = IF GI<Retailer_Forecast THEN GI ELSE Retailer_Forecast
OUTFLOWS:
Goods_Out = Goods_In
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact = if 5000000-Total_Stock<0 then 1 else
Total_Stock/5000000
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
GI =
OSVardem+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+OSPilsan
+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
```

```
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Supplier_Forecast = SuppServLevel * (
IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
```

```
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0)
SuppServLevel = IF TIME=0 THEN 0.94 ELSE
IF TIME=1 THEN 0.93 ELSE
IF TIME=2 THEN 0.38 ELSE
IF TIME=3 THEN 0.97 ELSE
IF TIME=4 THEN 0.95 ELSE
IF TIME=5 THEN 0.89 ELSE
IF TIME=6 THEN 0.38 ELSE
IF TIME=7 THEN 0.48 ELSE
IF TIME=8 THEN 0.67 ELSE
IF TIME=9 THEN 0.35 ELSE
IF TIME=10 THEN 1 ELSE
IF TIME=11 THEN 1 ELSE
IF TIME=12 THEN 0.78 ELSE
IF TIME=13 THEN 1 ELSE
IF TIME=14 THEN 0.49 ELSE
IF TIME=15 THEN 0.33 ELSE
IF TIME=16 THEN 0.89 ELSE
IF TIME=17 THEN 0.56 ELSE
IF TIME=18 THEN 0.96 ELSE
IF TIME=19 THEN 1 ELSE
IF TIME=20 THEN 0.78 ELSE
IF TIME=21 THEN 0.91 ELSE
IF TIME=22 THEN 0.31 ELSE
IF TIME=23 THEN 0.77 ELSE
IF TIME=24 THEN 0.65 ELSE
IF TIME=25 THEN 0.52 ELSE
IF TIME=26 THEN 0.91 ELSE
IF TIME=27 THEN 0.52 ELSE
IF TIME=28 THEN 1 ELSE
IF TIME=29 THEN 0.78 ELSE
IF TIME=30 THEN 0.88 ELSE
IF TIME=31 THEN 0.45 ELSE
IF TIME=32 THEN 0.86 ELSE
IF TIME=33 THEN 0.33 ELSE
IF TIME=34 THEN 0.62 ELSE
IF TIME=35 THEN 0.72 ELSE
IF TIME=36 THEN 1 ELSE
IF TIME=37 THEN 0.71 ELSE
IF TIME=38 THEN 0.33 ELSE
IF TIME=39 THEN 0.85 ELSE
IF TIME=40 THEN 1 ELSE
IF TIME=41 THEN 0.8 ELSE
IF TIME=42 THEN 1 ELSE
IF TIME=43 THEN 0.31 ELSE
IF TIME=44 THEN 0.86 ELSE
IF TIME=45 THEN 1 ELSE
IF TIME=46 THEN 0.43 ELSE
IF TIME=47 THEN 0.34 ELSE
IF TIME=48 THEN 1 ELSE
IF TIME=49 THEN 1 ELSE
IF TIME=50 THEN 1 ELSE
IF TIME=51 THEN 0.32 ELSE
IF TIME=52 THEN 0.5 ELSE
IF TIME=53 THEN 0.91 ELSE
0
```

```
Tan_Order = Supplier_Forecast*0.014
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
Vardem_Order = Supplier_Forecast*0.545
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE 0
```

APPENDIX 26 : STELLA Model for "Scenario 4 : Supplier Number Reduction Improving Performance"



APPENDIX 27 : STELLA Model Equations for "Scenario 4 - Supplier Number Reduction Improving Performance"

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Goods_Out*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = Goods_Out*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = Goods_Out*0.295
OUTFLOWS:
```

```
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = Goods_Out*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Goods_Out*0.047
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE Retailer_Forecast*0.014
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.545 THEN Vardem ELSE Retailer_Forecast*0.545
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
```

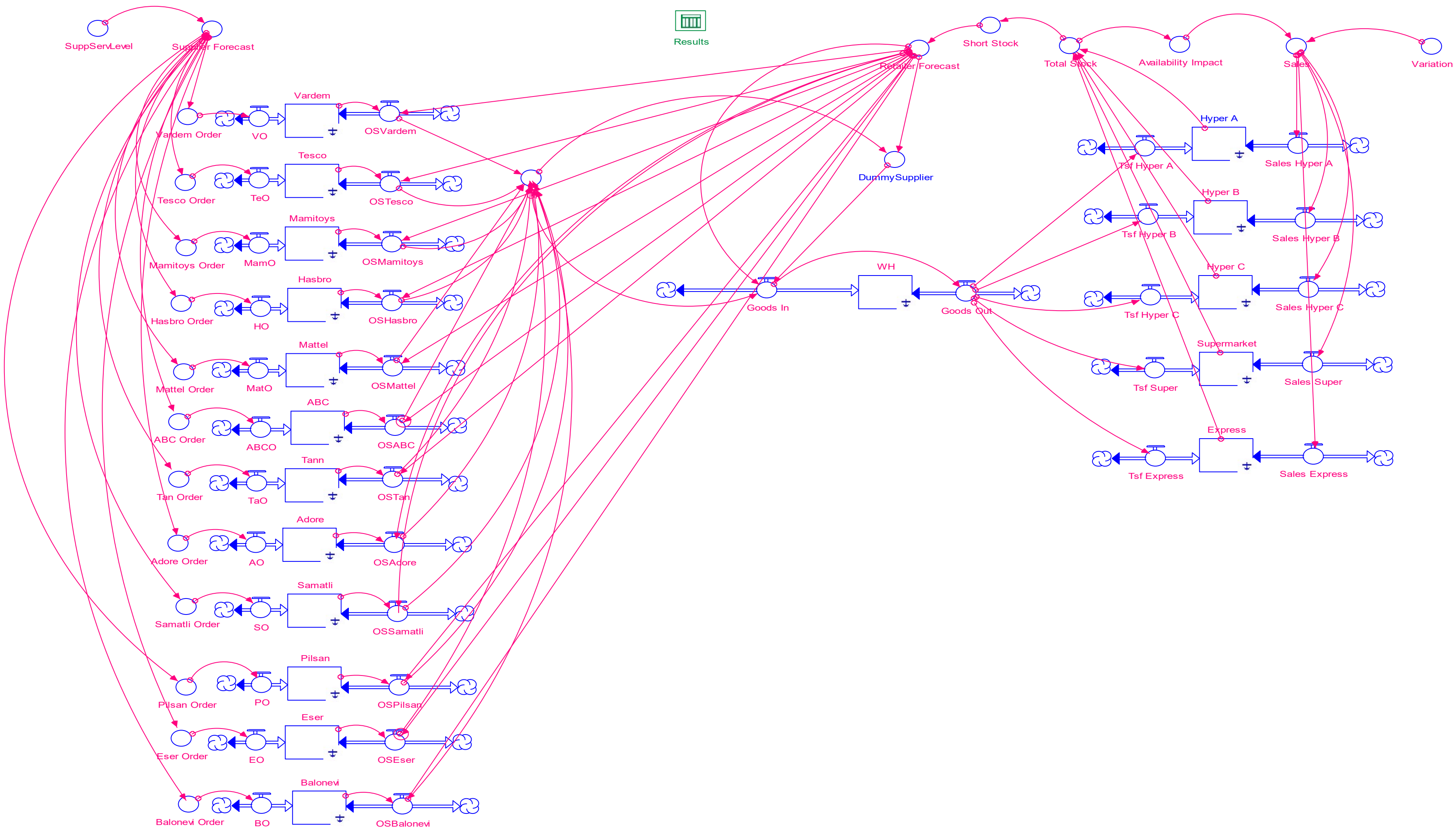
```
INIT WH = 0
INFLOWS:
Goods_In = IF GI<Retailer_Forecast THEN GI ELSE Retailer_Forecast
OUTFLOWS:
Goods_Out = Goods_In
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact = if 5000000-Total_Stock<0 then 1 else
Total_Stock/5000000
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
GI =
OSVardem+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+OSPilsan
+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
```

```
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Supplier_Forecast = SuppServLevel * (
IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
```

```
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0)
SuppServLevel = IF TIME=0 THEN 0.94 ELSE
IF TIME=1 THEN 0.93 ELSE
IF TIME=2 THEN 0.38 ELSE
IF TIME=3 THEN 0.97 ELSE
IF TIME=4 THEN 0.95 ELSE
IF TIME=5 THEN 0.89 ELSE
IF TIME=6 THEN 0.38 ELSE
IF TIME=7 THEN 0.48 ELSE
IF TIME=8 THEN 0.67 ELSE
IF TIME=9 THEN 0.35 ELSE
IF TIME=10 THEN 1 ELSE
IF TIME=11 THEN 1 ELSE
IF TIME=12 THEN 0.78 ELSE
IF TIME=13 THEN 1 ELSE
IF TIME=14 THEN 0.49 ELSE
IF TIME=15 THEN 0.33 ELSE
IF TIME=16 THEN 0.89 ELSE
IF TIME=17 THEN 0.56 ELSE
IF TIME=18 THEN 0.96 ELSE
IF TIME=19 THEN 1 ELSE
IF TIME=20 THEN 0.78 ELSE
IF TIME=21 THEN 0.91 ELSE
IF TIME=22 THEN 0.31 ELSE
IF TIME=23 THEN 0.77 ELSE
IF TIME=24 THEN 0.65 ELSE
IF TIME=25 THEN 0.52 ELSE
IF TIME=26 THEN 0.91 ELSE
IF TIME=27 THEN 0.52 ELSE
IF TIME=28 THEN 1 ELSE
IF TIME=29 THEN 0.78 ELSE
IF TIME=30 THEN 0.88 ELSE
IF TIME=31 THEN 0.45 ELSE
IF TIME=32 THEN 0.86 ELSE
IF TIME=33 THEN 0.33 ELSE
IF TIME=34 THEN 0.62 ELSE
IF TIME=35 THEN 0.72 ELSE
IF TIME=36 THEN 1 ELSE
IF TIME=37 THEN 0.71 ELSE
IF TIME=38 THEN 0.33 ELSE
IF TIME=39 THEN 0.85 ELSE
IF TIME=40 THEN 1 ELSE
IF TIME=41 THEN 0.8 ELSE
IF TIME=42 THEN 1 ELSE
IF TIME=43 THEN 0.31 ELSE
IF TIME=44 THEN 0.86 ELSE
IF TIME=45 THEN 1 ELSE
IF TIME=46 THEN 0.43 ELSE
IF TIME=47 THEN 0.34 ELSE
IF TIME=48 THEN 1 ELSE
IF TIME=49 THEN 1 ELSE
IF TIME=50 THEN 1 ELSE
IF TIME=51 THEN 0.32 ELSE
IF TIME=52 THEN 0.5 ELSE
IF TIME=53 THEN 0.91 ELSE
0
```

```
Tan_Order = Supplier_Forecast*0.014
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
Vardem_Order = Supplier_Forecast*0.545/SuppServLevel
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE 0
```

APPENDIX 28 : STELLA Model for "Scenario 4 : Using a dummy supplier"



APPENDIX 29 : STELLA Model Equations for "Scenario 4 : Using a dummy supplier"

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Goods_Out*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = Goods_Out*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = Goods_Out*0.295
OUTFLOWS:
```

```
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = Goods_Out*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Goods_Out*0.047
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE Retailer_Forecast*0.014
Tesco(t) = Tesco(t - dt) + (TeO - OSTesco) * dt
INIT Tesco = 0
INFLOWS:
TeO = Tesco_Order
OUTFLOWS:
OSTesco = IF MOD(TIME,4)=0 THEN Tesco ELSE
IF Tesco<Retailer_Forecast*0.260 THEN Tesco ELSE Retailer_Forecast*0.260
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
```

```
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.285 THEN Vardem ELSE Retailer_Forecast*0.285
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
INIT WH = 0
INFLOWS:
Goods_In = IF GI+DummySupplier<Retailer_Forecast THEN GI+DummySupplier ELSE
Retailer_Forecast
OUTFLOWS:
Goods_Out = Goods_In
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact = if 5000000-Total_Stock<0 then 1 else
Total_Stock/5000000
Balonevi_Order = Supplier_Forecast*0.009
DummySupplier = IF GI<Retailer_Forecast THEN Retailer_Forecast-GI ELSE 0
Eser_Order = Supplier_Forecast*0.010
GI =
OSVardem+OSTesco+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+
OSPilsan+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
```

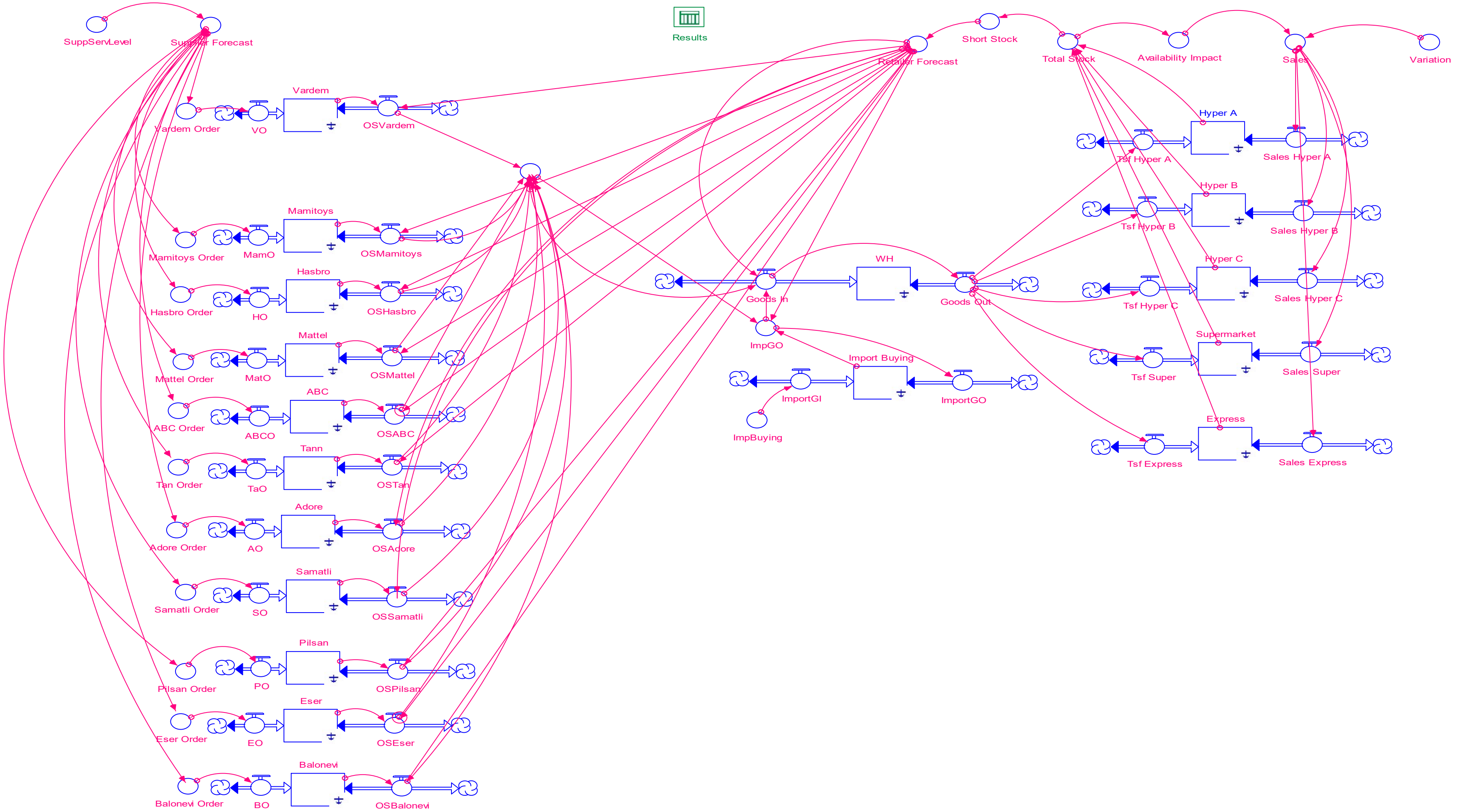
```
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Supplier_Forecast = SuppServLevel * (
IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
```

```
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0)
SuppServLevel = IF TIME=0 THEN 0.94 ELSE
IF TIME=1 THEN 0.93 ELSE
IF TIME=2 THEN 0.38 ELSE
IF TIME=3 THEN 0.97 ELSE
IF TIME=4 THEN 0.95 ELSE
IF TIME=5 THEN 0.89 ELSE
IF TIME=6 THEN 0.38 ELSE
IF TIME=7 THEN 0.48 ELSE
IF TIME=8 THEN 0.67 ELSE
IF TIME=9 THEN 0.35 ELSE
IF TIME=10 THEN 1 ELSE
IF TIME=11 THEN 1 ELSE
IF TIME=12 THEN 0.78 ELSE
IF TIME=13 THEN 1 ELSE
IF TIME=14 THEN 0.49 ELSE
IF TIME=15 THEN 0.33 ELSE
IF TIME=16 THEN 0.89 ELSE
IF TIME=17 THEN 0.56 ELSE
IF TIME=18 THEN 0.96 ELSE
IF TIME=19 THEN 1 ELSE
IF TIME=20 THEN 0.78 ELSE
IF TIME=21 THEN 0.91 ELSE
IF TIME=22 THEN 0.31 ELSE
IF TIME=23 THEN 0.77 ELSE
IF TIME=24 THEN 0.65 ELSE
IF TIME=25 THEN 0.52 ELSE
IF TIME=26 THEN 0.91 ELSE
IF TIME=27 THEN 0.52 ELSE
IF TIME=28 THEN 1 ELSE
IF TIME=29 THEN 0.78 ELSE
IF TIME=30 THEN 0.88 ELSE
IF TIME=31 THEN 0.45 ELSE
IF TIME=32 THEN 0.86 ELSE
IF TIME=33 THEN 0.33 ELSE
IF TIME=34 THEN 0.62 ELSE
IF TIME=35 THEN 0.72 ELSE
IF TIME=36 THEN 1 ELSE
IF TIME=37 THEN 0.71 ELSE
IF TIME=38 THEN 0.33 ELSE
IF TIME=39 THEN 0.85 ELSE
IF TIME=40 THEN 1 ELSE
IF TIME=41 THEN 0.8 ELSE
IF TIME=42 THEN 1 ELSE
IF TIME=43 THEN 0.31 ELSE
IF TIME=44 THEN 0.86 ELSE
IF TIME=45 THEN 1 ELSE
```

```
IF TIME=46 THEN 0.43 ELSE
IF TIME=47 THEN 0.34 ELSE
IF TIME=48 THEN 1 ELSE
IF TIME=49 THEN 1 ELSE
IF TIME=50 THEN 1 ELSE
IF TIME=51 THEN 0.32 ELSE
IF TIME=52 THEN 0.5 ELSE
IF TIME=53 THEN 0.91 ELSE
0
Tan_Order = Supplier_Forecast*0.014
Tesco_Order = Supplier_Forecast*0.260
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
Vardem_Order = Supplier_Forecast*0.285
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
```

```
IF TIME=44 THEN -1.85 ELSE
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE
0
```

APPENDIX 30 : STELLA Model for “Scenario 4 - Private Label”



APPENDIX 31 : STELLA Model Equations for “Scenario 4 - Private Label”

```
ABC(t) = ABC(t - dt) + (ABCO - OSABC) * dt
INIT ABC = 0
INFLOWS:
ABCO = ABC_Order
OUTFLOWS:
OSABC = IF MOD(TIME,4)=0 THEN ABC ELSE
IF ABC<Retailer_Forecast*0.025 THEN ABC ELSE Retailer_Forecast*0.025
Adore(t) = Adore(t - dt) + (AO - OSAdore) * dt
INIT Adore = 0
INFLOWS:
AO = Adore_Order
OUTFLOWS:
OSAdore = IF MOD(TIME,4)=0 THEN Adore ELSE
IF Adore<Retailer_Forecast*0.017 THEN Adore ELSE Retailer_Forecast*0.017
Balonevi(t) = Balonevi(t - dt) + (BO - OSBalonevi) * dt
INIT Balonevi = 0
INFLOWS:
BO = Balonevi_Order
OUTFLOWS:
OSBalonevi = IF MOD(TIME,4)=0 THEN Balonevi ELSE
IF Balonevi<Retailer_Forecast*0.009 THEN Balonevi ELSE
Retailer_Forecast*0.009
Eser(t) = Eser(t - dt) + (EO - OSEser) * dt
INIT Eser = 0
INFLOWS:
EO = Eser_Order
OUTFLOWS:
OSEser = IF MOD(TIME,4)=0 THEN Eser ELSE
IF Eser<Retailer_Forecast*0.010 THEN Eser ELSE Retailer_Forecast*0.010
Express(t) = Express(t - dt) + (Tsf_Express - Sales_Express) * dt
INIT Express = 41354
INFLOWS:
Tsf_Express = Goods_Out*0.007
OUTFLOWS:
Sales_Express = Sales*0.007
Hasbro(t) = Hasbro(t - dt) + (HO - OSHasbro) * dt
INIT Hasbro = 0
INFLOWS:
HO = Hasbro_Order
OUTFLOWS:
OSHasbro = IF MOD(TIME,4)=0 THEN Hasbro ELSE
IF Hasbro<Retailer_Forecast*0.129 THEN Hasbro ELSE Retailer_Forecast*0.129
Hyper_A(t) = Hyper_A(t - dt) + (Tsf_Hyper_A - Sales_Hyper_A) * dt
INIT Hyper_A = 1880840
INFLOWS:
Tsf_Hyper_A = Goods_Out*0.355
OUTFLOWS:
Sales_Hyper_A = Sales*0.355
Hyper_B(t) = Hyper_B(t - dt) + (Tsf_Hyper_B - Sales_Hyper_B) * dt
INIT Hyper_B = 1547159
INFLOWS:
Tsf_Hyper_B = Goods_Out*0.295
OUTFLOWS:
Sales_Hyper_B = Sales*0.295
Hyper_C(t) = Hyper_C(t - dt) + (Tsf_Hyper_C - Sales_Hyper_C) * dt
```

```
INIT Hyper_C = 1304741
INFLOWS:
Tsf_Hyper_C = Goods_Out*0.296
OUTFLOWS:
Sales_Hyper_C = Sales*0.296
Import_Buying(t) = Import_Buying(t - dt) + (ImportGI - ImportGO) * dt
INIT Import_Buying = 0
INFLOWS:
ImportGI = ImpBuying
OUTFLOWS:
ImportGO = ImpGO
Mamitoys(t) = Mamitoys(t - dt) + (MamO - OSMamitoys) * dt
INIT Mamitoys = 0
INFLOWS:
MamO = Mamitoys_Order
OUTFLOWS:
OSMamitoys = IF MOD(TIME,4)=0 THEN Mamitoys ELSE
IF Mamitoys<Retailer_Forecast*0.120 THEN Mamitoys ELSE
Retailer_Forecast*0.120
Mattel(t) = Mattel(t - dt) + (MatO - OSMattel) * dt
INIT Mattel = 0
INFLOWS:
MatO = Mattel_Order
OUTFLOWS:
OSMattel = IF MOD(TIME,4)=0 THEN Mattel ELSE
IF Mattel<Retailer_Forecast*0.103 THEN Mattel ELSE Retailer_Forecast*0.103
Pilsan(t) = Pilsan(t - dt) + (PO - OSPilsan) * dt
INIT Pilsan = 0
INFLOWS:
PO = Pilsan_Order
OUTFLOWS:
OSPilsan = IF MOD(TIME,4)=0 THEN Pilsan ELSE
IF Pilsan<Retailer_Forecast*0.012 THEN Pilsan ELSE Retailer_Forecast*0.012
Samatli(t) = Samatli(t - dt) + (SO - OSSamatli) * dt
INIT Samatli = 0
INFLOWS:
SO = Samatli_Order
OUTFLOWS:
OSSamatli = IF MOD(TIME,4)=0 THEN Samatli ELSE
IF Samatli<Retailer_Forecast*0.016 THEN Samatli ELSE Retailer_Forecast*0.016
Supermarket(t) = Supermarket(t - dt) + (Tsf_Super - Sales_Super) * dt
INIT Supermarket = 236739
INFLOWS:
Tsf_Super = Goods_Out*0.047
OUTFLOWS:
Sales_Super = Sales*0.047
Tann(t) = Tann(t - dt) + (TaO - OSTan) * dt
INIT Tann = 0
INFLOWS:
TaO = Tan_Order
OUTFLOWS:
OSTan = IF MOD(TIME,4)=0 THEN Tann ELSE
IF Tann<Retailer_Forecast*0.014 THEN Tann ELSE Retailer_Forecast*0.014
Vardem(t) = Vardem(t - dt) + (VO - OSVardem) * dt
INIT Vardem = 0
INFLOWS:
VO = Vardem_Order
```

```
OUTFLOWS:
OSVardem = IF MOD(TIME,4)=0 THEN Vardem ELSE
IF Vardem<Retailer_Forecast*0.285 THEN Vardem ELSE Retailer_Forecast*0.285
WH(t) = WH(t - dt) + (Goods_In - Goods_Out) * dt
INIT WH = 0
INFLOWS:
Goods_In = IF GI+ImpGO<Retailer_Forecast THEN GI+ImpGO ELSE
Retailer_Forecast
OUTFLOWS:
Goods_Out = Goods_In
ABC_Order = Supplier_Forecast*0.025
Adore_Order = Supplier_Forecast*0.017
Availability_Impact = if 5000000-Total_Stock<0 then 1 else
Total_Stock/5000000
Balonevi_Order = Supplier_Forecast*0.009
Eser_Order = Supplier_Forecast*0.010
GI =
OSVardem+OSMamitoys+OSHasbro+OSMattel+OSABC+OSTan+OSAdore+OSSamatli+OSPilsan
+OSEser+OSBalonevi
Hasbro_Order = Supplier_Forecast*0.129
ImpBuying = IF TIME=0 THEN 1702820 ELSE
IF TIME=25 THEN 2013262 ELSE 0
ImpGO = IF GI<Retailer_Forecast THEN MIN(Retailer_Forecast-GI,Import_Buying)
ELSE 0
Mamitoys_Order = Supplier_Forecast*0.120
Mattel_Order = Supplier_Forecast*0.103
Pilsan_Order = Supplier_Forecast*0.012
Retailer_Forecast = MAX(0, Short_Stock + (
IF TIME=1 THEN 393024 ELSE
IF TIME=3 THEN 340023 ELSE
IF TIME=5 THEN 304092 ELSE
IF TIME=7 THEN 419785 ELSE
IF TIME=9 THEN 430727 ELSE
IF TIME=11 THEN 300926 ELSE
IF TIME=13 THEN 328028 ELSE
IF TIME=15 THEN 653993 ELSE
IF TIME=17 THEN 648563 ELSE
IF TIME=19 THEN 619029 ELSE
IF TIME=21 THEN 579069 ELSE
IF TIME=23 THEN 1029365 ELSE
IF TIME=25 THEN 502685 ELSE
IF TIME=27 THEN 435555 ELSE
IF TIME=29 THEN 401373 ELSE
IF TIME=31 THEN 376967 ELSE
IF TIME=33 THEN 897656 ELSE
IF TIME=35 THEN 410747 ELSE
IF TIME=37 THEN 437498 ELSE
IF TIME=39 THEN 459058 ELSE
IF TIME=41 THEN 719138 ELSE
IF TIME=43 THEN 1193906 ELSE
IF TIME=45 THEN 682411 ELSE
IF TIME=47 THEN 678334 ELSE
IF TIME=49 THEN 584111 ELSE
IF TIME=51 THEN 466563 ELSE 0))
Sales = Availability_Impact*(
IF TIME=1 THEN 204709+49000*Variation ELSE
IF TIME=2 THEN 188314+49000*Variation ELSE
```

```
IF TIME=3 THEN 183856+49000*Variation ELSE
IF TIME=4 THEN 156167+49000*Variation ELSE
IF TIME=5 THEN 150128+49000*Variation ELSE
IF TIME=6 THEN 153963+49000*Variation ELSE
IF TIME=7 THEN 159199+49000*Variation ELSE
IF TIME=8 THEN 260586+49000*Variation ELSE
IF TIME=9 THEN 244435+49000*Variation ELSE
IF TIME=10 THEN 186292+49000*Variation ELSE
IF TIME=11 THEN 149969+49000*Variation ELSE
IF TIME=12 THEN 150957+49000*Variation ELSE
IF TIME=13 THEN 151898+49000*Variation ELSE
IF TIME=14 THEN 176130+49000*Variation ELSE
IF TIME=15 THEN 275140+49000*Variation ELSE
IF TIME=16 THEN 378852+49000*Variation ELSE
IF TIME=17 THEN 337475+49000*Variation ELSE
IF TIME=18 THEN 311089+49000*Variation ELSE
IF TIME=19 THEN 310335+49000*Variation ELSE
IF TIME=20 THEN 308693+49000*Variation ELSE
IF TIME=21 THEN 291128+49000*Variation ELSE
IF TIME=22 THEN 287941+49000*Variation ELSE
IF TIME=23 THEN 604299+49000*Variation ELSE
IF TIME=24 THEN 425066+49000*Variation ELSE
IF TIME=25 THEN 262989+49000*Variation ELSE
IF TIME=26 THEN 239696+49000*Variation ELSE
IF TIME=27 THEN 234193+49000*Variation ELSE
IF TIME=28 THEN 201362+49000*Variation ELSE
IF TIME=29 THEN 210812+49000*Variation ELSE
IF TIME=30 THEN 190561+49000*Variation ELSE
IF TIME=31 THEN 169134+49000*Variation ELSE
IF TIME=32 THEN 207833+49000*Variation ELSE
IF TIME=33 THEN 624892+49000*Variation ELSE
IF TIME=34 THEN 272764+49000*Variation ELSE
IF TIME=35 THEN 191015+49000*Variation ELSE
IF TIME=36 THEN 219731+49000*Variation ELSE
IF TIME=37 THEN 205921+49000*Variation ELSE
IF TIME=38 THEN 231578+49000*Variation ELSE
IF TIME=39 THEN 213185+49000*Variation ELSE
IF TIME=40 THEN 245873+49000*Variation ELSE
IF TIME=41 THEN 291455+49000*Variation ELSE
IF TIME=42 THEN 427683+49000*Variation ELSE
IF TIME=43 THEN 499341+49000*Variation ELSE
IF TIME=44 THEN 694565+49000*Variation ELSE
IF TIME=45 THEN 457046+49000*Variation ELSE
IF TIME=46 THEN 225365+49000*Variation ELSE
IF TIME=47 THEN 299395+49000*Variation ELSE
IF TIME=48 THEN 378939+49000*Variation ELSE
IF TIME=49 THEN 317768+49000*Variation ELSE
IF TIME=50 THEN 266343+49000*Variation ELSE
IF TIME=51 THEN 254464+49000*Variation ELSE
IF TIME=52 THEN 212099+49000*Variation ELSE
0)
Samatli_Order = Supplier_Forecast*0.016
Short_Stock = IF Total_Stock<5000000 THEN 5000000-Total_Stock ELSE 5000000-
Total_Stock
Supplier_Forecast = SuppServLevel * (
IF TIME=0 THEN 977157 ELSE
IF TIME=4 THEN 888599 ELSE
```

```
IF TIME=8 THEN 895520 ELSE
IF TIME=12 THEN 1182494 ELSE
IF TIME=16 THEN 1294299 ELSE
IF TIME=20 THEN 1655382 ELSE
IF TIME=24 THEN 1120190 ELSE
IF TIME=28 THEN 1231844 ELSE
IF TIME=32 THEN 1228569 ELSE
IF TIME=36 THEN 1071480 ELSE
IF TIME=40 THEN 2178965 ELSE
IF TIME=44 THEN 1860036 ELSE
IF TIME=48 THEN 1062828 ELSE 0)
SuppServLevel = IF TIME=0 THEN 0.94 ELSE
IF TIME=1 THEN 0.93 ELSE
IF TIME=2 THEN 0.38 ELSE
IF TIME=3 THEN 0.97 ELSE
IF TIME=4 THEN 0.95 ELSE
IF TIME=5 THEN 0.89 ELSE
IF TIME=6 THEN 0.38 ELSE
IF TIME=7 THEN 0.48 ELSE
IF TIME=8 THEN 0.67 ELSE
IF TIME=9 THEN 0.35 ELSE
IF TIME=10 THEN 1 ELSE
IF TIME=11 THEN 1 ELSE
IF TIME=12 THEN 0.78 ELSE
IF TIME=13 THEN 1 ELSE
IF TIME=14 THEN 0.49 ELSE
IF TIME=15 THEN 0.33 ELSE
IF TIME=16 THEN 0.89 ELSE
IF TIME=17 THEN 0.56 ELSE
IF TIME=18 THEN 0.96 ELSE
IF TIME=19 THEN 1 ELSE
IF TIME=20 THEN 0.78 ELSE
IF TIME=21 THEN 0.91 ELSE
IF TIME=22 THEN 0.31 ELSE
IF TIME=23 THEN 0.77 ELSE
IF TIME=24 THEN 0.65 ELSE
IF TIME=25 THEN 0.52 ELSE
IF TIME=26 THEN 0.91 ELSE
IF TIME=27 THEN 0.52 ELSE
IF TIME=28 THEN 1 ELSE
IF TIME=29 THEN 0.78 ELSE
IF TIME=30 THEN 0.88 ELSE
IF TIME=31 THEN 0.45 ELSE
IF TIME=32 THEN 0.86 ELSE
IF TIME=33 THEN 0.33 ELSE
IF TIME=34 THEN 0.62 ELSE
IF TIME=35 THEN 0.72 ELSE
IF TIME=36 THEN 1 ELSE
IF TIME=37 THEN 0.71 ELSE
IF TIME=38 THEN 0.33 ELSE
IF TIME=39 THEN 0.85 ELSE
IF TIME=40 THEN 1 ELSE
IF TIME=41 THEN 0.8 ELSE
IF TIME=42 THEN 1 ELSE
IF TIME=43 THEN 0.31 ELSE
IF TIME=44 THEN 0.86 ELSE
IF TIME=45 THEN 1 ELSE
```

```
IF TIME=46 THEN 0.43 ELSE
IF TIME=47 THEN 0.34 ELSE
IF TIME=48 THEN 1 ELSE
IF TIME=49 THEN 1 ELSE
IF TIME=50 THEN 1 ELSE
IF TIME=51 THEN 0.32 ELSE
IF TIME=52 THEN 0.5 ELSE
IF TIME=53 THEN 0.91 ELSE
0
Tan_Order = Supplier_Forecast*0.014
Total_Stock = Hyper_A+Hyper_B+Hyper_C+Supermarket+Express
Vardem_Order = Supplier_Forecast*0.285
Variation = IF TIME=0 THEN -0.49 ELSE
IF TIME=1 THEN -0.56 ELSE
IF TIME=2 THEN -1.99 ELSE
IF TIME=3 THEN -0.76 ELSE
IF TIME=4 THEN 0.37 ELSE
IF TIME=5 THEN -1.52 ELSE
IF TIME=6 THEN 1.22 ELSE
IF TIME=7 THEN -2 ELSE
IF TIME=8 THEN -0.84 ELSE
IF TIME=9 THEN -0.06 ELSE
IF TIME=10 THEN 1.17 ELSE
IF TIME=11 THEN 1.54 ELSE
IF TIME=12 THEN -0.07 ELSE
IF TIME=13 THEN -1.21 ELSE
IF TIME=14 THEN -0.35 ELSE
IF TIME=15 THEN -0.58 ELSE
IF TIME=16 THEN -0.03 ELSE
IF TIME=17 THEN 0.11 ELSE
IF TIME=18 THEN 1.46 ELSE
IF TIME=19 THEN -0.8 ELSE
IF TIME=20 THEN 1.76 ELSE
IF TIME=21 THEN 0.81 ELSE
IF TIME=22 THEN 1.51 ELSE
IF TIME=23 THEN 0.03 ELSE
IF TIME=24 THEN 0.23 ELSE
IF TIME=25 THEN 1.03 ELSE
IF TIME=26 THEN -0.86 ELSE
IF TIME=27 THEN -0.95 ELSE
IF TIME=28 THEN -0.54 ELSE
IF TIME=29 THEN -0.24 ELSE
IF TIME=30 THEN -1.83 ELSE
IF TIME=31 THEN 0.51 ELSE
IF TIME=32 THEN -0.83 ELSE
IF TIME=33 THEN -0.58 ELSE
IF TIME=34 THEN -0.82 ELSE
IF TIME=35 THEN 1 ELSE
IF TIME=36 THEN -0.94 ELSE
IF TIME=37 THEN -0.25 ELSE
IF TIME=38 THEN 0.89 ELSE
IF TIME=39 THEN 0.84 ELSE
IF TIME=40 THEN -0.68 ELSE
IF TIME=41 THEN 0.5 ELSE
IF TIME=42 THEN 0.4 ELSE
IF TIME=43 THEN -0.46 ELSE
IF TIME=44 THEN -1.85 ELSE
```

```
IF TIME=45 THEN -1.44 ELSE
IF TIME=46 THEN 0.46 ELSE
IF TIME=47 THEN -0.22 ELSE
IF TIME=48 THEN -0.52 ELSE
IF TIME=49 THEN -0.29 ELSE
IF TIME=50 THEN 2.18 ELSE
IF TIME=51 THEN -0.85 ELSE
IF TIME=52 THEN -0.73 ELSE
IF TIME=53 THEN -1.4 ELSE
0
```

APPENDIX 32 : Network Matrix for “Scenario 4 – Original Model”

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	4,328,314	233,063	199,768	1,997,684	1,714,678	2,147,510	4,744,498	0	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	15,218	219,304	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	23,778	342,662	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	9,511	137,065	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	16,169	233,010	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	8,560	123,358	0	0	0	0	0	0	0	**131,918**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	247,292	3,563,685	0	0	0	0	0	0	0	**3,810,977**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	13,316	191,891	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	11,413	164,478	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	114,135	1,644,778	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	97,966	1,411,768	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	122,695	1,768,136	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	271,070	3,906,347	0	0	0	0	0	0	0	**4,177,418**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18,031,896	0	0	0	0	0	0	**18,031,896**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,865,801	4,043,412	4,057,118	644,205	95,945	0	**13,706,481**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,856,453	**4,856,453**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,035,644	**4,035,644**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,049,324	**4,049,324**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	642,967	**642,967**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	95,761	**95,761**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**4,328,314**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**4,744,498**	**951,124**	**13,706,481**	**18,031,896**	**4,865,801**	**4,043,412**	**4,057,118**	**644,205**	**95,945**	**13,680,148**	

APPENDIX 33 : Network Matrix for "Scenario 4 – Supplier Number Reduction"

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	233,063	199,768	1,997,684	1,714,678	2,147,510	9,072,813	0	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	15,218	219,304	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	23,778	342,662	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	9,511	137,065	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	16,169	233,010	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	8,560	123,358	0	0	0	0	0	0	0	**131,918**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	13,316	191,891	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	11,413	164,478	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	114,135	1,644,778	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	97,966	1,411,768	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	122,695	1,768,136	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	518,363	7,470,032	0	0	0	0	0	0	0	**7,988,395**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18,031,896	0	0	0	0	0	0	**18,031,896**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,865,801	4,043,412	4,057,118	644,205	95,945	0	**13,706,481**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,856,453	**4,856,453**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,035,644	**4,035,644**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,049,324	**4,049,324**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	642,967	**642,967**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	95,761	**95,761**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**9,072,813**	**951,124**	**13,706,481**	**18,031,896**	**4,865,801**	**4,043,412**	**4,057,118**	**644,205**	**95,945**	**13,680,148**	

APPENDIX 34 : Network Matrix for "Scenario 4 : Supplier Number Reduction Improving Performance"

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	233,063	199,768	1,997,684	1,714,678	2,147,510	9,072,813	0	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	23,115	211,407	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	36,117	330,323	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	14,447	132,129	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	24,559	224,620	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	13,002	118,916	0	0	0	0	0	0	0	**131,918**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	20,225	184,981	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	17,336	158,555	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	173,361	1,585,552	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	148,801	1,360,932	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	186,363	1,704,468	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	1,225,654	7,847,159	0	0	0	0	0	0	0	**9,072,813**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,082,947	0	0	0	0	0	0	**15,082,947**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,919,960	4,088,418	4,102,277	651,375	97,013	0	**13,859,043**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,910,612	**4,910,612**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,080,649	**4,080,649**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,094,482	**4,094,482**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	650,137	**650,137**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96,829	**96,829**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**9,072,813**	**1,882,981**	**13,859,043**	**15,082,947**	**4,919,960**	**4,088,418**	**4,102,277**	**651,375**	**97,013**	**13,832,710**	

APPENDIX 35 : Network Matrix for "Scenario 4 - Using a Dummy Supplier"

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tesco	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Other Supplier	Dummy Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	4,328,314	233,063	199,768	1,997,684	1,714,678	2,147,510	4,744,498	0	0	0	0	0	0	0	0	0	0	**16,647,363**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	29,833	0	204,688	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	46,615	0	319,825	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	18,646	0	127,930	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	31,698	0	217,481	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	16,781	0	115,137	0	0	0	0	0	0	0	**131,918**
Supplier: Tesco	0	0	0	0	0	0	0	0	0	0	0	0	0	484,794	0	3,326,184	0	0	0	0	0	0	0	**3,810,977**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	26,104	0	179,102	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	22,375	0	153,516	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	223,751	0	1,535,162	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	192,053	0	1,317,680	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	240,532	0	1,650,299	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	531,409	0	3,646,009	0	0	0	0	0	0	0	**4,177,417**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Dummy Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,161,569	0	0	0	0	0	0	0	**1,161,569**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,161,569	0	13,954,583	0	0	0	0	0	0	**15,116,153**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,953,877	4,116,602	4,130,557	655,865	97,682	0	**13,954,583**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,928,839	**4,928,839**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,095,796	**4,095,796**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,109,680	**4,109,680**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	652,551	**652,551**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	97,188	**97,188**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**4,328,314**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**4,744,498**	**1,864,591**	**1,161,569**	**13,954,583**	**13,954,583**	**4,953,877**	**4,116,602**	**4,130,557**	**655,865**	**97,682**	**13,884,054**	

APPENDIX 36 : Network Matrix for “Scenario 4 - Private Label”

	Supplier Forecasting	Supplier: Samatli	Supplier: ABC	Supplier: Eser	Supplier: Adore	Supplier: Balonevi	Supplier: Tan	Supplier: Pilsan	Supplier: Mamitoys	Supplier: Mattel	Supplier: Hasbro	Supplier: Vardem	Import Warehouse	Other Supplier	Retailer Forecasting	Warehouse	Hyper A	Hyper B	Hyper C	Supermarket	Express	Customers	SUM
Supplier Forecasting	0	266,358	416,184	166,474	283,005	149,826	233,063	199,768	1,997,684	1,714,678	2,147,510	4,744,498	3,716,082	0	0	0	0	0	0	0	0	0	**16,035,131**
Supplier: Samatli	0	0	0	0	0	0	0	0	0	0	0	0	0	25,413	209,109	0	0	0	0	0	0	0	**234,522**
Supplier: ABC	0	0	0	0	0	0	0	0	0	0	0	0	0	39,708	326,732	0	0	0	0	0	0	0	**366,440**
Supplier: Eser	0	0	0	0	0	0	0	0	0	0	0	0	0	15,883	130,693	0	0	0	0	0	0	0	**146,576**
Supplier: Adore	0	0	0	0	0	0	0	0	0	0	0	0	0	27,001	222,178	0	0	0	0	0	0	0	**249,179**
Supplier: Balonevi	0	0	0	0	0	0	0	0	0	0	0	0	0	14,295	117,624	0	0	0	0	0	0	0	**131,918**
Supplier: Tan	0	0	0	0	0	0	0	0	0	0	0	0	0	22,236	182,970	0	0	0	0	0	0	0	**205,206**
Supplier: Pilsan	0	0	0	0	0	0	0	0	0	0	0	0	0	19,060	156,831	0	0	0	0	0	0	0	**175,891**
Supplier: Mamitoys	0	0	0	0	0	0	0	0	0	0	0	0	0	190,597	1,568,315	0	0	0	0	0	0	0	**1,758,913**
Supplier: Mattel	0	0	0	0	0	0	0	0	0	0	0	0	0	163,596	1,346,137	0	0	0	0	0	0	0	**1,509,733**
Supplier: Hasbro	0	0	0	0	0	0	0	0	0	0	0	0	0	204,892	1,685,939	0	0	0	0	0	0	0	**1,890,831**
Supplier: Vardem	0	0	0	0	0	0	0	0	0	0	0	0	0	452,669	3,724,749	0	0	0	0	0	0	0	**4,177,417**
Import Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3,716,082	0	0	0	0	0	0	0	**3,716,082**
Other Supplier	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Retailer Forecasting	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,587,501	0	0	0	0	0	0	**15,587,501**
Warehouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,752,512	3,949,271	3,962,658	629,206	93,712	0	**13,387,359**
Hyper A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,903,535	**4,903,535**
Hyper B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,074,768	**4,074,768**
Hyper C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,088,581	**4,088,581**
Supermarket	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	649,200	**649,200**
Express	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96,689	**96,689**
Customers	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
SUM	**0**	**266,358**	**416,184**	**166,474**	**283,005**	**149,826**	**233,063**	**199,768**	**1,997,684**	**1,714,678**	**2,147,510**	**4,744,498**	**3,716,082**	**1,175,351**	**13,387,359**	**15,587,501**	**4,752,512**	**3,949,271**	**3,962,658**	**629,206**	**93,712**	**13,812,774**	

APPENDIX 37 : STELLA Output of "Scenario 4 - Original Model"

AVERAGE					- 91,424		4,908,576	
TOTAL	**16,647,363**	**14,657,605**	**18,031,896**	**13,706,481**		**13,680,148**		**951,124**
Time	**Supplier Forecast**	**Actual Supplier Stock Receiving**	**Retailer Forecast**	**WH Goods In**	**Over/Short Stock**	**Sales**	**Total Stock**	**Stock Shared with Other Retailers**
0	977,157	918,528	-	-	10,833	-	5,010,833	-
1	-	-	382,191	382,191	10,833	177,269	5,010,833	-
2	-	-	-	-	215,755	90,804	5,215,755	-
3	-	-	215,072	215,072	124,951	146,616	5,124,951	-
4	888,599	844,169	-	-	193,407	174,297	5,193,407	321,265
5	-	-	284,982	284,982	19,110	75,648	5,019,110	-
6	-	-	-	-	228,444	213,743	5,228,444	-
7	-	-	405,084	405,084	14,701	61,199	5,014,701	-
8	895,520	599,998	-	-	358,586	219,426	5,358,586	154,103
9	-	-	291,567	291,567	139,160	241,495	5,139,160	-
10	-	-	-	-	189,232	243,622	5,189,232	-
11	-	-	355,316	308,431	- 54,390	222,977	4,945,610	-
12	1,182,494	922,345	-	-	31,065	147,527	5,031,065	-
13	-	-	444,490	444,490	- 116,462	90,451	4,883,538	-
14	-	-	-	-	237,577	158,980	5,237,577	-
15	-	-	575,396	477,855	78,597	246,720	5,078,597	-
16	1,294,299	1,151,926	-	-	309,732	377,382	5,309,732	-
17	-	-	716,213	716,213	- 67,650	338,226	4,932,350	-
18	-	-	-	-	310,337	382,629	5,310,337	-
19	-	-	691,321	435,713	- 72,292	267,215	4,927,708	-
20	1,655,382	1,291,198	-	-	96,206	394,933	5,096,206	-
21	-	-	877,796	877,796	- 298,727	311,053	4,701,273	-
22	-	-	-	-	268,016	361,931	5,268,016	-
23	-	-	1,123,280	413,402	- 93,915	594,391	4,906,085	-
24	1,120,190	728,124	274,904	-	- 274,904	412,346	4,725,096	-
25	-	-	1,189,935	728,124	- 687,250	270,374	4,312,750	-
26	-	-	229,500	-	- 229,500	188,488	4,770,500	-
27	-	-	853,543	-	- 417,988	171,956	4,582,012	-
28	1,231,844	1,231,844	589,945	-	- 589,945	154,265	4,410,055	-
29	-	-	1,145,583	1,145,583	- 744,210	169,425	4,255,790	-
30	-	-	-	-	231,948	100,891	5,231,948	-
31	-	-	245,910	86,261	131,057	194,124	5,131,057	-
32	1,228,569	1,056,569	-	-	23,194	167,163	5,023,194	-
33	-	-	1,041,625	1,041,625	- 143,969	579,297	4,856,031	-
34	-	-	-	-	318,359	232,584	5,318,359	-
35	-	-	324,972	14,944	85,775	240,015	5,085,775	-
36	1,071,480	1,071,480	139,296	-	- 139,296	168,833	4,860,704	-
37	-	-	745,627	745,627	- 308,129	181,736	4,691,871	-
38	-	-	-	-	255,762	275,188	5,255,762	-
39	-	-	478,484	325,853	- 19,426	253,357	4,980,574	-
40	2,178,965	2,178,965	-	-	53,071	212,553	5,053,071	-
41	-	-	878,620	878,620	- 159,482	305,877	4,840,518	-
42	-	-	-	-	413,261	447,283	5,413,261	-
43	-	-	1,227,928	1,227,928	- 34,022	473,557	4,965,978	-
44	1,860,036	1,599,631	-	-	720,349	603,915	5,720,349	72,416
45	-	-	565,977	565,977	116,434	386,486	5,116,434	-
46	-	-	-	-	295,925	247,905	5,295,925	-
47	-	-	630,314	630,314	48,020	288,615	5,048,020	-
48	1,062,828	1,062,828	-	-	389,719	353,459	5,389,719	403,340
49	-	-	547,851	547,851	36,260	303,558	5,036,260	-
50	-	-	-	-	280,553	373,163	5,280,553	-
51	-	-	559,173	514,977	- 92,610	208,872	4,907,390	-
52	-	-	-	-	213,495	176,329	5,213,495	-
Final	-	-	-		37,166	-	5,037,166	-

APPENDIX 38 : STELLA Output of “Scenario 4 - Supplier Number Reduction”

AVERAGE					-91,424		4,908,576	
TOTAL	16,647,363	14,657,605	18,031,896	13,706,481		13,680,148		951,124
Time	Supplier Forecast	Actual Supplier Stock Receiving	Retailer Forecast	WH Goods In	Over/Short Stock	Sales	Total Stock	Stock Shared with Other Retailers
0	977,157	918,528	-	-	10,833	-	5,010,833	-
1	-	-	382,191	382,191	10,833	177,269	5,010,833	-
2	-	-	-	-	215,755	90,804	5,215,755	-
3	-	-	215,072	215,072	124,951	146,616	5,124,951	-
4	888,599	844,169	-	-	193,407	174,297	5,193,407	321,265
5	-	-	284,982	284,982	19,110	75,648	5,019,110	-
6	-	-	-	-	228,444	213,743	5,228,444	-
7	-	-	405,084	405,084	14,701	61,199	5,014,701	-
8	895,520	599,998	-	-	358,586	219,426	5,358,586	154,103
9	-	-	291,567	291,567	139,160	241,495	5,139,160	-
10	-	-	-	-	189,232	243,622	5,189,232	-
11	-	-	355,316	308,431	-54,390	222,977	4,945,610	-
12	1,182,494	922,345	-	-	31,065	147,527	5,031,065	-
13	-	-	444,490	444,490	-116,462	90,451	4,883,538	-
14	-	-	-	-	237,577	158,980	5,237,577	-
15	-	-	575,396	477,855	78,597	246,720	5,078,597	-
16	1,294,299	1,151,926	-	-	309,732	377,382	5,309,732	-
17	-	-	716,213	716,213	-67,650	338,226	4,932,350	-
18	-	-	-	-	310,337	382,629	5,310,337	-
19	-	-	691,321	435,713	-72,292	267,215	4,927,708	-
20	1,655,382	1,291,198	-	-	96,206	394,933	5,096,206	-
21	-	-	877,796	877,796	-298,727	311,053	4,701,273	-
22	-	-	-	-	268,016	361,931	5,268,016	-
23	-	-	1,123,280	413,402	-93,915	594,391	4,906,085	-
24	1,120,190	728,124	274,904	-	-274,904	412,346	4,725,096	-
25	-	-	1,189,935	728,124	-687,250	270,374	4,312,750	-
26	-	-	229,500	-	-229,500	188,488	4,770,500	-
27	-	-	853,543	-	-417,988	171,956	4,582,012	-
28	1,231,844	1,231,844	589,945	-	-589,945	154,265	4,410,055	-
29	-	-	1,145,583	1,145,583	-744,210	169,425	4,255,790	-
30	-	-	-	-	231,948	100,891	5,231,948	-
31	-	-	245,910	86,261	131,057	194,124	5,131,057	-
32	1,228,569	1,056,569	-	-	23,194	167,163	5,023,194	-
33	-	-	1,041,625	1,041,625	-143,969	579,297	4,856,031	-
34	-	-	-	-	318,359	232,584	5,318,359	-
35	-	-	324,972	14,944	85,775	240,015	5,085,775	-
36	1,071,480	1,071,480	139,296	-	-139,296	168,833	4,860,704	-
37	-	-	745,627	745,627	-308,129	181,736	4,691,871	-
38	-	-	-	-	255,762	275,188	5,255,762	-
39	-	-	478,484	325,853	-19,426	253,357	4,980,574	-
40	2,178,965	2,178,965	-	-	53,071	212,553	5,053,071	-
41	-	-	878,620	878,620	-159,482	305,877	4,840,518	-
42	-	-	-	-	413,261	447,283	5,413,261	-
43	-	-	1,227,928	1,227,928	-34,022	473,557	4,965,978	-
44	1,860,036	1,599,631	-	-	720,349	603,915	5,720,349	72,416
45	-	-	565,977	565,977	116,434	386,486	5,116,434	-
46	-	-	-	-	295,925	247,905	5,295,925	-
47	-	-	630,314	630,314	48,020	288,615	5,048,020	-
48	1,062,828	1,062,828	-	-	389,719	353,459	5,389,719	403,340
49	-	-	547,851	547,851	36,260	303,558	5,036,260	-
50	-	-	-	-	280,553	373,163	5,280,553	-
51	-	-	559,173	514,977	-92,610	208,872	4,907,390	-
52	-	-	-	-	213,495	176,329	5,213,495	-
Final	-	-	-		37,166	-	5,037,166	-

APPENDIX 39 : STELLA Output of "Scenario 4 - Supplier Number Reduction Improving Performance"

Time	Supplier Forecast	Actual Supplier Stock Receiving	Retailer Forecast	WH Goods In	Over/Short Stock	Sales	Total Stock	Stock Shared with Other Retailers
AVERAGE					- 23,688		4,976,312	
TOTAL	16,647,363	15,742,023	15,082,947	13,859,043		13,832,710		1,882,981
0	977,157	950,481	-	-	10,833	-	5,010,833	-
1	-	-	382,191	382,191	10,833	177,269	5,010,833	-
2	-	-	-	-	215,755	90,804	5,215,755	-
3	-	-	215,072	215,072	124,951	146,616	5,124,951	-
4	888,599	868,383	-	-	193,407	174,297	5,193,407	353,218
5	-	-	284,982	284,982	19,110	75,648	5,019,110	-
6	-	-	-	-	228,444	213,743	5,228,444	-
7	-	-	405,084	405,084	14,701	61,199	5,014,701	-
8	895,520	761,058	-	-	358,586	219,426	5,358,586	178,317
9	-	-	291,567	291,567	139,160	241,495	5,139,160	-
10	-	-	-	-	189,232	243,622	5,189,232	-
11	-	-	355,316	333,984	- 54,390	222,977	4,945,610	-
12	1,182,494	1,064,126	-	-	56,617	147,527	5,056,617	135,507
13	-	-	418,938	418,938	- 90,910	90,924	4,909,090	-
14	-	-	-	-	237,104	158,980	5,237,104	-
15	-	-	575,869	542,899	78,124	246,720	5,078,124	-
16	1,294,299	1,229,519	-	-	374,303	377,382	5,374,303	102,289
17	-	-	651,642	651,642	- 3,079	342,654	4,996,921	-
18	-	-	-	-	305,909	382,629	5,305,909	-
19	-	-	695,749	577,877	- 76,720	266,975	4,923,280	-
20	1,655,382	1,489,678	-	-	234,183	394,933	5,234,183	-
21	-	-	739,820	739,820	- 160,751	320,182	4,839,250	-
22	-	-	-	-	258,887	361,931	5,258,887	-
23	-	-	1,132,409	749,859	- 103,044	593,285	4,896,956	-
24	1,120,190	941,800	-	-	53,530	436,336	5,053,530	-
25	-	-	885,491	813,889	- 382,806	289,460	4,617,194	-
26	-	-	-	-	141,623	197,556	5,141,623	-
27	-	-	491,489	127,911	- 55,934	185,544	4,944,067	-
28	1,231,844	1,231,844	113,567	-	- 113,567	170,929	4,886,433	-
29	-	-	685,869	685,869	- 284,496	187,726	4,715,504	-
30	-	-	-	-	213,647	100,891	5,213,647	-
31	-	-	264,211	264,211	112,756	194,124	5,112,756	-
32	1,228,569	1,150,309	-	-	182,843	167,163	5,182,843	281,764
33	-	-	881,976	881,976	15,680	596,472	5,015,680	-
34	-	-	-	-	301,184	232,584	5,301,184	-
35	-	-	342,147	265,910	68,600	240,015	5,068,600	-
36	1,071,480	1,071,480	-	-	94,495	173,671	5,094,495	2,423
37	-	-	516,674	516,674	- 79,176	190,604	4,920,824	-
38	-	-	-	-	246,894	275,188	5,246,894	-
39	-	-	487,352	487,352	- 28,294	252,906	4,971,706	-
40	2,178,965	2,178,965	-	-	206,152	212,553	5,206,152	67,454
41	-	-	725,539	725,539	- 6,401	315,551	4,993,599	-
42	-	-	-	-	403,587	447,283	5,403,587	-
43	-	-	1,237,602	1,237,602	- 43,696	472,634	4,956,304	-
44	1,860,036	1,741,552	-	-	721,272	603,915	5,721,272	215,825
45	-	-	565,054	565,054	117,357	386,486	5,117,357	-
46	-	-	-	-	295,925	247,905	5,295,925	-
47	-	-	630,314	630,314	48,020	288,615	5,048,020	-
48	1,062,828	1,062,828	-	-	389,719	353,459	5,389,719	546,184
49	-	-	547,851	547,851	36,260	303,558	5,036,260	-
50	-	-	-	-	280,553	373,163	5,280,553	-
51	-	-	559,173	514,977	- 92,610	208,872	4,907,390	-
52	-	-	-	-	213,495	176,329	5,213,495	-
Final	-	-	-		37,166	-	5,037,166	-

APPENDIX 40 : STELLA Output of "Scenario 4 - Using a Dummy Supplier"

Time	Supplier Forecast	Actual Supplier Stock Receiving	Retailer Forecast	WH Goods In	Over/Short Stock	Sales	Total Stock	Stock Shared with Other Retailers	Goods in from Dummy Supplier
AVERAGE					15,533		5,015,533		
TOTAL	16,647,363	14,657,605	13,954,583	13,954,583		13,884,055		1,864,591	1,161,569
0	977,157	918,528	-	-	10,833	-	5,010,833	-	-
1	-	-	382,191	382,191	10,833	177,269	5,010,833	-	-
2	-	-	-	-	215,755	90,804	5,215,755	-	-
3	-	-	215,072	215,072	124,951	146,616	5,124,951	-	-
4	888,599	844,169	-	-	193,407	174,297	5,193,407	321,265	-
5	-	-	284,982	284,982	19,110	75,648	5,019,110	-	-
6	-	-	-	-	228,444	213,743	5,228,444	-	-
7	-	-	405,084	405,084	14,701	61,199	5,014,701	-	-
8	895,520	599,998	-	-	358,586	219,426	5,358,586	154,103	-
9	-	-	291,567	291,567	139,160	241,495	5,139,160	-	-
10	-	-	-	-	189,232	243,622	5,189,232	-	-
11	-	-	355,316	355,316	-54,390	222,977	4,945,610	-	46,885
12	1,182,494	922,345	-	-	77,949	147,527	5,077,949	-	-
13	-	-	397,606	397,606	-69,578	91,319	4,930,422	-	-
14	-	-	-	-	236,709	158,980	5,236,709	-	-
15	-	-	576,264	576,264	77,729	246,720	5,077,729	-	51,525
16	1,294,299	1,151,926	-	-	407,273	377,382	5,407,273	-	-
17	-	-	618,672	618,672	29,891	342,865	5,029,891	-	-
18	-	-	-	-	305,698	382,629	5,305,698	-	-
19	-	-	695,960	695,960	-76,931	266,963	4,923,069	-	162,706
20	1,655,382	1,291,198	-	-	352,066	394,933	5,352,066	-	-
21	-	-	621,936	621,936	-42,867	327,982	4,957,133	-	-
22	-	-	-	-	251,087	361,931	5,251,087	-	-
23	-	-	1,140,209	1,140,209	-110,844	592,340	4,889,156	-	470,947
24	1,120,190	728,124	-	-	437,025	436,336	5,437,025	-	-
25	-	-	501,996	501,996	689	313,459	5,000,689	-	-
26	-	-	-	-	189,226	197,556	5,189,226	-	-
27	-	-	443,885	443,885	-8,330	187,330	4,991,670	-	217,757
28	1,231,844	1,231,844	-	-	248,225	174,902	5,248,225	-	-
29	-	-	328,050	328,050	73,323	199,052	5,073,323	-	-
30	-	-	-	-	202,321	100,891	5,202,321	-	-
31	-	-	275,537	275,537	101,430	194,124	5,101,430	-	-
32	1,228,569	1,056,569	-	-	182,843	167,163	5,182,843	628,257	-
33	-	-	881,976	881,976	15,680	596,472	5,015,680	-	-
34	-	-	-	-	301,184	232,584	5,301,184	-	-
35	-	-	342,147	342,147	68,600	240,015	5,068,600	-	167,554
36	1,071,480	1,071,480	-	-	170,732	173,671	5,170,732	-	-
37	-	-	440,437	440,437	-2,939	193,557	4,997,061	-	-
38	-	-	-	-	243,941	275,188	5,243,941	-	-
39	-	-	490,305	490,305	-31,247	252,755	4,968,753	-	-
40	2,178,965	2,178,965	-	-	206,303	212,553	5,206,303	140,738	-
41	-	-	725,388	725,388	-6,250	315,560	4,993,750	-	-
42	-	-	-	-	403,578	447,283	5,403,578	-	-
43	-	-	1,237,611	1,237,611	-43,705	472,633	4,956,295	-	-
44	1,860,036	1,599,631	-	-	721,273	603,915	5,721,273	215,966	-
45	-	-	565,053	565,053	117,358	386,486	5,117,358	-	-
46	-	-	-	-	295,925	247,905	5,295,925	-	-
47	-	-	630,314	630,314	48,020	288,615	5,048,020	-	-
48	1,062,828	1,062,828	-	-	389,719	353,459	5,389,719	404,264	-
49	-	-	547,851	547,851	36,260	303,558	5,036,260	-	-
50	-	-	-	-	280,553	373,163	5,280,553	-	-
51	-	-	559,173	559,173	-92,610	208,872	4,907,390	-	44,196
52	-	-	-	-	257,691	176,329	5,257,691	-	-
Final	-	-	-		81,362	-	5,081,362	-	-

APPENDIX 41 : STELLA Output of “Scenario 4 - Private Label”

Time	Supplier Forecast	Actual Supplier Stock Receiving	Retailer Forecast	WH Goods In	Import Stock	Over/Short Stock	Sales	Total Stock	Stock Shared with Other Retailers
AVERAGE						- 48,825		4,951,175	
TOTAL	12,319,049	10,846,628	16,002,083	13,387,359	3,716,082		13,812,774		1,175,351
0	723,096	679,710	-	-	-	10,833	-	5,010,833	-
1	-	-	382,191	382,191	1,702,820	10,833	177,269	5,010,833	-
2	-	-	-	-	1,603,450	215,755	90,804	5,215,755	-
3	-	-	215,072	215,072	1,603,450	124,951	146,616	5,124,951	-
4	657,563	624,685	-	-	1,547,532	193,407	174,297	5,193,407	237,736
5	-	-	284,982	284,982	1,547,532	19,110	75,648	5,019,110	-
6	-	-	-	-	1,473,436	228,444	213,743	5,228,444	-
7	-	-	405,084	405,084	1,473,436	14,701	61,199	5,014,701	-
8	662,685	443,999	-	-	1,368,114	358,586	219,426	5,358,586	114,036
9	-	-	291,567	291,567	1,368,114	139,160	241,495	5,139,160	-
10	-	-	-	-	1,292,307	189,232	243,622	5,189,232	-
11	-	-	355,316	355,316	1,292,307	- 54,390	222,977	4,945,610	-
12	875,046	682,536	-	-	1,165,230	77,949	147,527	5,077,949	-
13	-	-	397,606	397,606	1,165,230	- 69,578	91,319	4,930,422	-
14	-	-	-	-	1,061,853	236,709	158,980	5,236,709	-
15	-	-	576,264	576,264	1,061,853	77,729	246,720	5,077,729	-
16	957,781	852,425	-	-	873,896	407,273	377,382	5,407,273	-
17	-	-	618,672	618,672	873,896	29,891	342,865	5,029,891	-
18	-	-	-	-	713,041	305,698	382,629	5,305,698	-
19	-	-	695,960	695,960	713,041	- 76,931	266,963	4,923,069	-
20	1,224,983	955,487	-	-	411,689	352,066	394,933	5,352,066	-
21	-	-	621,936	621,936	411,689	- 42,867	327,982	4,957,133	-
22	-	-	-	-	249,986	251,087	361,931	5,251,087	-
23	-	-	1,140,209	745,239	249,986	- 110,844	592,340	4,889,156	-
24	828,941	538,811	-	-	-	42,056	436,336	5,042,056	-
25	-	-	896,965	538,811	-	- 394,280	288,741	4,605,720	-
26	-	-	144,210	144,210	2,013,262	- 144,210	191,858	4,855,790	-
27	-	-	627,413	627,413	1,869,052	- 191,858	180,443	4,808,142	-
28	911,565	911,565	-	-	1,241,639	255,112	174,902	5,255,112	-
29	-	-	321,163	321,163	1,241,639	80,210	199,052	5,080,210	-
30	-	-	-	-	1,158,137	202,321	100,891	5,202,321	-
31	-	-	275,537	275,537	1,158,137	101,430	194,124	5,101,430	-
32	909,141	781,861	-	-	1,086,497	182,843	167,163	5,182,843	470,007
33	-	-	881,976	881,976	1,086,497	15,680	596,472	5,015,680	-
34	-	-	-	-	857,183	301,184	232,584	5,301,184	-
35	-	-	342,147	342,147	857,183	68,600	240,015	5,068,600	-
36	792,895	792,895	-	-	644,235	170,732	173,671	5,170,732	-
37	-	-	440,437	440,437	644,235	- 2,939	193,557	4,997,061	-
38	-	-	-	-	529,722	243,941	275,188	5,243,941	-
39	-	-	490,305	490,305	529,722	- 31,247	252,755	4,968,753	-
40	1,612,434	1,612,434	-	-	402,242	206,303	212,553	5,206,303	104,146
41	-	-	725,388	725,388	402,242	- 6,250	315,560	4,993,750	-
42	-	-	-	-	213,641	403,578	447,283	5,403,578	-
43	-	-	1,237,611	1,129,474	213,641	- 43,705	472,633	4,956,295	-
44	1,376,427	1,183,727	-	-	-	613,135	603,915	5,613,135	159,814
45	-	-	673,191	498,161	-	9,220	386,486	5,009,220	-
46	-	-	-	-	-	120,895	247,905	5,120,895	-
47	-	-	805,344	595,954	-	- 127,010	281,284	4,872,990	-
48	786,493	786,493	-	-	-	187,661	353,459	5,187,661	89,612
49	-	-	749,909	554,933	-	- 165,798	293,492	4,834,202	-
50	-	-	-	-	-	95,643	373,163	5,095,643	-
51	-	-	744,083	231,560	-	- 277,520	201,002	4,722,480	-
52	-	-	246,962	-	-	- 246,962	167,620	4,753,038	-
Final	-	-	414,582		-	- 414,582	-	4,585,418	-