RETAIL SHELF SPACE ALLOCATION ANALYSIS USING SYSTEM DYNAMICS APPROACH

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ABSTRACT

Shelf space is a limited and expensive resource as a large number of brands compete for it in a retailing store. These brands compete with each to obtain maximum shelf space to get exposure to the customer. Objective of the retailer is to allocate shelf space to each brand in such a combination that maximizes profit of the retail store. This paper uses data, part collected and part hypothetical, based on interviews and sales record to study the shelf space allocation decision in a retail store using system dynamics approach. The system dynamics model considers the retail store specific parameters and demand pattern of the considered brands to find out the optimal shelf space allocation. The study finds that shelf space allocation decision is sensitive to demand behavior of individual brands as well as the retail store specific demographic characteristics. The system dynamics model aims to provide a pragmatic and manager friendly platform for evaluating various shelf space allocation scenarios. The paper sets down a foundation study towards the application of system dynamics approach in taking shelf space allocation decisions.

Keyword: Retail, Shelf Space Allocation, System Dynamics, Demographic Characteristics, Sensitivity Analysis.

INTRODUCTION

Better shelf space management provides a source of competitive advantage in retail industry. The competition among a large number of brands to get display space at retail store makes the shelf space a constraint. Shelf space is a limited resource in a retailing outlet which in many cases is expensive as well. There is broad appreciation that better shelf space management has positive impact on an outlet's performance (Desmet and Renaudin, 1998).

Organizations develop various ways to optimize shelf space utilization to maximize sales and the outlet's profit. For example, quantitative

optimization models have been developed in order to help managers make optimal shelf space allocation decisions under store specific constraints. Similarly, softer factors such as a brand's strategic importance, demographic suitability, and seasonal demand behavior also play important roles in specifying shelf space to a brand (Amrouche and Zaccour, 2007, Hübner, 2011).

System dynamics modeling provides a more appropriate approach to analyze such dynamic and complex problems (Milling, 1996). This paper conceptualizes shelf space allocation decisions as a dynamic model and uses system dynamics approach to investigate this problem. This paper uses data from a retail outlet in Pakistan to develop and test the model. The next section presents a brief literature review of shelf space allocation problem. Then the paper develops a system dynamics model that conceptualizes and analyzes shelf space allocation decisions. The paper attempts to interpret the model results, does sensitivity analysis, and presents future research directions.

LITERATURE REVIEW

The question of shelf space allocation has attracted research attention from marketing as well as operations research areas. The research presents empirical studies which present and test theoretical relationship of the factors affecting brand space allocation and develops mathematical models for determining optimal brand space for the competing brands. This paper reviews the literature which seeks to present empirical and quantitative models on shelf space allocation decisions. Table 1 presents relevant research on the research question.

Table 1: Summary of Literature on Shelf Space Allocation in Retailing Industry

	Title	Reference	Key Features
Mathematical Model	The Retail Space-Exchange Problem with Pricing and Space Allocation Decisions	(Leng et al., 2013)	Using the hoteling model, finds two retailers' optimal prices, given their host and guest space in two stores under the space-exchange strategy.
	Retail space design considering revenue and adjacencies using a racetrack aisle network	(Yapicioglu and Smith, 2011)	A model and solution approach for the design of the block layout of a single-story department store is presented.
	Shelf-space allocation of national and private brands	(Amrouche and Zaccour, 2007)	Game theoretic model for shelf space allocation.

	Title	Reference	Key Features
	A piecewise linearization for retail shelf space allocation problem and a local search heuristic	(Gajjar and Adil, 2010)	Integrate linear program with integer program to address the retail space shelf allocation problem
	An efficient algorithm to allocate shelf space	(Yang, 2001)	Heuristic for shelf space allocation and evaluation of solution methodology.
	A study on shelf space allocation and management	(Yang and Chen, 1999)	Space allocation model and interpretation of space management strategies using survey data.
	Optimal Competition and Allocation of Space in Shopping Centers	(Miceli et al., 1998)	Analysis of the issues faced by profit-maximizing developer during space allocation of shopping centre.
	A Sensitivity Analysis of Retailer Shelf Management Models	(Borin and Farris, 1995)	Comparison of accuracy of mathematical models and thumb rules used for shelf space allocation.
	A Dynamic Model for Strategically Allocating Retail Space	(Corstjens and Doyle, 1983)	Incorporates changing needs and changing product life cycle in existing static shelf space allocation model.
	A Model for Optimizing Retail Space Allocations	(Corstjens and Doyle, 1981)	Space allocation model which incorporates cross-space elasticity and cost function using a case study.
	A Mathematical Model for Simultaneously Determining the Optimal Brand-Collection and Display-Area Allocation	(Anderson and Amato, 1974)	Employs an algorithm that uses brand preferences of final market for finding optimal brand mix and display-area allocation.
Empirical and Mathematical Model	A Hybrid Knowledge-Based System for Allocating Retail Space and for Other Allocation Problems	(Singh et al., 1988)	Decision support system (Resource-opt) for resource allocation with a practical example.
Empirical studies	The impact of location factors on the attractiveness and optimal space shares of product categories	(Campo et al., 2000b)	A framework for explaining the impact of store and trading area characteristics on category and store performance.
	Shelf Management and Space Elasticity	(Drèze et al., 1994)	Field experiments for comparing two shelf management approaches: "space-to-movement" and "product reorganization".

	Title	Reference	Key Features
	SH.A.R.P.: Shelf Allocation for Retailers' Profit	(Bultez and Naert, 1988)	A theoretical shelf space allocation model focusing on the demand interdependencies prevailing across and within product-groups. Comparison of the model with the rules of thumb.
	The Relationship between Shelf Space and Unit Sales in Supermarkets	(Curhan, 1972)	Impact of shelf space changes on unit sales using stepwise multiple regression.
	The Effect of Shelf Space upon Sales of Branded Products	(Cox, 1970)	A randomized block field experiment for testing the influence of shelf space on sales of branded products.
Comparative Studies	Metaheuristics with Local Search Techniques for Retail Shelf-Space Optimization	(Lim et al., 2004)	A practicable linear allocation model for optimizing shelf-space allocation and strategy that combines a strong local search with a metaheuristic approach to space allocation.

The literature presents various factors affecting and approaches to decide shelf space allocation decisions. Campo et al. (2000a) highlight the role of demographic characteristics on shelf space allocation decisions. They note that demographic profiles of the potential customers of an outlet impact on sales and profit of relevant brands. They argue that demographically incited differences among attractiveness of brands have a role in optimal allocation of the store space across categories. They emphasize on addressing local needs in each store and allocating space, manpower, and promotional budget accordingly. Over a period of time the number of potential factors including demographic as well as a store's internal operations related such as display locations within the store and ordering quantities have increased (Hariga et al., 2007, Murray et al., 2010).

Various quantitative techniques including non-linear modeling and integer programming techniques are used to solve shelf space allocation problem. Corstjens and Doyle (1981) present a non-linear model incorporating both demand and cost for determining optimal shelf space allocation. However, since their model does not take into account integer nature of the shelf space the solution may become sub-optimal. Further their model is too complex mathematically to be used by practitioners in a real sense. Further, Corstjens and Doyle (1983) present a more comprehensive strategic space allocation model which incorporates

factors other than those included in their previous work. They emphasize that profitable retail space allocation depends on changing customers' preferences, product life cycles of competing brands, and varying growth rates.

Further, the work of (Mason and Mayer, 1990) seeks to propose more easy to use methods. They argue there are two methods which can be used in industry for managing shelf space in retailing stores: "sales productivity method," and "build-up method". Sales productivity method emphasizes to increase sales and tends to give more display to the brand which contributes more towards sales, whereas "build-up method" does not give credit to a brand's contribution towards sale. Similarly, Yang and Chen (1999) present a shelf space allocation model with an alternate form applicable in the retail practice. The model considers space elasticity, cross space brand elasticity, profit margin, and demand of individual brands for determining optimal solution of shelf space allocation for each brand. They also show that the retailers who adopted some strategy for shelf space allocation their performance is significantly different from the retailers who do not implement any strategy for shelf space management. They argue that shelf space management strategy affects performance through shelf space allocation operations.

The scholarly literature seems to imply that shelf space management is a complex and dynamic problem. Most existing studies tend to avoid this complexity by focusing only on those variables which are purely quantitative or by limiting the number of variables to be addressed in their models. Thus the current research models investigating shelf space allocation problem present either too simplistic scenario or lack practical nuance. Also, the emphasis on theoretical rigor founded on a large number of assumptions alienates these models from their managerial application. This situation provides an excellent space for the use of system dynamics technique to solve the problem using system dynamics approach (Milling, 1996).

THE RESEARCH VARIABLES

Product Space Elasticity

Space elasticity is the ratio of relative change in unit sales to relative change in shelf space (Hübner and Kuhn, 2012). Positive change in space

allocated to a brand brings positive change in sales. This change may not be a linear function. Appendix 2 notes relationship of the display space with the brand's sale. This relationship has been developed from interview data from the brand manager. Similarly, the values of product space elasticity have been estimated from the interview data.

Inter Product Space Elasticity

Sale of one brand can affect sale of another brand (Gillooley and Varley, 2001). However, the change in sale depends upon the relation of brands with each other as to whether they complement or substitute each other. When two brands complement each other, the increase in sale of one brand may increase sale of the other brand. Whereas, in case where brands are substitutes of each other, increased sale of one brand shall decrease sale of the former brand. This relationship between brands may vary from perfect substitutes to perfects complements. In the current study, the selected brands are in general substitutes of each other. The substitution relationship, coming from interviews with the brand managers, is incorporated in the model (Appendix 2).

Operating Cost Elasticity

Operating cost elasticity function refers to the impact of increased sales of a brand on its operating cost (Hwang et al., 2009). As the sales of a particular brand increases, its fixed cost and even variable cost per unit of production may decrease. In the current study the relationship between the brand sale and cost is assumed to be linear (Appendix 2). The data on profit margin of each brand is taken from relevant brand managers. The relationship can be further refined after collecting the relevant empirical data.

Total Available Shelf Space

Total shelf space is the maximum number facings that can be displayed in the store. Shelf space is measured in square feet or number of facing, depending on the implications of the model. In the retail store selected for the current study the maximum number of facings that can be allocated to the three brands under consideration is 15. This number is specific to the retail store under study.

Upper and Lower Bounds of Brand Space Allocation

Interviews from the brand managers suggest that usually, during earlier part of product life cycle, a brand's demand is lower and increases gradually with time. In order to promote a certain brand during the initial stage of product life cycle a minimum bound of display space for that brand is fixed. The current study's model follows the same pattern. The feature of upper and lower bound space allocation may also be included when a large number of established and competing brands are included in the model and space allocation to a strategically significant brand is to be restricted within a specific range. In this manner the strategically important new brand is not out-spaced by the existing brands with outperforming sales potential. The rationale behind allocating the upper bound is that beyond a certain amount of display, sale of a brand does not improve significantly and it may be suboptimal to give more space for display to that specific brand at the cost of giving display space to other brands.

The values of upper and lower bound are decided carefully because they set a restriction in the process of arriving at optimal shelf space allocation. These values can be determined from empirical data. In the current model all of the brands are assumed to be in maturity stage of their product life cycles and all of them are strategically intended to compete on the basis of their profit contribution. Therefore, the feature of upper and lower bounds of space is not included in the current model.

Brand Shelf Space

The shelf space of a brand is the number of shoes of the brand that can be displayed. The maximum allowable shelf space for the three brands that have been selected in the study is 15. The number 15 is decided by the store and brand manager from their and the company's overall experience. The shop and brand managers decide this number on the basis of the global optimal space allocation solution of the store. The global optimal of the retail store is determined on the basis of analysis of all the potential brands of a particular store. The model's objective is to arrive at the optimal shelf space to be allocated to each brand.

Demographic Factors

Demographic profiles of the potential customers which influence their purchase decisions and brand sales depend upon social positioning of the retail store. Based on interviews with the brand managers two main demographic factors which can impact sale of the selected brands are identified and included in the system dynamics model in the current study. These factors are average monthly income and education level of the potential customers which can be obtained from local government agencies in terms of monthly income and number of years of schooling respectively. The relationships between sales of the three brands and average education and average monthly income are determined from interviews of the experienced brand managers. These relationships are given in Appendix 2.

Environmental Factors

The environmental factors such as temperature and rainfall have the potential to impact the sale of particular brands in a shoe retail store. These factors depend upon the geographic location of the retail store. Based on interviews with the brand managers, temperature has been identified as a variable that has direct influence on the sale of the three brands considered in this study. The relationship between the sales of the brands and the average monthly temperature of location of the retail store are determined on the basis of previous years' sales and interviews with the relevant brand managers. The same goes for estimating the relationship of sales of the three brands with the rainfall. The relationships are given in Appendix 2.

Price of the Competition

It is widely accepted in marketing literature that price of competitive brands has a direct relationship with a brand's sale. Therefore, impact of price of competition has been included in the current study. Although it is complex to determine the relationship between price of competitive brands and sale of the three brands used in the study but this study makes an attempt using the data from interviews with brand managers to estimate the relationship. The relationships are given in Appendix 2.

THE SYSTEM DYNAMICS MODEL

This paper develops a system dynamics model (SD) for solving the space allocation problem. The model incorporates important variables, such as price and demand, already used in the literature. The model also introduces new variables, such as education and income level, which comes from interviews with concerned brand and shop managers from the selected retail company.

Research Site and Data

An SD model is developed for a retail store of one of the largest shoe manufacturer and retailing firm in Pakistan. The firm owns more than 400 retail outlets and a large number of shoe brands. Each brand has a number of categories. However, all the brands and categories are not displayed at each store. Display of a particular brand depends on the retailing strategy of the firm and a particular retail store. The firm's retail stores also display and sell brands other than firm's own brands. The firm has set a policy not to allocate more than ten percent of a store's total shelf space to the external brands. For the SD modeling purpose of the selected store factual data related to the location of the store as well as the data based on perceptions of the brand/shop managers is used.
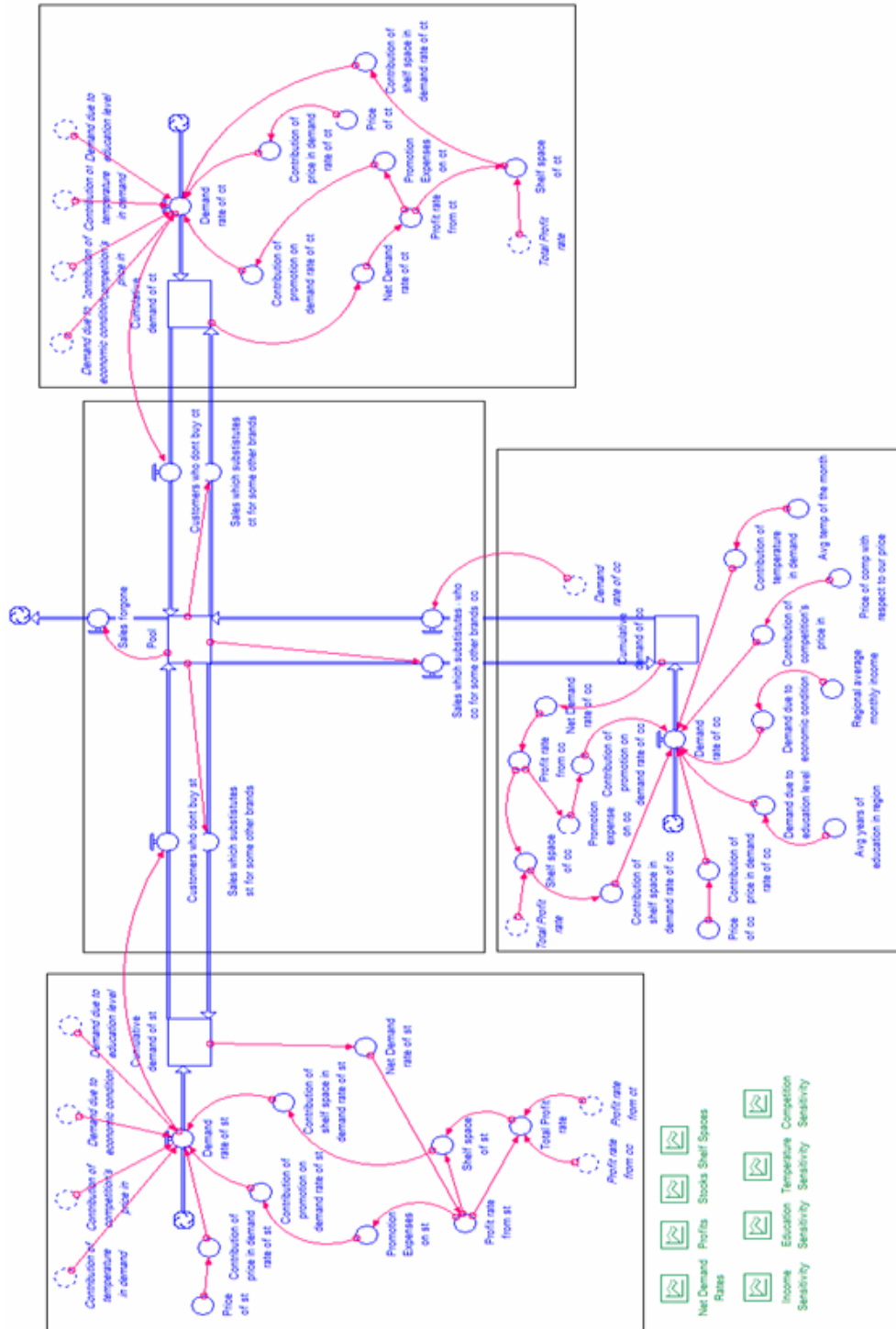
Figure 1: System dynamics model

The Model's Scope

There are 20 brands competing for the limited shelf space in the selected shoe retailing store. Since the inclusion of 20 brands in the model makes the model too complex for the research purposes the current study's model investigates the shelf space relationship of three brands with each other. A full scale model that incorporates all twenty brands or all brands of the firm can be developed for practical and managerial purposes. For the sake of maintaining anonymity, these brands are denoted as 'st', 'cc', and 'ct' in this study.
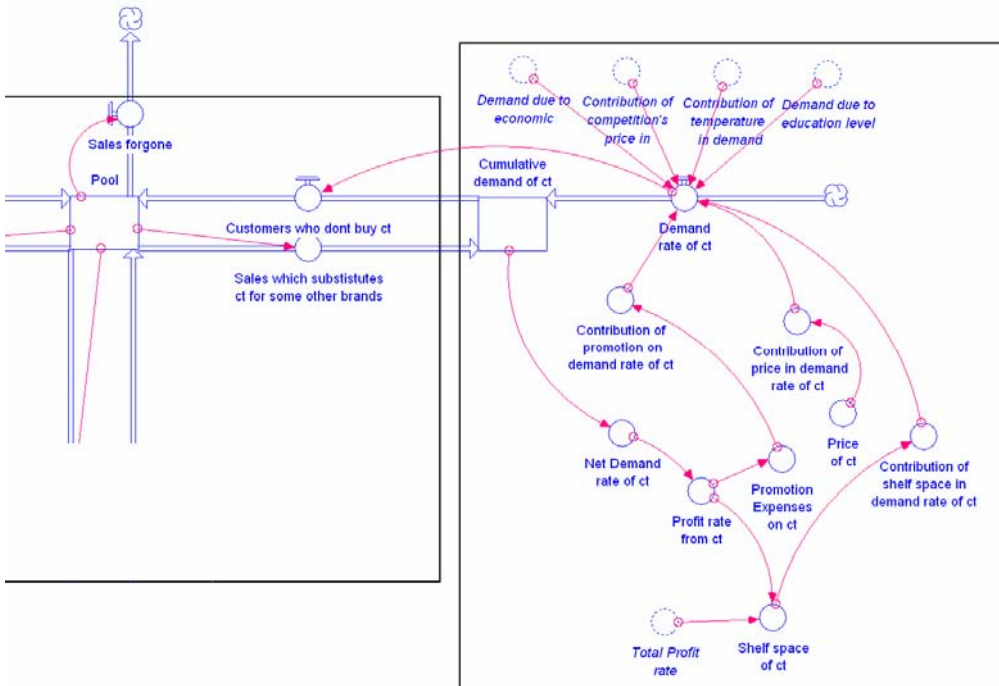
Figure 2: Stock and Flow Diagram of Brand 'ct'

Model Development

The study identifies a number of variables that can potentially play a role in shelf space management decisions in the shoe retail industry and particularly of the firm under investigation. However, given the research constraints, perhaps it is not doable to incorporate all of them in this study. The variables that affect shelf space allocation decision and have been included in this study are described below. These variables have been identified from the literature on shelf space allocation and from interviews with brand and shop managers. The study collects the store

specific data on these variables from interviews with the managers and from sales record. The relationships between the research variables come from the regression analysis of the sales data and store specific demographic variables. The regression results provide the basis to propose relationships among the research variables in the system dynamics model.

The system dynamics model thus developed on a system dynamics analysis software IThink is presented in Figure 1. Figure 1 is divided into four rectangular sections to improve visual understanding of the reader. The three rectangles (left, right, and bottom) show stock and flow diagram of the three brands under study. The central rectangle models the switching phenomenon among the three brands under study by customers. Each rectangle show similar physical structure to model a brand. The Figure 2 shows an enlarged view of the brand 'ct' which is modeled similar to the brands 'cc' and 'st'. The Figure 2 also shows customer's switching portion of the model.

There are two stocks in Figure 2: 'Cumulative demand of ct'; and 'Pool'. 'Cumulative demand of ct' has two inflows and one outflow. The two inflows are 'demand rate of ct', and 'sales which substitutes 'ct' for some other brands'. The outflow from 'cumulative demand of ct' is 'customers who don't buy 'ct'.' 'Demand rate of ct' is a function of seven variables whose arrows are directed into it. The conceptual relationships among the seven incoming variables are explained here. Mathematical relationships among 'Demand rate of ct' and the seven incoming variables are noted in Appendix 2. 'Sales which substitutes 'ct' for other brands' is a function of 'Pool' and it has positive relationship with it.

'Pool' has three inflows and four outflows. The three 'pool' inflows are the rate of customers who are willing to switch from one brand to another. These customers are represented by inflows 'customers who don't buy i', where 'i' stands for the three brands. These three inflows increase the level of 'pool' and the four outflows decrease the level of 'pool'. The four outflows are 'sales forgone' and 'Sales which substitute 'i' for some other brands'. 'Sales which substitute 'i' for some other brands' are the three outflows of 'loop' which contribute positively in the demand of other brands.

Moreover, there are some customers who come in the retail store and they do not find their first choice and are unwilling to substitute their choice with any of the other two brands. As a result they leave the retail store without making any purchase. Such customers are represented as 'sales forgone'. Mathematical relationships between these variables are given in Appendix 2.

The variables discussed above influence the stocks or inflows directly. Moreover, there are some other variables that are indirectly affecting the stocks and inflows. 'Net demand rate of ct' is the first derivative of 'Cumulative demand rate of ct' and it helps in finding 'Profit rate from ct'. Some of the profit from 'ct' is spent on further promotion of the brand 'ct' and it is represented by 'Promotion expenses on ct'. 'Price of ct' negatively affects demand of 'ct'. Whereas 'Shelf space of ct' positively influences demand of 'ct' and the former is assigned on the basis of contribution of 'ct' in 'Total profit rate' and relationship between 'Shelf space of ct' and its impact on sales of 'ct'. Mathematical relationships between these variables are given in Appendix 2.

RESULTS AND DISCUSSION

Profit of a retail store depends on sales and profit margins of all the brands in the store. Objective of the SD model is to seek and implement a combination of sales (the term demand is used synonymous to sale, which assumes that all the demand is met by the retail store and there is no stock out) of 'st', 'cc', and 'ct' that maximizes the retail store's total profit. In this SD model the graphical results are used to find out the values of shelf space to be allocated to the three brands to maximize the total profit by optimizing the brand's sales.

Charts 1-4 show behavior of net demand, profit rate, cumulative demand, and shelf spaces in the SD model. These Charts indicate that there is instability in the model in the left sides of the Charts. However, the model becomes noticeably stable after time 7.5. Therefore, the values of the variables after time 7.5 are more meaningful for the current study's objectives.

Chart 1 shows the relationship between net demand rates of the three brands and total profit rate. Net demand rates are monthly sales of the each brand and total profit rate is the total profit per month from sales of

the three brands. The chart indicates that net demand rate of 'st' is more than 'ct' and that of 'ct' is more than the demand rate of 'cc'. These findings make sense because the three brands have cost sensitive demand. The price of 'st' is less than 'ct' and the price of 'ct' is less than that of 'cc'.

The comparison of the net profit rates of the three brands is shown in Chart 2. Relationship between the net profit rates match with values of their net demand rate and respective profit margins. Values of both net demand rate and profit margin of 'st' are higher than the both respective values of 'ct' individually. Similarly, values of both net demand rate and profit margin of 'ct' are higher than the respective values of 'cc'. Hence the comparison shown in Chart 4 rightly predicts that the profit rate of 'st' is more than that of 'ct' and the profit rate of 'ct' is more than that of 'cc'. The Chart 4 indicates the optimal shelf spaces to be allocated to 'cc', 'st', and 'ct' are 3, 7, and 5 respectively.

Chart 3 shows comparison of the accumulated sales of the three brands and their relationship with the total profit rate. Total profit rate is sum of monthly profits from three brands under study. Accumulated sales of the three brands are represented in the form of stocks in the system dynamics model. The chart indicates that the accumulated demands are increasing as the time passes. When the system becomes stable, which is after time 7.5, the accumulated demands of each brand are increasing with a constant slope. As a result the total profit rate has become almost constant after this time period.

Sensitivity Analysis

This study incorporate four regional variables in the system dynamics model: average monthly income of the a household around the retailing store; average education level of the target customers; average monthly temperature of the region where the retailing store is located; and price of the brands with respect to the price of competition. The Charts 5-16 show sensitivity of these variables in the Appendix 1.

Sensitivity for Average Monthly Income

The model corroborates the interviewed brand managers' perception that average monthly income of household around the retailing store would

impact brand specific sales. The sensitivity of the model towards average monthly income is shown in Charts 5-7. When the value of average monthly income varies from PKR 2000 to PKR25000 to PKR 50000, keeping other variables of the model constant, the value of total profit of the retail store from the three brands varies from PKR 338000 to PKR 399000 to PKR 465000 respectively. The charts show that when location of the retail store is changed from low level to higher level of monthly income sales of the retail store also increases.

Sensitivity for Average Education Level

According to the brand managers the selected brands are liked by more educated people. The model corroborates perception of the interviewed brand managers that average education level around the retailing store would impact brand specific sales. The sensitivity of the model towards average education level is shown in Charts 8-10. These charts show the change in purchasing decisions of the shoe buyers with the change in their education level. When the value of average education level varies from 2 years to 5years to 10 years, keeping other variables of the model constant, the value of total profit of the retail store from the three brands varies from PKR 351000 to PKR 375000 to PKR 415000 respectively. Demand of the brands increases with the increase in the average education level of the potential customers of the shoe store. Such behavior is corroborated by the brand managers.

Sensitivity for Average Monthly Temperature

The model corroborates perception of the interviewed brand managers that average monthly temperature would impact brand specific sales. The

value of average monthly temperature generally varies from 12℃ to 35℃.

The sensitivity of the model towards this variable is shown in Charts 11-

13. When the value of average monthly temperature varies from 12℃ to

23˚C to 35˚C, keeping other variables of the model constant, the value of

total profit of the retail store from the three brands varies from PKR 379000 to PKR 406000 to PKR 435000 respectively. Demand of the selected brands is highest during summer and the same pattern is reflecting in the Charts 11-13.

Sensitivity for Price of Competition

The model finds reasonable relationship between price of competing brands and sales of the three brands being studied in the model. When price of the competition increases, sales of the three brands also increases and vice versa. The sensitivity of the model towards this variable is shown in Charts 14-16. When the value of ration between the price of the competition and the prices of three varies from 0.1 to 1 to 1.9, keeping the other variables of the model constant, the value of total profit of the retail store from the three brands varies from PKR 240000 to PKR 419000 to PKR 598000 respectively.

CONCLUSION AND FUTURE RESEARCH

This paper uses system dynamics model to solve the optimal shelf space allocation problem for a retail shoe store. Potential users of the model are shop/brand managers or the personnel who want to find out the optimal space allocation scheme for the competing brands. Inputs of the model are generally available to the brand and shop managers. The approach used in the current study can be used in many other retailing sectors, such as electronic goods and food retailers. In doing so the paper provides a foundation for the use of system dynamics modeling for space allocation decisions in retail industry.

The model developed so far has some limitations which can be addressed in future research. The data used in this study is largely based on managerial experience and perception. Similarly, the model makes some assumption such as linearity of the relationship among variables to avoid the complexity. The relationships between the variables in the model can be further refined by using empirical data to arrive at the fundamental store specific relationships among the variables included in the model.

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APPENDIX 1
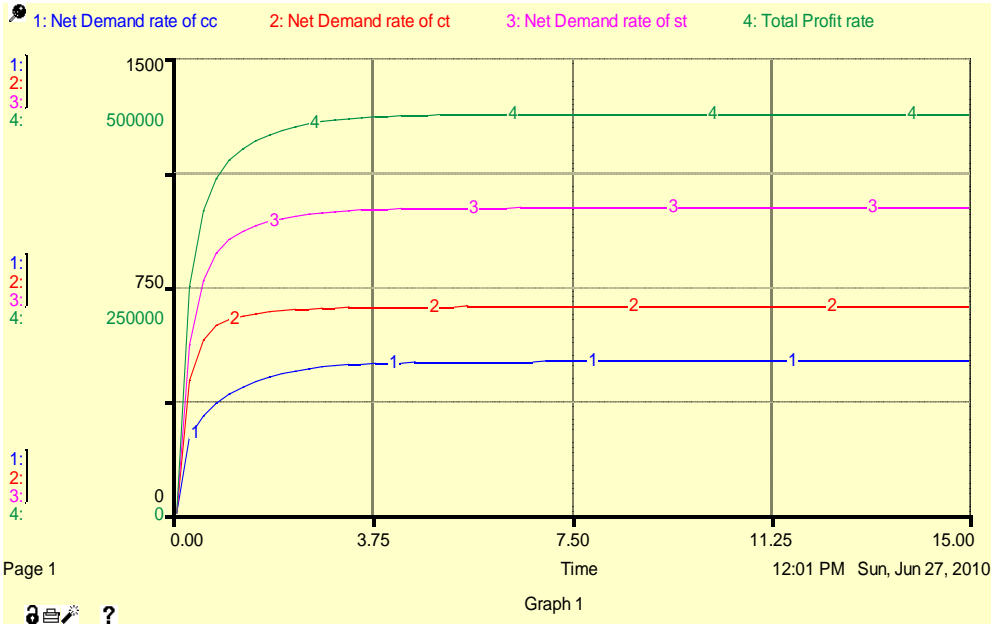
Chart 1: Net Demand Rates of Brands
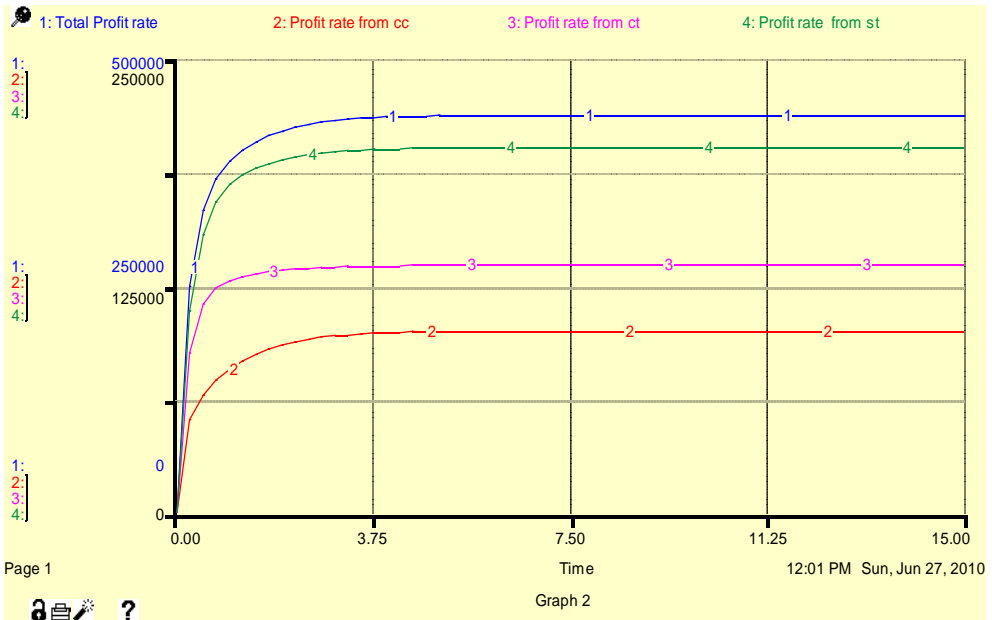
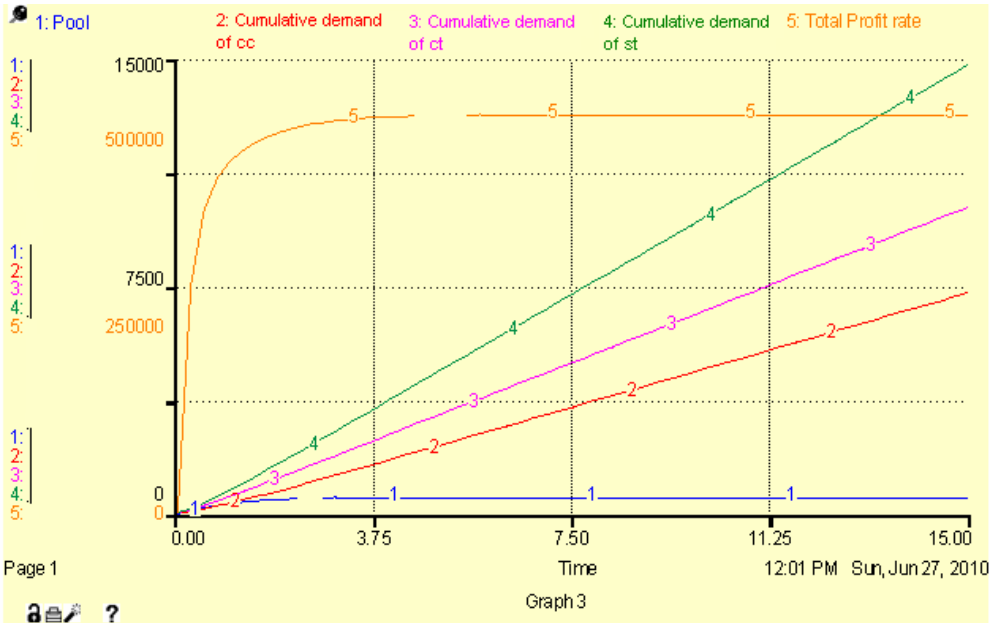
Chart 2: Profit Rates of the Three Brands
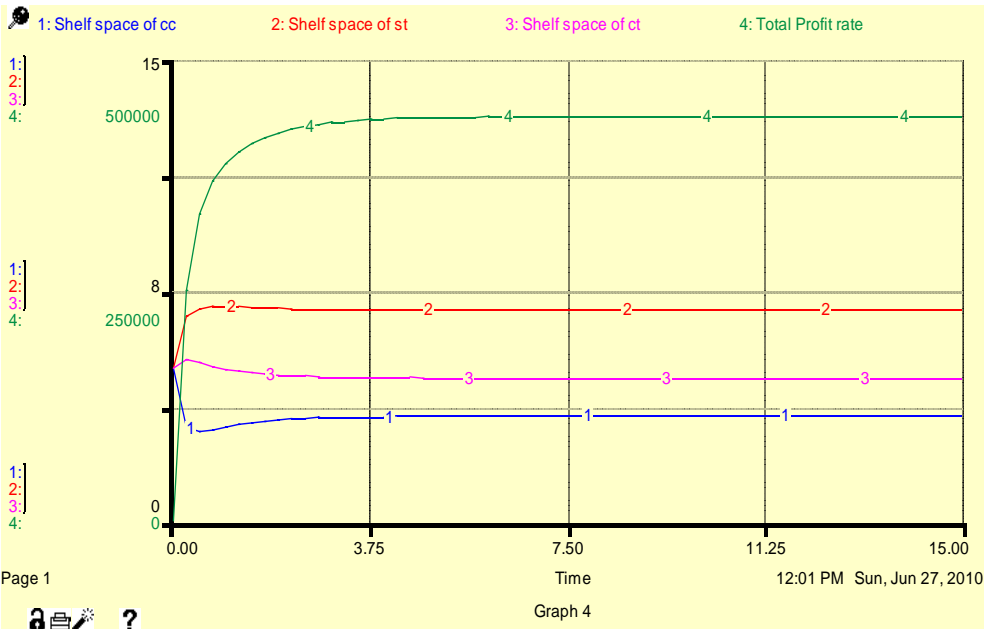
Chart 3: Cumulative Demands

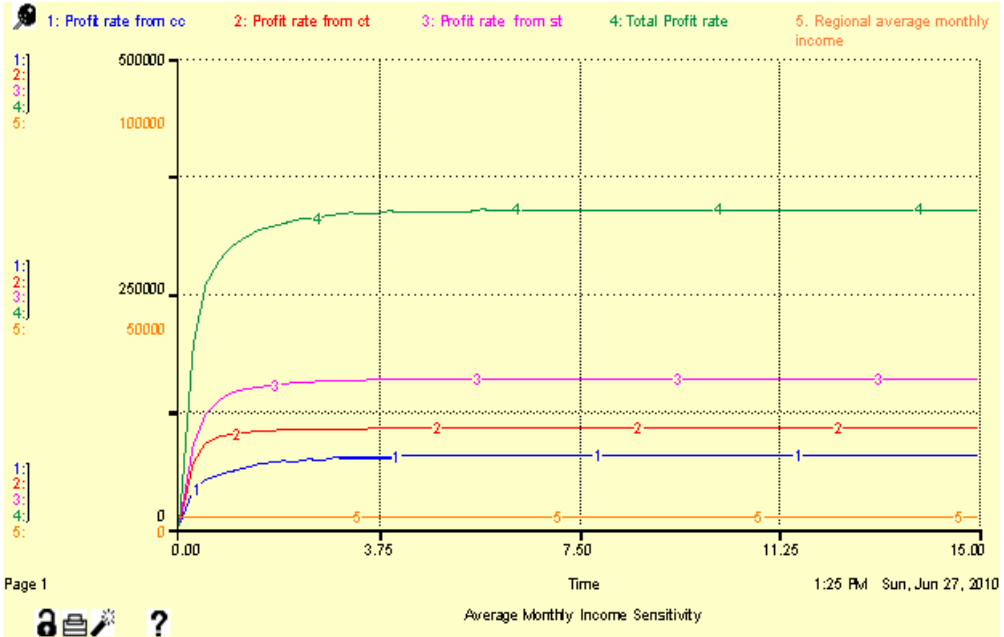**Chart 4: Shelf Spaces and Total Profit Rates**

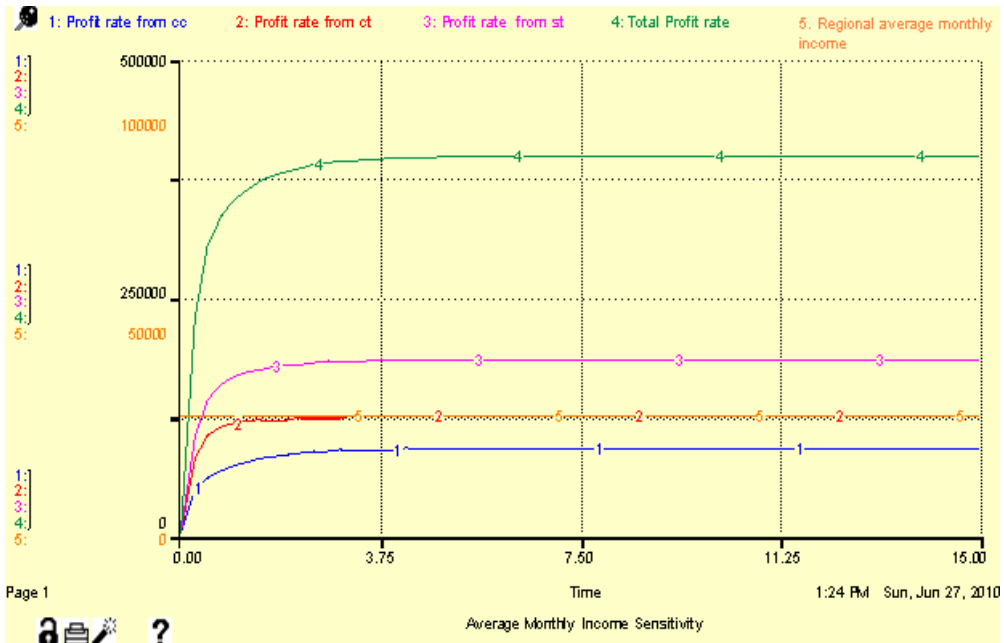*Chart 5: Sensitivity for Average Monthly Income (PKR 20000)*

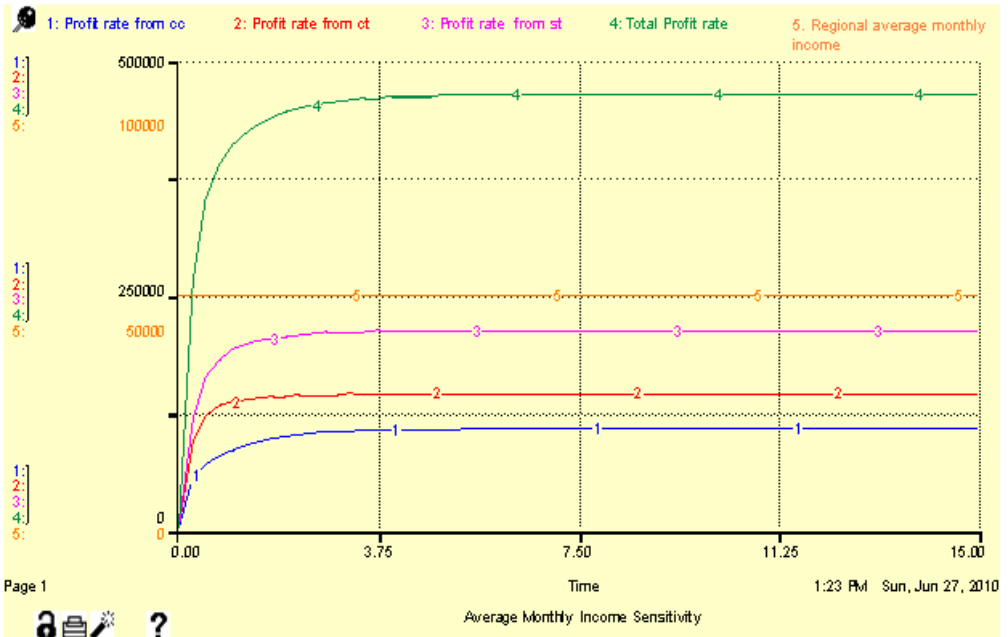*Chart 6: Sensitivity for Average Monthly Income (PKR 25000)*

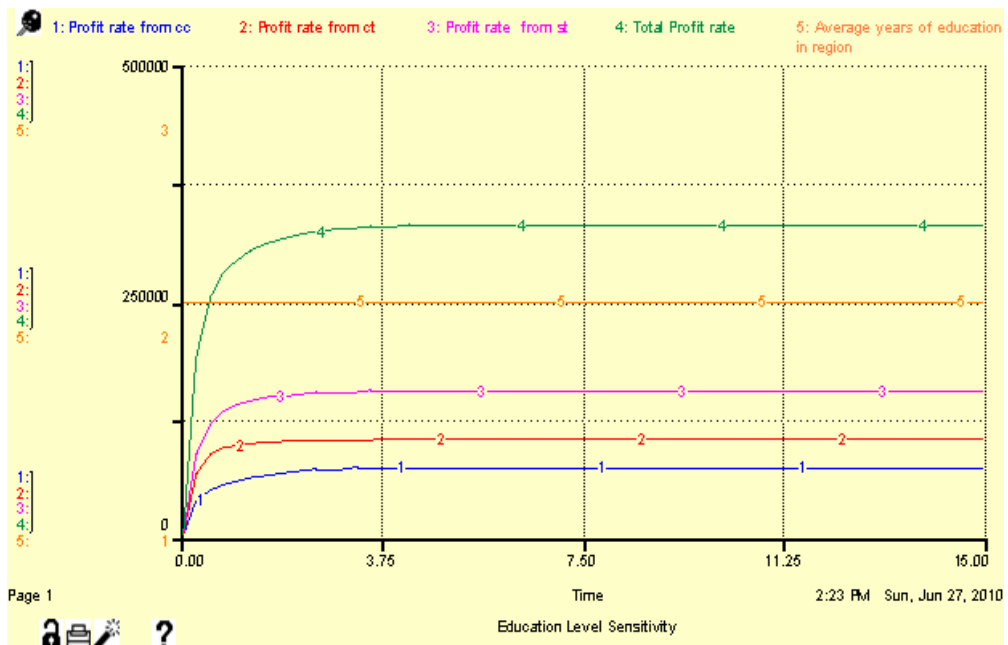*Chart 7: Sensitivity for Average Monthly Income (PKR 50000)*

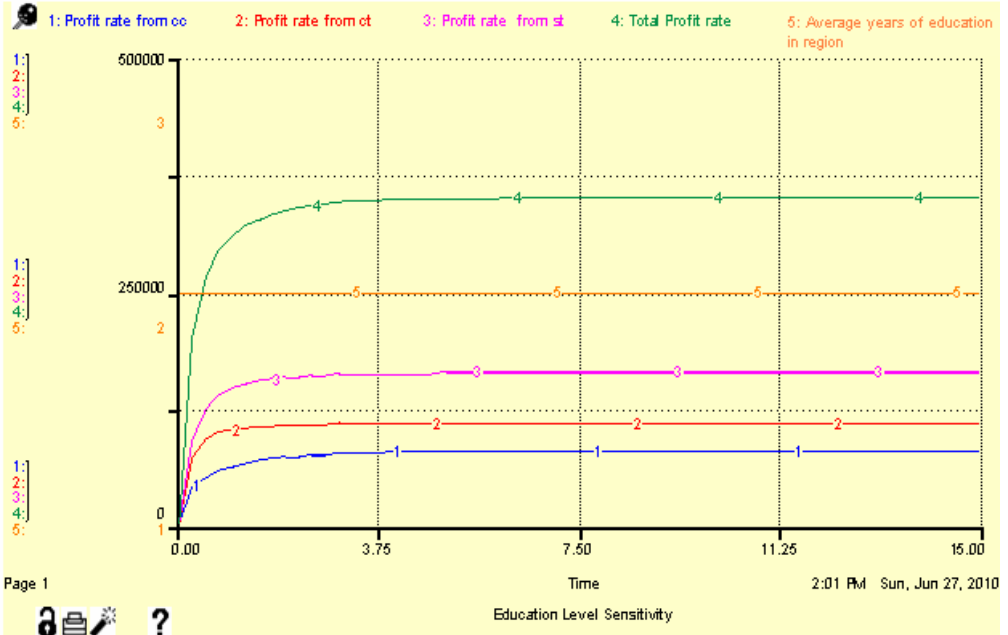*Chart 8: Sensitivity for Average Education Level (2 Years)*
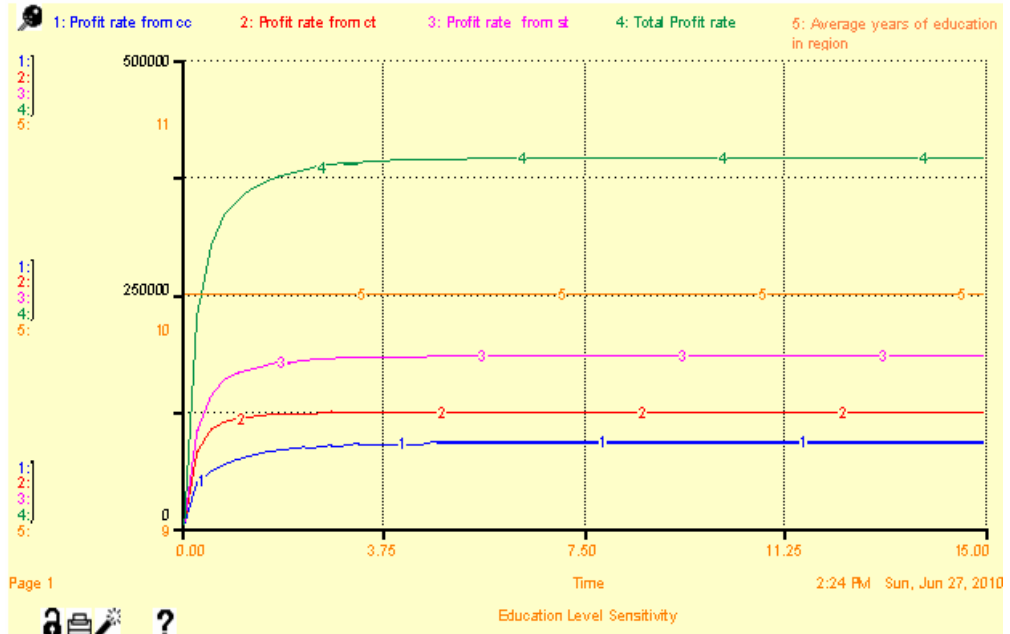
Chart 9: Sensitivity for Average Education Level (5 Years)

Chart 10: Sensitivity for Average Education Level (10 Years)
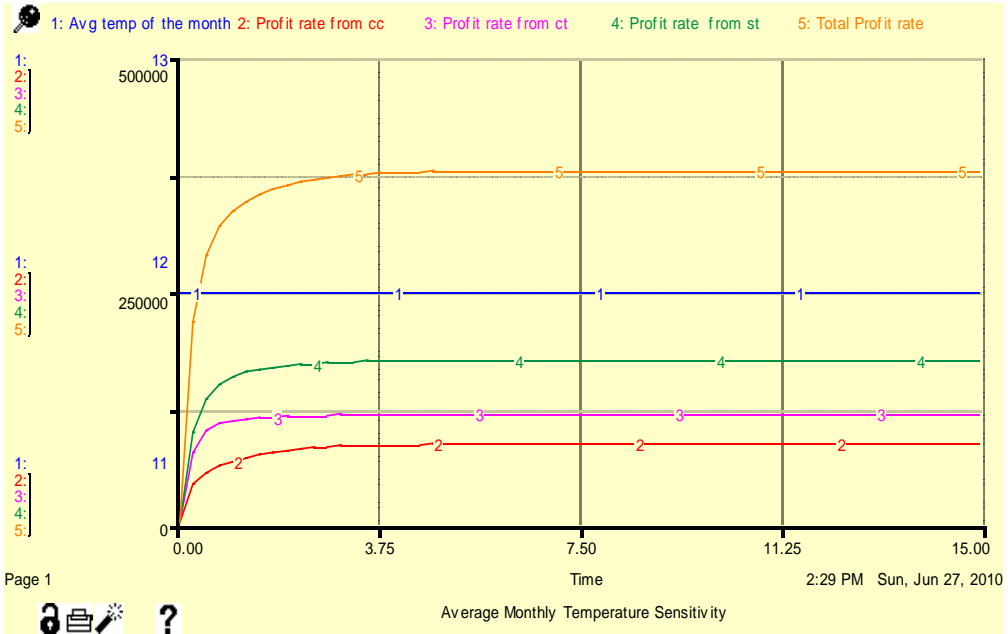
Chart 11: Sensitivity for Average Monthly Temperature (12 °C)
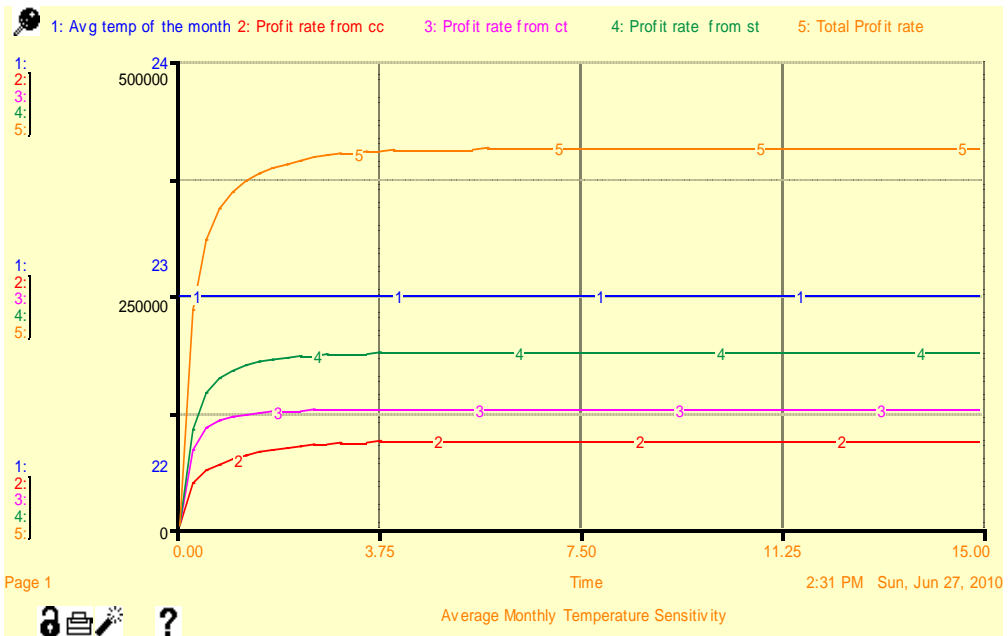
Chart 12: Sensitivity for Average Monthly Temperature (23 °C)
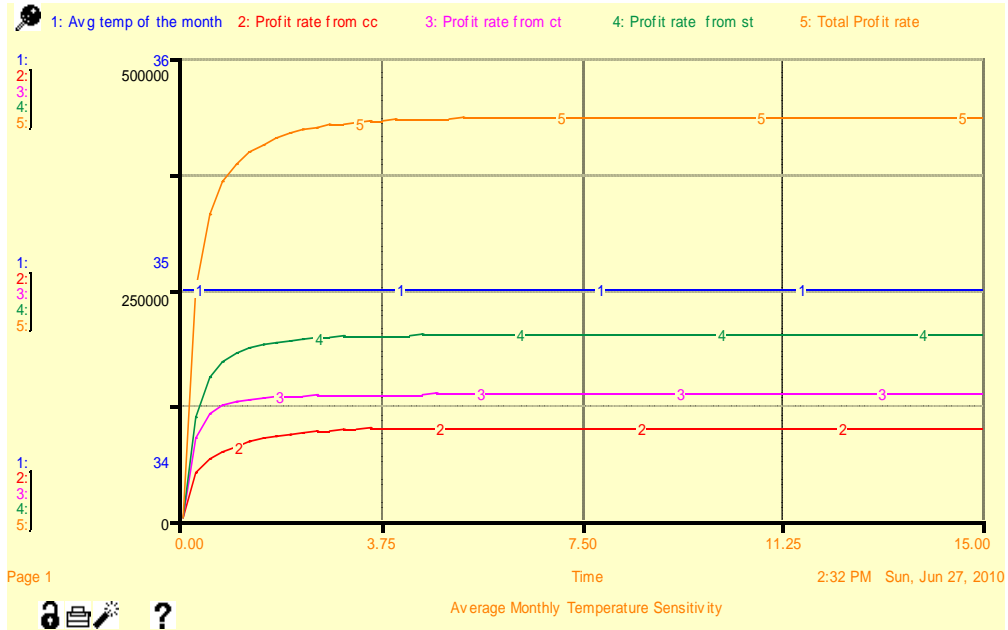
Chart 13: Sensitivity for Average Monthly Temperature (35 °C)
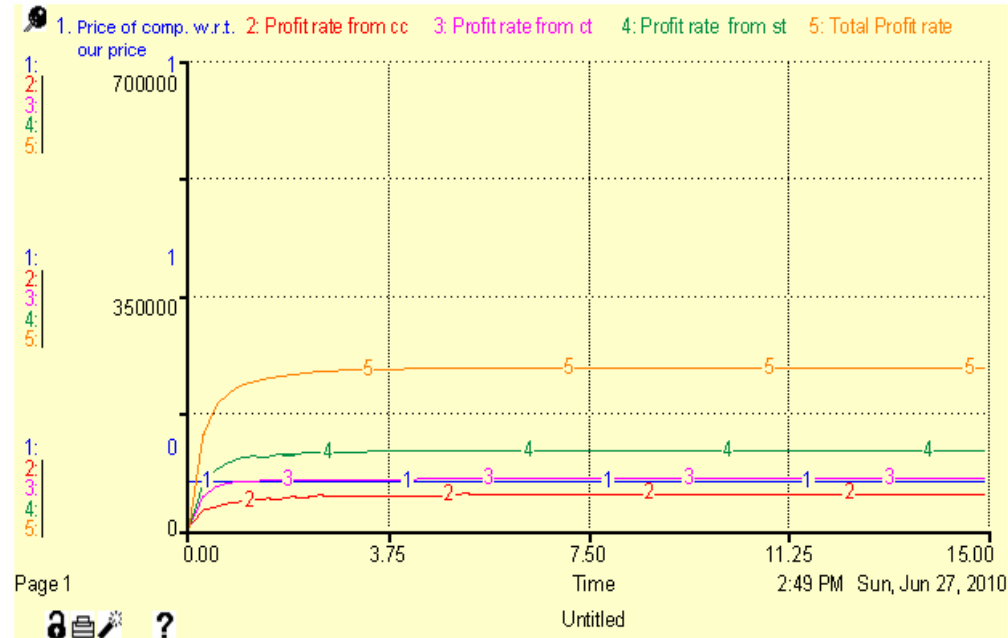
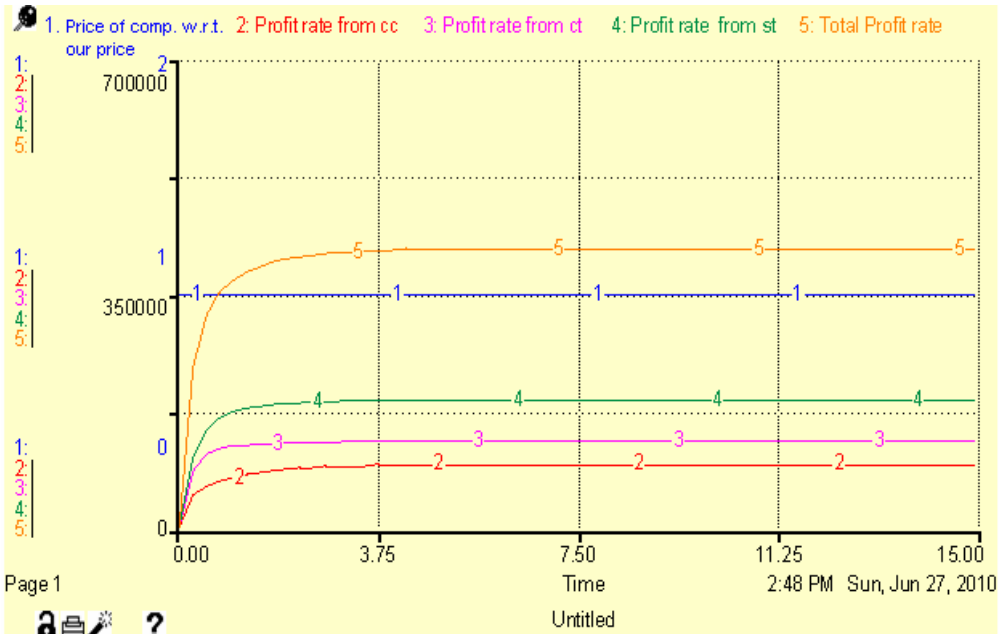*Chart 14: Sensitivity for Price of Competition (0.1)*
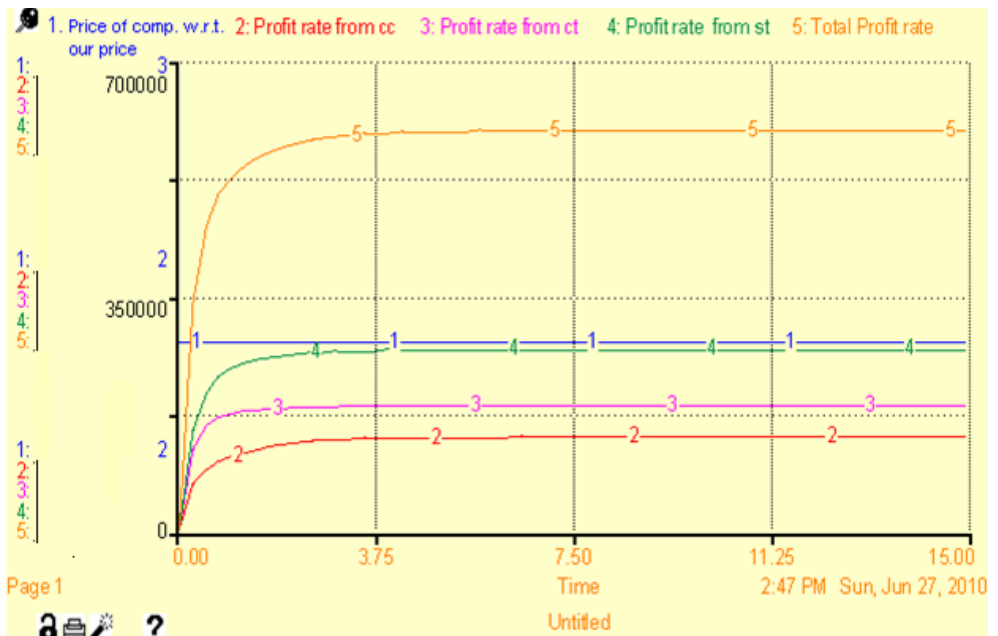
Chart 15: Sensitivity for Price of Competition (1)

Chart 16: Sensitivity for Price of Competition (1.9)

APPENDIX 2

STOCK: CUMULATIVE DEMAND OF CC

"Cumulative_demand_of_cc(t) = Cumulative_demand_of_cc(t - dt) +
(Demand_rate_of_cc +
Sales_which_substistutes_cc_for_some_other_brands -
Customers_who__dont_buy_cc) * dt
INIT Cumulative_demand_of_cc = 1
UNITS: Pairs

> **INFLOWS:**
> Demand_rate_of_cc =
> Contribution_of__competition's__price_in__demand+Demand_du
> e_to__education_level+Demand_due_to__economic_condition+Co
> ntribution_of__price_in_demand__rate_of_cc+Contribution_of__p
> romotion_on__demand_rate_of_cc+Contribution_of__shelf_space_
> in__demand_rate_of_cc+Contribution_of__temperature__in_dema
> nd
> UNITS: pairs/time
> Sales_which_substistutes_cc_for_some_other_brands = 0.3*Pool
> UNITS: pairs/time
> **OUTFLOWS:**
> Customers_who__dont_buy_cc = 0.5*Demand_rate_of_cc
> UNITS: pairs/time

STOCK: CUMULATIVE DEMAND OF CT

Cumulative_demand_of_ct(t) = Cumulative_demand_of_ct(t - dt) +
(Sales_which_substistutes_ct_for_some_other_brands +
Demand_rate_of_ct - Customers_who_dont_buy_ct) * dt
INIT Cumulative_demand_of_ct = 1
UNITS: Pairs

> **INFLOWS:**
> Sales_which_substistutes_ct_for_some_other_brands = 0.1*Pool
> UNITS: pairs/time
> Demand_rate_of_ct =
> Contribution_of__competition's__price_in__demand+Demand_du
> e_to__education_level+Demand_due_to__economic_condition+Co

ntribution_of__price_in_demand__rate_of_ct+Contribution_of__promotion_on__demand_rate_of_ct+Contribution_of__temperature__in_demand+Contribution_of__shelf_space_in__demand_rate_of_ct

UNITS: pairs/time

OUTFLOWS:
Customers_who_dont_buy_ct = 0.2*Demand_rate_of_ct
UNITS: pairs/time

STOCK: CUMULATIVE DEMAND OF ST

Cumulative__demand_of_st(t) = Cumulative__demand_of_st(t - dt) + (Sales_which_substistutes_st_for_some_other_brands + Demand__rate_of_st - Customers_who_dont_buy_st) * dt
INIT Cumulative__demand_of_st = 1
UNITS: Pairs

> **INFLOWS:**
> Sales_which_substistutes_st_for_some_other_brands = 0.2*Pool
> UNITS: pairs/time
> Demand__rate_of_st =
> Contribution_of__competition's__price_in__demand+Demand_due_to__education_level+Demand_due_to__economic_condition+Contribution_of__price_in_demand__rate_of_st+Contribution_of__promotion_on__demand_rate_of_st+Contribution_of__shelf_space_in__demand_rate_of_st+Contribution_of__temperature__in_demand
> UNITS: pairs/time
> **OUTFLOWS:**
> Customers_who_dont_buy_st = 0.05*Demand__rate_of_st
> UNITS: pairs/time

STOCK: POOL

Pool(t) = Pool(t - dt) + (Customers_who__dont_buy_cc + Customers_who_dont_buy_ct + Customers_who_dont_buy_st - Sales_which_substistutes_st_for_some_other_brands - Sales_which_substistutes_ct_for_some_other_brands - Sales_forgone - Sales_which_substistutes_cc_for_some_other_brands) * dt
INIT Pool = 0

UNITS: Pairs
> **INFLOWS:**
> Customers_who__dont_buy_cc = 0.5*Demand_rate_of_cc
> UNITS: pairs/time
> Customers_who_dont_buy_ct = 0.2*Demand_rate_of_ct
> UNITS: pairs/time
> Customers_who_dont_buy_st = 0.05*Demand__rate_of_st
> UNITS: pairs/time
> **OUTFLOWS:**
> Sales_which_substistutes_st_for_some_other_brands = 0.2*Pool
> UNITS: pairs/time
> Sales_which_substistutes_ct_for_some_other_brands = 0.1*Pool
> UNITS: pairs/time
> Sales_forgone = 0.4*Pool
> UNITS: pairs/time
> Sales_which_substistutes_cc_for_some_other_brands = 0.3*Pool
> UNITS: pairs/time

CONVERTERS:

Avg_temp_of_the_month = 20
UNITS: degC
Avg_years_of__education_in_region = 8
UNITS: yr
Contribution_of__competition's__price_in__demand = -275+250*Price_of_comp_with_respect_to_our_price
UNITS: pairs/time
Contribution_of__price_in_demand__rate_of_cc = 505-0.5*Price_of_cc
UNITS: pairs/time
Contribution_of__price_in_demand__rate_of_ct = 505-0.5*Price_of_ct
UNITS: pairs/time
Contribution_of__price_in_demand__rate_of_st = 505-0.5*Price_of_st
UNITS: pairs/time
Contribution_of__promotion_on__demand_rate_of_cc = -5+0.035*Promotion__expenses__on_cc
UNITS: pairs/time
Contribution_of__promotion_on__demand_rate_of_ct = -5+0.035*Promotion_Expenses_on_ct
UNITS: pairs/time

Contribution_of__promotion_on__demand_rate_of_st = -5+0.035*Promotion_Expenses_on_st

UNITS: pairs/time

Contribution_of__shelf_space_in__demand_rate_of_cc = 10+5*Shelf_space_of_cc

UNITS: pairs/time

Contribution_of__shelf_space_in__demand_rate_of_ct = 19+6*Shelf_space_of_ct

UNITS: pairs/time

Contribution_of__shelf_space_in__demand_rate_of_st = 16+4*Shelf_space_of_st

UNITS: pairs/time

Contribution_of__temperature__in_demand = 15.9+3.09*Avg_temp_of_the_month

UNITS: pairs/time

Demand_due_to__economic_condition = 20+0.0033*Regional_average__monthly_income

UNITS: pairs/time

Demand_due_to__education_level = 40+10*Avg_years_of__education_in_region

UNITS: pairs/time

Net_Demand_rate_of_cc = MAX(DERIVN(Cumulative_demand_of_cc,1), 0.0001)

UNITS: pairs/time

Net_Demand_rate_of_ct = MAX(DERIVN(Cumulative_demand_of_ct,1), 0.0001)

UNITS: pairs/time

Net_Demand_rate_of_st = MAX(DERIVN(Cumulative__demand_of_st,1), 0.0001)

UNITS: pairs/time

Price_of_cc = 650

UNITS: PKR

Price_of_comp_with_respect_to_our_price = 0.1

Price_of_ct = 600

UNITS: PKR

Price_of_st = 500

UNITS: PKR

Profit_rate_from_cc = Net_Demand_rate_of_cc*200

UNITS: PKR/time

Profit_rate_from_ct = Net_Demand_rate_of_ct*200

UNITS: PKR/time
Profit_rate__from_st = 200*Net_Demand_rate_of_st
UNITS: PKR/time
Promotion_Expenses_on_ct = 0.05*Profit_rate_from_ct
UNITS: PKR/time
Promotion_Expenses_on_st = 0.05*Profit_rate__from_st
UNITS: PKR/time
Promotion__expenses__on_cc = 0.05*Profit_rate_from_cc
UNITS: PKR/time
Regional_average__monthly_income = 25000
UNITS: PKR/time
Shelf_space_of_cc = 15*Profit_rate_from_cc/Total_Profit_rate
UNITS: Facings
Shelf_space_of_ct = 15*Profit_rate_from_ct/Total_Profit_rate
UNITS: Facings
Shelf_space_of_st = 15*Profit_rate__from_st/Total_Profit_rate
UNITS: Facings
Total_Profit_rate =
Profit_rate_from_cc+Profit_rate_from_ct+Profit_rate__from_st
UNITS: PKR/time"

Note

Further information on the System Dynamics model (model equations) and subsequent steps of model development are available on request.