Title:	Optimal Shelf Space Allocation Using System Dynamics Approach: A Case Study in Shoe Retailing Industry
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ABSTRACT

Shelf space is a limited resource in a retailing store and multiple brands compete to get the maximum of this resource for their exposure to customer. However, a retailer's objective usually is to allocate space to each brand in such a way that yields maximum cumulative profit from the shelf space available. A retailer would make space allocation decisions based on various attributes possessed by the brands to be displayed. Such attributes may include: relative demand, price, profit margin, price elasticity, demand-space elasticity, cross-space elasticity, weather and temporal effects on demand of brands, demographic characteristics of visiting customers, and substitution relationships of a brand with competing brands to name a few. Hence an analysis of these variables together to find out an optimal brand space allocation decision that maximizes total profit of the shelf-space is a fairly complex and dynamic problem.

This paper explores the use of system dynamics approach for studying shelf space allocation decisions in the context of shoe retailing stores. Based on data which is part collected, part hypothetical (but with reasonable assumptions) a system dynamics model is developed for finding a solution of the aforementioned problem. The objective of the model is to determine optimal shelf space allocation that maximizes net profit of the store at given set of retailing store's constraints. Further implications of the model results are discussed and future research directions are proposed.

1. INTRODUCTION

Retailing industry is becoming very competitive with time and one of the key factors in improving sales of a retail store is the shelf space management. ‘Shelf space’ is a scarce resource in a retail store which in many cases is also a very expensive resource. In order to better manage this resource, one strategy which most retailers adopt is of optimally allocating shelf space to each brand in such a way that maximizes total profit from the sales of the retail store. A number of studies emphasize that well-managed shelf space of a store has positive impact on the sales and net profit of the store (Urban, 1998; Desmet and Renaudin, 1998).

Shelf space management is a source of competitiveness. These days, the number of competing brands to be displayed at a store is becoming abound thus reducing display space per brand at the store. A number of other factors make shelf space management decisions much more complex such as advertising policy of manufacturer affecting demand, which in return impacts the space allocation policy of the retailer (Dreze et al., 1994; Amrouchea and Zaccour, 2007), profit margin of a brand for a retailer (Martín-Herrán et al., 2006), demographic characteristics of the potential customers (Creusen, 2010), and weather conditions (Praskievicz and Chang, 2009). Shelf space also has many operational implications for a retail store. For example, L. A. Fancher (1991) argues that poor space management in a retail store can lead towards customers' dissatisfaction and increased inventory.

Mathematical models have been developed in order to help managers make optimal shelf space allocation decisions under store specific constraints. These models do not capture time varying attributes of variables such as of 'demand of each brand'. In order to address such dynamic and complex problems system dynamics is considered a more appropriate approach (Milling, 1996). This paper conceptualizes shelf space allocation decisions a time-varying dynamic problem and tests the use of system dynamics approach to investigate this problem. The following sections in this paper present brief literature review of shelf space allocation problem, a system dynamics model that conceptualizes and analyzes shelf space allocation decisions, interpretation of the model results, sensitivity analysis, and future research directions.

2. LITERATURE REVIEW

The issue of shelf space management has generally attracted attention from researchers of marketing and operations research. As a result, research studies have been conducted on both the prediction of theoretical relationship between factors affecting brand space allocation and on development of mathematical models for determining optimal brand space allocation. The system dynamics model developed in the current study is based on mathematical relationships among the relevant variables. Therefore, restricted by lack of space, this paper limits the literature review to studies on mathematical models for shelf space allocation. Summary of the relevant papers is shown in table 1.

There are different approaches suggested in literature for addressing the issue of shelf space management. According to Mayer et al. (1990) there are two methods which are used in industry for managing shelf space in retailing stores. These methods are "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.

Kampo and Goossens (1981) highlight the role of demographic characteristics on shelf space allocation decisions. Objective of their research was to shed light on impact of demographic factors on relevant appeal of particular categories' sale and profit. They argue that such local differences in category attractiveness 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.

	Title	Authors	Key Features	Year
Mathematical Model	Shelf-space allocation of national and private brands	Nawel Amrouche, Georges Zaccour	Game theoretic model for shelf space allocation.	2007
	An efficient algorithm to allocate shelf space	Ming-Hsein Yang	Heuristic for shelf space allocation and evaluation of solution methodology.	2001
	A study on shelf space allocation and management	Ming-Hsien Yang, Wen-Cher Chen	Space allocation model and interpretation of space management strategies using survey data.	1999
	Optimal Competition and Allocation of Space in Shopping Centers	Thomas J. Miceli, C. F. Sirmans, Denise Stake	Analysis of the issues faced by profit-maximizing developer during space allocation of shopping centre.	1998
	A Sensitivity Analysis of Retailer Shelf Management Models	Norm Borin, Paul Farris	Comparison of accuracy of mathematical models and thumb rules used for shelf space allocation.	1994
	A Dynamic Model for Strategically Allocating Retail Space	Marcel Corstjens and Peter Doyle	Incorporates changing needs and changing product life cycle in existing static shelf space allocation model.	1983
	A Model for Optimizing Retail Space Allocations	Marcel Corstjens and Peter Doyle	Space allocation model which incorporates cross-space elasticities and cost function using a case study.	1981
	A Mathematical Model for Simultaneously Determining the Optimal Brand-Collection and Display-Area Allocation	Evan E. Anderson and Henry N. Amato	Employs an algorithm that uses brand preferences of final market for finding optimal brand mix and display-area allocation.	1974

Empiric-al and Mathe-matical Model	A Hybrid Knowledge-Based System for Allocating Retail Space and for Other Allocation Problems	Madan G. Singh, Roderick Cook, Marcel Corstjens	Decision support system (Resource-opt) for resource allocation with a practical example.	1988
Empiric-al studies	The impact of location factors on the attractiveness and optimal space shares of product categories	K. Campo, E. Gijsbrechts, T. Goossens , A. Verhetsel	A framework for explaining the impact of store and trading area characteristics on category and store performance.	2000
	Shelf Management and Space Elasticity	Xavier Drèze, Stephen J. Hoch, Mary E. Purk	Field experiments for comparing two shelf management approaches: "space-to-movement" and "product reorganization".	1994
	SH.A.R.P.: Shelf Allocation for Retailers' Profit	Alain Bultez and Philippe Naert Source	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.	1988
	The Relationship between Shelf Space and Unit Sales in Supermarkets	Ronald C. Curhan,	Impact of shelf space changes on unit sales using stepwise multiple regression.	1972
	The Effect of Shelf Space upon Sales of Branded Products	Keith K. Cox	A randomized block field experiment for testing the influence of shelf space on sales of branded products.	1970

Compar-ative Studies	Metaheuristics with Local Search Techniques for Retail Shelf-Space Optimization	Andrew Lim, Brian Rodrigues, Xingwen Zhang	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.	2004

Table1: Summary of Literature on Shelf Space Allocation in Retailing Industry

Crostjens and Doyle (1981) present a non linear model incorporating both demand and cost for determining optimal shelf space allocation solution. However, their model does not take into account integer nature of the shelf space allocated and hence the solution may become sub-optimal. Further their model is too complex mathematically to be used by practitioners in a real sense. Crostjens and Doyle (1983) present another strategic space allocation model which incorporates more factors than the previous one. They emphasize that profitable retail space allocation depends on changing customers' preferences, product life cycles of competing brands, and varying growth rates.

Yang and Chen (1999) present a space allocation model with an alternate form that is 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. These authors 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.

In general the scholarly literature seems to have reached a consensus 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 not soft or by limiting number of variables to be addressed collectively. As a result the models thus developed become too simplistic to be practical or too hard to be solved. The current study develops a system dynamics model for solving the space allocation problem. The model incorporates important variables such as price and demand as highlighted by the literature review. The model also introduces new variables, such as education and income level, which were brought forward during interviews with concerned brand/shop managers in the store.

3. SYSTEM DYNAMICS (SD) MODEL

Research Site: An SD model is produced for a retail store of one of the most prominent shoe manufacturer and retailing firm in Pakistan. The firm owns more than 400 retail outlets that display many brands each having 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 a particular retail store. The stores also retail brands other than firm's own brands. However, those external brands capture less than ten percent of the total shelf space. For SD modeling purpose of the selected store either factual data related to the location of the store is taken or data based on the perception of brand/shop managers is used.

Research Scope: There are almost twenty brands competing for shelf space in the selected shoe retailing store. As one objective of this study is to test the use of SD for shelf space allocation decisions, it is considered that initially a simpler model that captures the essence of the problem is sufficient to be developed. Once the simpler SD model is developed and its benefits tested then a full scale model that incorporates all twenty brands can be developed for a more realistic analysis. Thus this study investigates the relationship of three brands with each other. For the sake of creating anonymity, these brands are denoted as 'st', 'cc', 'ct'.

Research has identified a large number of variables that can play a role in shelf space management decisions. However, given the time constraint, it was difficult 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 in the previous literature in different studies and were brought forward by the interviewed brand managers. The system dynamics model thus developed is shown in Figure 1. IThink software, which was readily available to the researchers, was used for developing and analyzing the model.

The SD model shown in Figure 1 seems divided in four rectangles for enhancing visual understanding of the reader. The three boundary rectangles show stock and flow diagram for the three brands under study. The central rectangle models the switching phenomenon among brands by customers. Each rectangle show similar physical structure to model a brand. Figure 2 represents enlarged view of one representative physical structure of SD model for the brand 'ct'. 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. Theoretical relationships of the seven incoming variables are explained in the later paragraphs. Mathematical relationships between 'Demand rate of ct' and the seven incoming variables are given in Appendix 2. 'Sales which substitutes ct for other brands' is a function of 'Pool' and it has positive relationship with it.

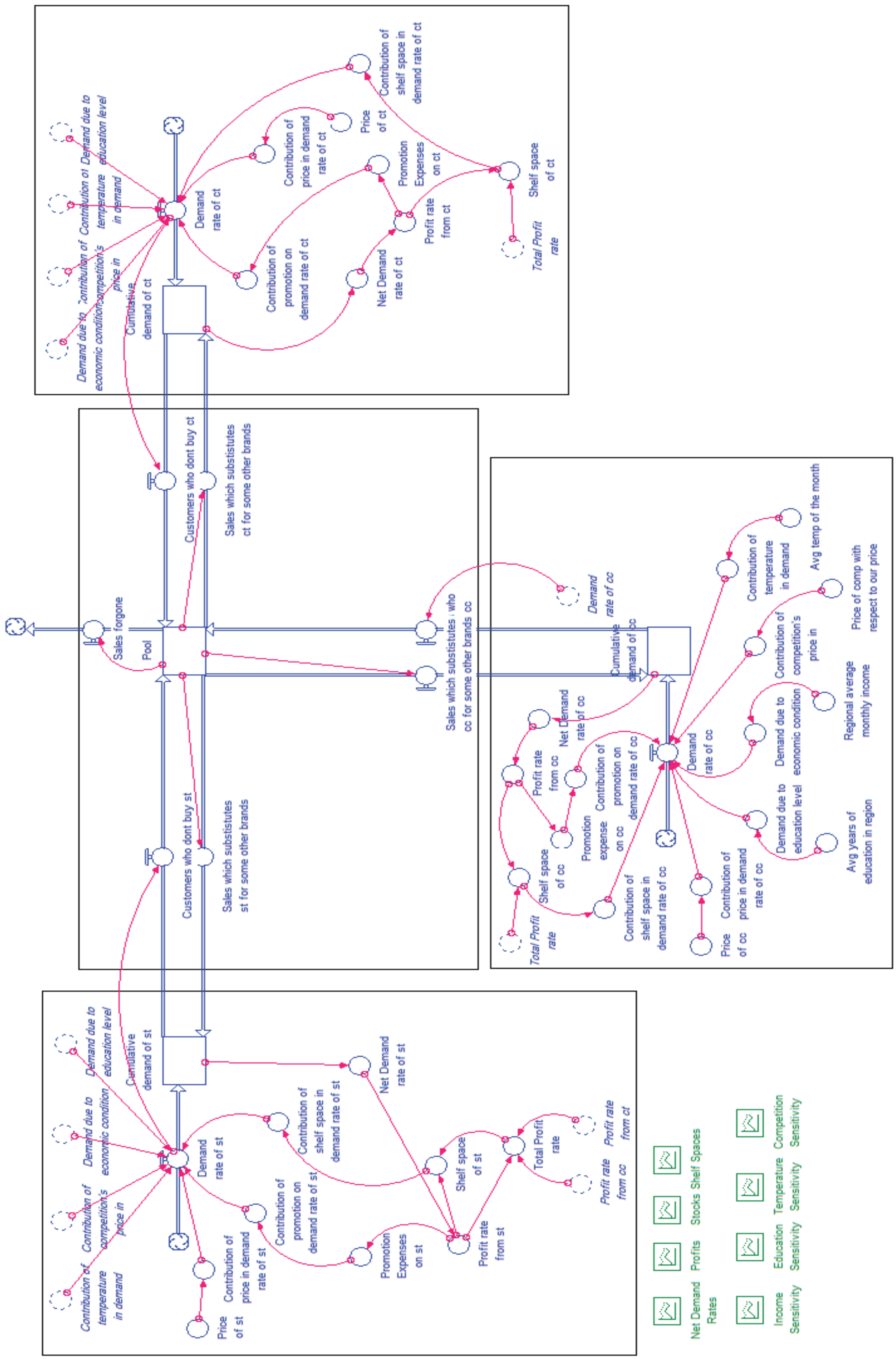


Figure 1. System Dynamics Model of the Shoe Retailing Store Developed in IThink

'Pool' has three inflows and four outflows. The three inflows are the rate of customers who want to switch from one brand to another and these are represented by inflows 'Customers who don't buy i', where 'i' may stand for one of the three brands. These three inflows increase '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. Whereas there are some customers who come in the retail store and they do not like their first choice and are unwilling to substitute their choice with any of the other two brands and 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.

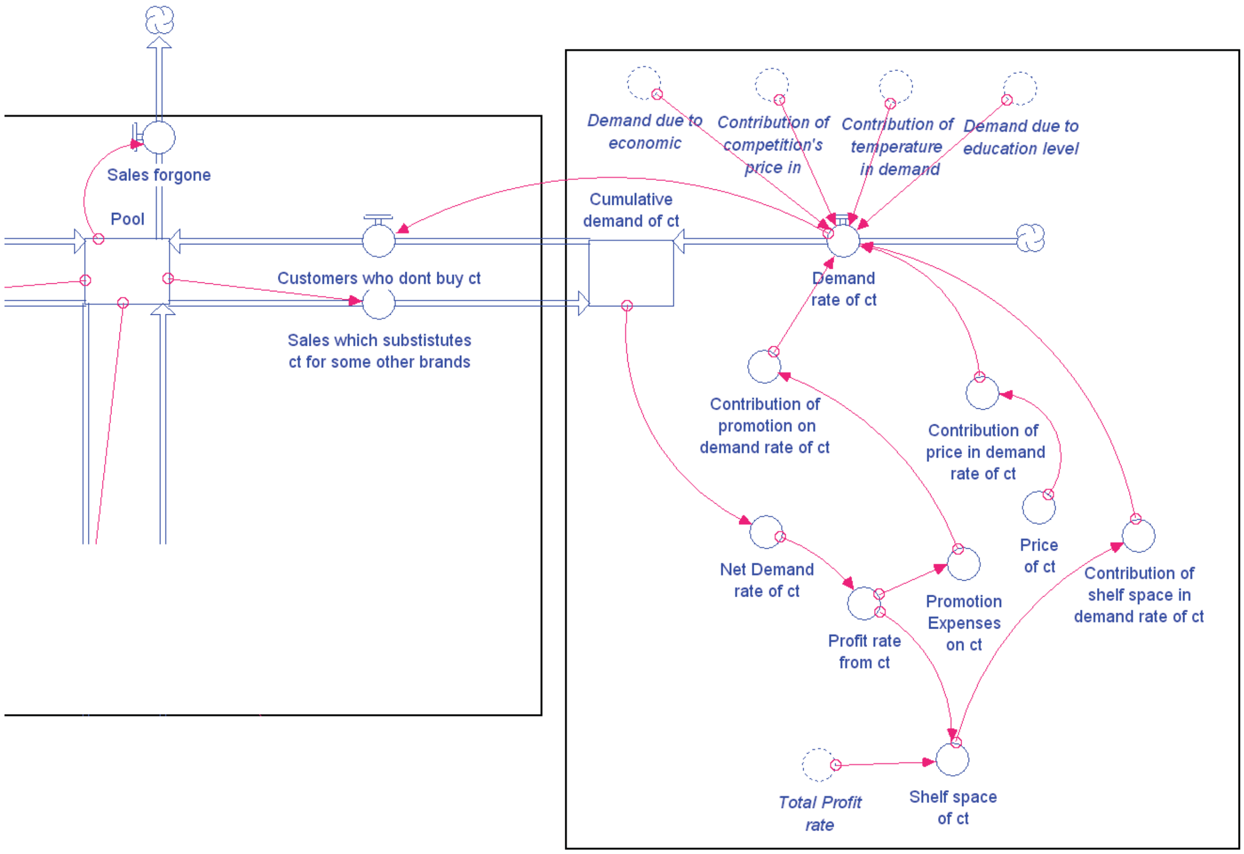


Figure 2. Stock and Flow Diagram of Brand 'ct'

Apart from the above mentioned variables which are directly influencing either stocks or inflows, there are some other variables that are indirectly affecting them. 'Net demand rate of ct' is 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. Following subsections describe important variables used in previous research and their usage in the current model.

Product Space Elasticity: According to Curhan (1972) space elasticity is the ratio of relative change in unit sales to relative change in shelf space. Positive change in space allocated to a brand brings positive change in sales; however, this change may not be a linear function (see Appendix 2 for its relation with display space). This relationship has been developed after interviewing retailing manager. However, the values of product space elasticity have been assumed in this study.

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, complement or substitute. When two brands complement each other, the increase in sale of one brand shall increase sale of the other brand. Whereas, in case where brands are substitute of each other, increased sale of one brand may result in decreased sale of substitutive brands. In the current study the selected brands are in general substitute of each other. The relationship of their substitution are put in the model after interviewing with the retailing manager and given in Appendix 2.

Operating Cost Elasticity: Marcel and Peter (1981) define operating cost elasticity function as the impact on operating cost by increased sales. 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 sales and profit is assumed to be linear and the relationship for each brand is given in Appendix 2. The data on profit margin of each brand is taken from relevant brand manager. The relationship can be further refined after collecting relevant empirical data.

Total Shelf Space Available: 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 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: In the start of product life cycle, a brand's demand is low however with time it increases gradually. In order to promote a certain brand in the initial stage of product life cycle a minimum bound of display space for that brand can be fixed in the model. This feature may also be included when number of brands is large and one strategically wants to restrict the model from allocating all the space to one or few brands whose profit margins are the highest. Another rationale behind allocating upper bound is that generally 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.

The values of upper and lower bound are decided very carefully because it is a restriction on the model while determining optimal solution. 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.

Shelf Space/Display Space: Shelf space of each brand is the number of shoes that can be displayed for that brand. The maximum allowable shelf space for the three brands that we have selected in the study is 15. The number 15 is decided by the shop / brand manager. The shop / brand manager decides 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. In this shoe retailing company the shop /brand managers usually allocate this number on the basis of their experience and team agreement. However, the model presented in this study can be extended for this purpose too.

Demographic Factors: The demographic factors of the location of the retail store affect on the sale of the different brands of the shoes. Based on the interviews with the brand managers two main demographic factors have been identified and included in the system dynamics model. 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 the sales of the three brands and average education and average monthly income are determined from interviews of the brand managers. These relationships are given in Appendix 2.

Environmental Factors: The environmental factors such as temperature and rainfall have potential to impact on the sale of shoe brands in a retail store. These factors depend upon the location of the retail store. Based on the interviews from the brand managers, temperature has been identified as a significant category that has direct influence on the demand/sale of the three brands of 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 relationships are given in Appendix 2.

Price of the Competition: It is widely accepted in marketing literature that price of competitive brands is a direct threat on the sale of a brand. Therefore, impact of price of competition has been included in the current study. It is hard to determine the relationship between price of competitive brands and sale of the three brands used in the study. Interviews of brand managers are used for estimating the relationship between price of competition with respect to the price of the three brands and the sales of the three brands. The relationships are given in Appendix 2.

4. RESULTS OF THE SYSTEM DYNAMICS MODEL

The profit of the retail store depends on the sales and profit margins of all the brands in the store. Objective of the retailer is to seek and implement such combination of sales of different brands with varying profits that maximizes the retail store's total profit. In the current study, the term demand will be used synonymous to sale, which assumes that all the demand is met by the retail store and there is no stock out. In this SD model the graphical results shall be used to find out the values of shelf spaces to be allocated to the three brands when profit is at its maximum value.

Graphs 1-4 show behavior of the important variables in the SD model. These graphs indicate that there is disturbance in the model in the early parts of the graphs. 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.

Graph 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 graph indicates that net demand rate of ‘st’ is more than ‘ct’, which in turn is more than the demand rate of ‘cc’. These results reasonably match with anticipated demand. The price of ‘st’ is less than ‘ct’ and the price of ‘ct’ is less than that of ‘cc’. Generally, such relationship of price produces similar sales results. Other variables such as, expenses on promotion, brand elasticity, and brand substitutability also show theoretical harmony with the graphical results of Graph 1. The comparison of the net profit rates of the three brands is shown in Graph 2. The relationship between the net profit rates show congruity with the 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 Graph 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’.

Graph 3 shows the comparison of the accumulated sales of the three brands and their relationship with the total profit rate. Accumulated sales of the three brands are represented in the form of stocks in the system dynamics model. The graph indicates that the accumulated demands are increasing as the time passes, which is a reasonable relationship. Total profit rate is sum of monthly profits from three brands under study. 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, which is also a reasonable relationship between accumulated sales and the total profit rate of the retail store.

5. SENSITIVITY ANALYSIS OF THE SYSTEM DYNAMICS MODEL

In the current study four regional variables have been incorporated 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 model shows an acceptable level of accuracy and sensitivity in its results when values of these variables are changed. The graphs showing sensitivity of these variables are given in Appendix 1.

Sensitivity for Average Monthly Income: The model shows reasonable (corroborated by the interviewed brand managers) sensitivity towards average monthly income of household around the retailing store. The sensitivity of the model towards this variable is shown in Graphs 5-7. When the value of average monthly income varies from PKR 2000 to PKR25000 to PKR 50000, setting the 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 graphs show that when location of the retail store is changed from low level of monthly income to higher level sales of the retail store also increases.

Sensitivity for Average Education Level: The model shows reasonable (corroborated by the interviewed brand managers) sensitivity towards average education level of the potential customers of the retailing store. The sensitivity of the model towards this variable is shown in

Graphs 8-10. These graphs 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, setting the 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. The 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. According to the brand managers the selected brands are liked by more educated people.

Sensitivity for Average Monthly Temperature: The model shows reasonable (corroborated by the interviewed brand managers) sensitivity towards average monthly temperature of region where the retailing store is located. The value of average monthly temperature generally varies from 12 □C to 35 □C. The sensitivity of the model towards this variable is shown in Graphs 11-13. When the value of average monthly temperature varies from 12 □C to 23 □C to 35 □C, setting the 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 some of the brands of the shoes is weather sensitive. Demand of the selected brands is highest during summer and the same pattern is reflecting in the graphs 11-13.

Sensitivity for Price of Competition: The model shows reasonable (corroborated by the interviewed brand managers) sensitivity towards price of competition. 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 Graphs 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, setting 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.

6. CONCLUSION AND FUTURE RESEARCH
7.

The desired output of the model is the optimal space allocation scheme for the case-study retail store specific conditions. Graph 4 shows the relationship between shelf spaces allocated to each brand and the total profit rate. Our objective is to find those values of shelf spaces of each brand at which the total profit rate is maximum. It is clear from the graph that from time 7.5 onwards the value of total profit rate has reached its maximum value and is almost constant. The values of shelf spaces of ‘st’, ‘ct’, and ‘cc’ from time 7.5 onwards are 7, 5, and 3 respectively. Hence, these values of shelf spaces are optimal values that yield maximum profit from the three brands with the given store specific parameters incorporated in the model. These values may change if values of other store specific variables such as, education level and brand specific values such as, shelf space elasticity are changed.

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/shop managers. The approach used in the current study can be used in many other retailing sectors, such as GMCG, electronic goods, and food 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. The relationships between the variables in the model can be further refined by collecting empirical data.

All areas in the store do not have same potential of getting customers' attention and contribution in sales. Therefore, the retailer has to decide that which brand is to be displayed at which place. The current model has not incorporated this aspect so far. Future research can further the model by building its capability to handle varying potential of shelf space.

The model developed in this study assumes that profit margin and operating cost is a linear function of sales/demand, which may not be a reasonable assumption. Future research can be conducted for incorporating such non-linear relationship between demand/sales and profit margin.

8. REFERENCES

1. Amrouchea, N. and G. Zaccour (2007). "Shelf-space allocation of national and private brands." European Journal of Operational Research 180, 648–663.

2. Anderson, E. E. and H. N. Amato (1974). "A Mathematical Model for Simultaneously Determining the Optimal Brand-Collection and Display-Area Allocation." Operations Research Vol. 22, No. 1, pp. 13-21.

3. Borin, N. and P. Farris (1995). "A Sensitivity Analysis of Retailer Shelf Management Models." Journal of Retailing 71(2): 153-171.

4. Bultez, A. and P. Naert (1988). "SH.A.R.P.: Shelf Allocation for Retailers' Profit." Marketing Science Vol. 7, No. 3, pp. 211-231.

5. Buttle, F. (1984). "Retail space allocation." International Journal of Physical Distribution and Material Management Vol. 14 Iss: 4, pp.3 - 23.

6. Cairns, J. P. (1962). "Suppliers, Retailers, and Shelf Space." The Journal of Marketing Vol. 26, No. 3, pp. 34-36.

7. Campo, K., E. Gijsbrechts, et al. (2000). "The impact of location factors on the attractiveness and optimal space shares of product categories." Intern. J. of Research in Marketing 255-279.

8. Cox, K. K. (1970). "The Effect of Shelf Space upon Sales of Branded Products." Journal of Marketing Research Vol. 7, No. 1, pp. 55-58.

9. Corstjens, M. and P. Doyle (1983). "A Dynamic Model for Strategically Allocating Retail Space." The Journal of the Operational Research Society Vol. 34, No. 10, pp. 943-951.

10. Corstjens, M. and P. Doyle (1981). "A Model for Optimizing Retail Space Allocations." Management Science Vol. 27, No. 7, pp. 822-833.

11. Creusen, M. E. H. (2010). "The importance of product aspects in choice: the influence of demographic characteristics." Journal of Consumer Marketing 27(1): 26-34.

12. Curhan, R. C. (1972). "The Relationship between Shelf Space and Unit Sales in Supermarkets." Journal of Marketing Research Vol. 9, No. 4, pp. 406-412.

13. Drèze, X., S. J. Hoch, et al. (1994). "Shelf Management and Space Elasticity." Journal of Retailing: 301-326.

14. Fancher, L. A. (1991). "Computerized space management: A strategic weapon." Discount Merchandiser 31 (3) 64-65.

15. Gillooley, D. and R. Varley (2001). Retail Product Management: Buying and Merchandising. London, Routledge.

16. Lim, A., B. Rodrigues, et al. (2004). "Metaheuristics with Local Search Techniques for Retail Shelf-Space Optimization" Management Science, Vol. 50, No. 1, pp. 117-131.

17. Mason, J. B. and M. L. Mayer (1990). Modern retailing: Theory and Practice. Boston, Irwin.

18. Martín-Herrán, G., S. Taboubi, et al. (2006). "The Impact of Manufacturers' Wholesale Prices on a Retailer's Shelf-Space and Pricing Decisions." Decision Sciences 17(1): 71-90.

19. Mendelson, H., J. S. Pliskin, et al. (1980). "A Stochastic Allocation Problem." Operations Research Vol. 28, No. 3, pp. 687-693.

20. Miceli, T. J., C. F. Sirmans, et al. (1998). "Optimal Competition and Allocation of Space in Shopping Centers." Journal of Real Estate Research 16(113-126).

21. Milling, P. M. (1996). "Modeling Innovation Processes for Decision Support and Management Simulation." System Dynamics Review 12(3): 211–234.

22. Praskievicz, S. and H. Chang (2009). "Identifying the Relationships Between Urban Water Consumption and Weather Variables in Seoul, Korea." Journal Physical Geography 30(4): 324-337.

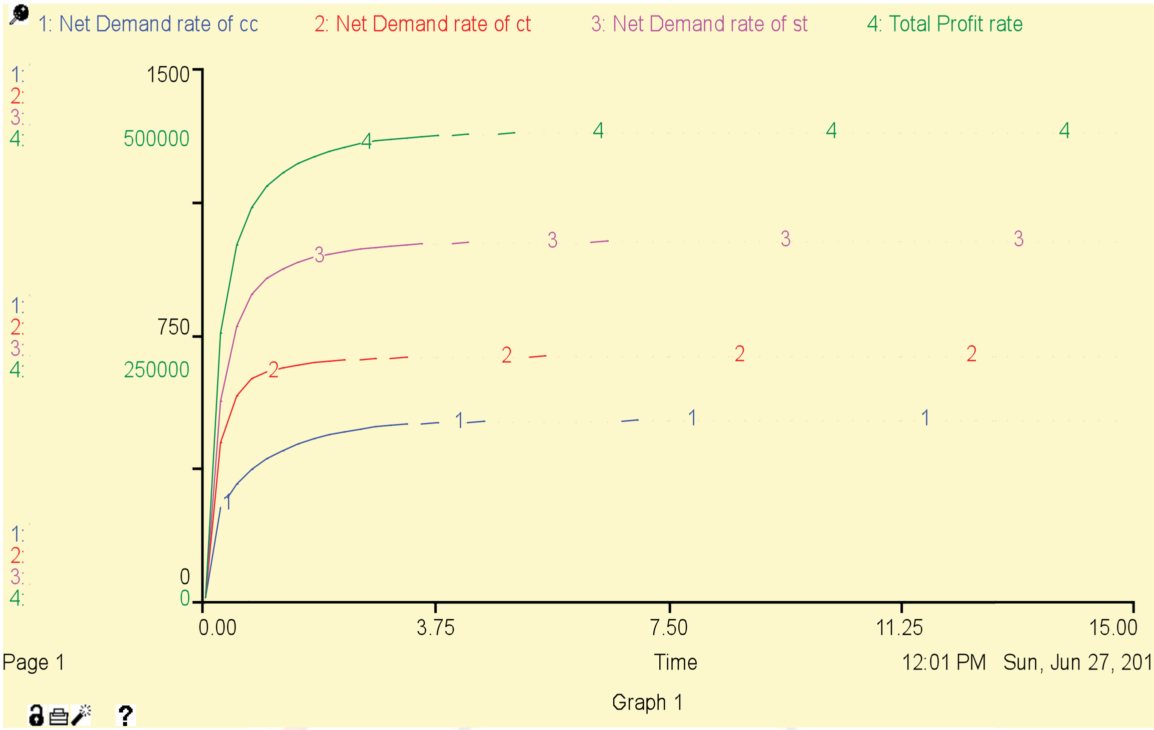
23. Singh, M. G., R. Cook, et al. (1988). "A Hybrid Knowledge-Based System for Allocating Retail Space and for Other Allocation Problems." Interfaces Vol. 18, No. 5, pp. 13-22.

24. Yang, M.-H. (2001). "An efficient algorithm to allocate shelf space." European Journal of Operational Research 146, 284–301.

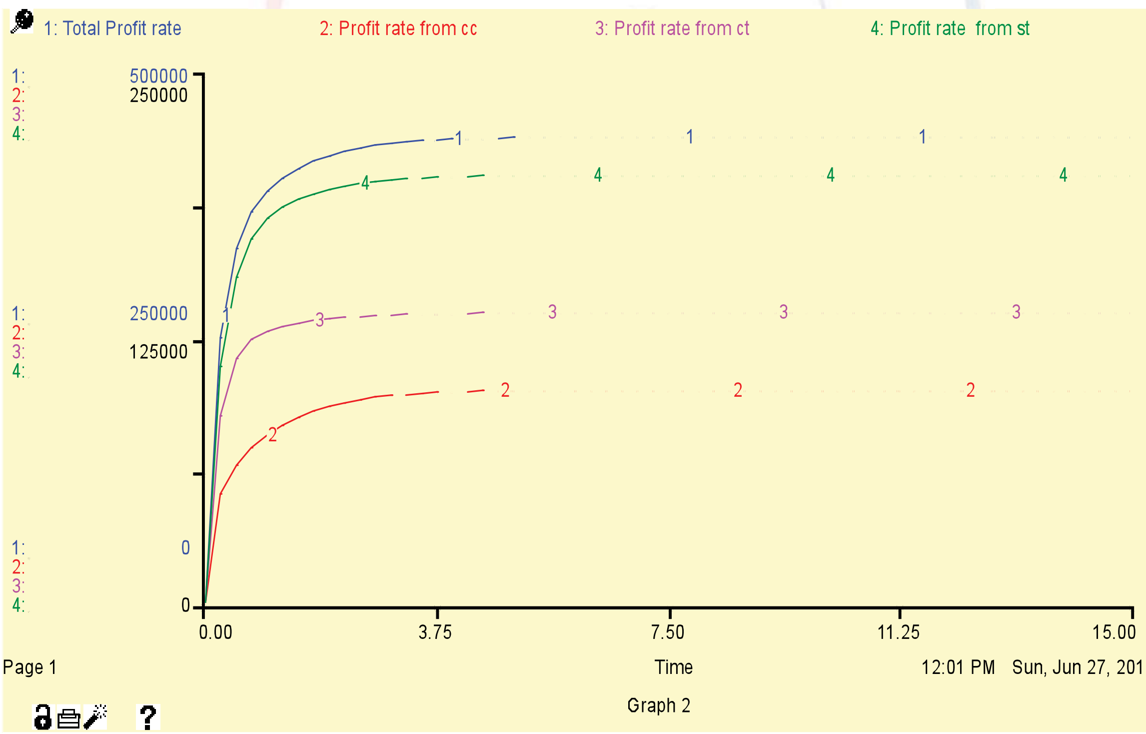
25. Yang, M. H. and W. C. Chen (1999). "A study on shelf space allocation and management." Int. J. Production Economics 60-61: 309-317.

26. Zufryden, F. S. (1986). "A dynamic programming approach for product selection and supermarket shelf-space allocation." Journal of Operations Research Society 37 (4).

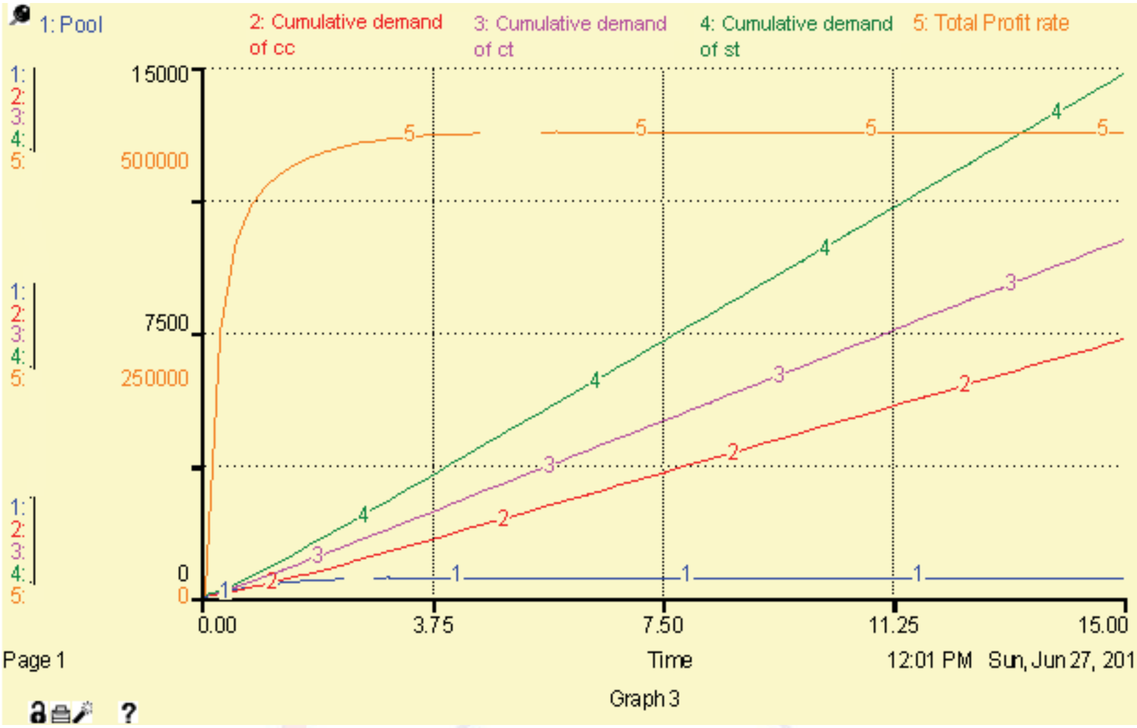
Appendix 1



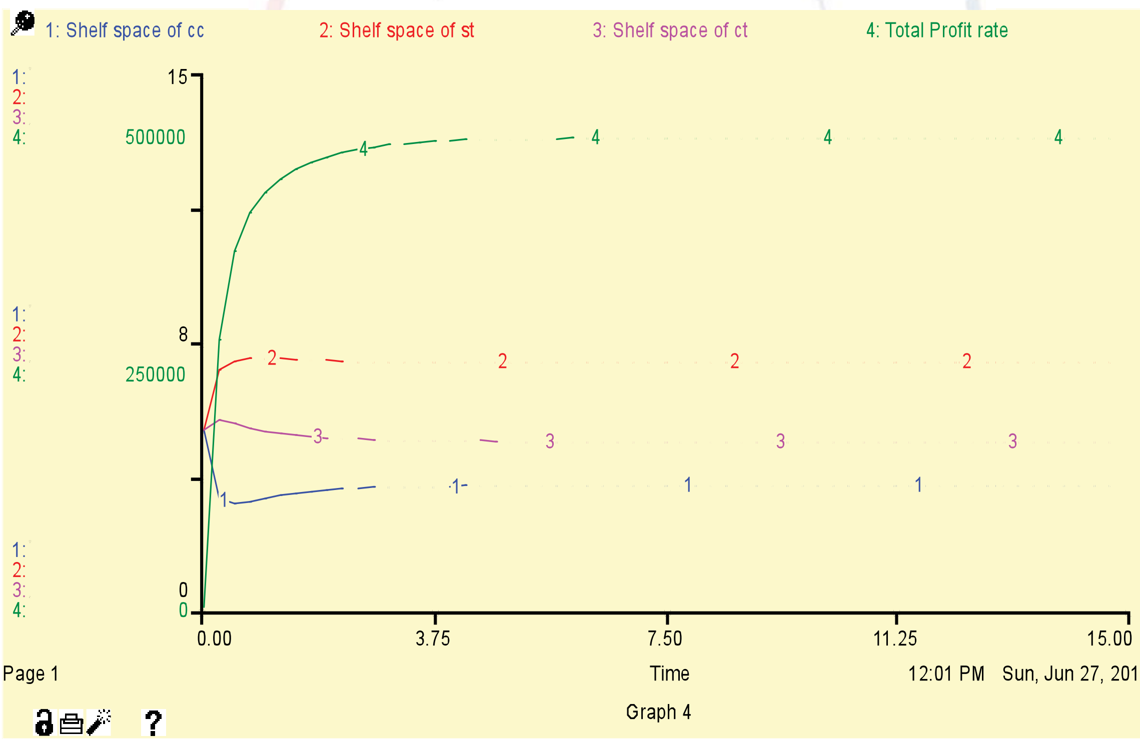
Graph 1. Net Demand Rates of Brands



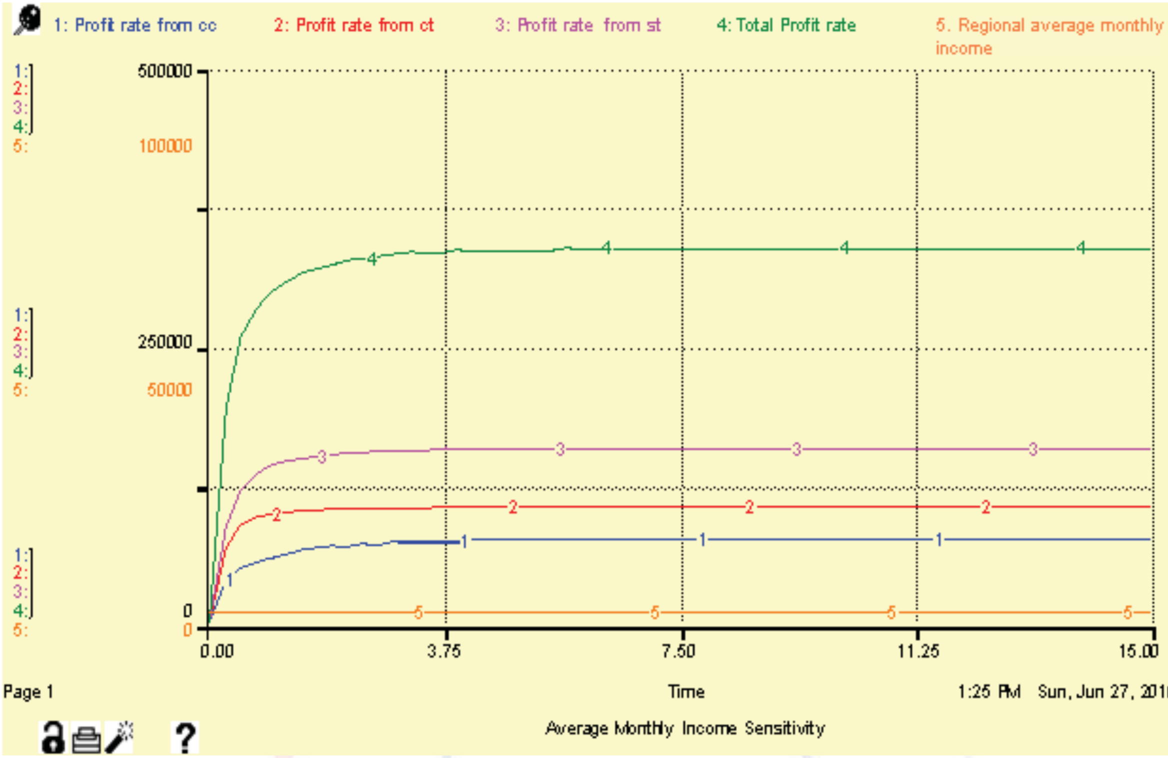
Graph 2. Profit Rates of the Three Brands



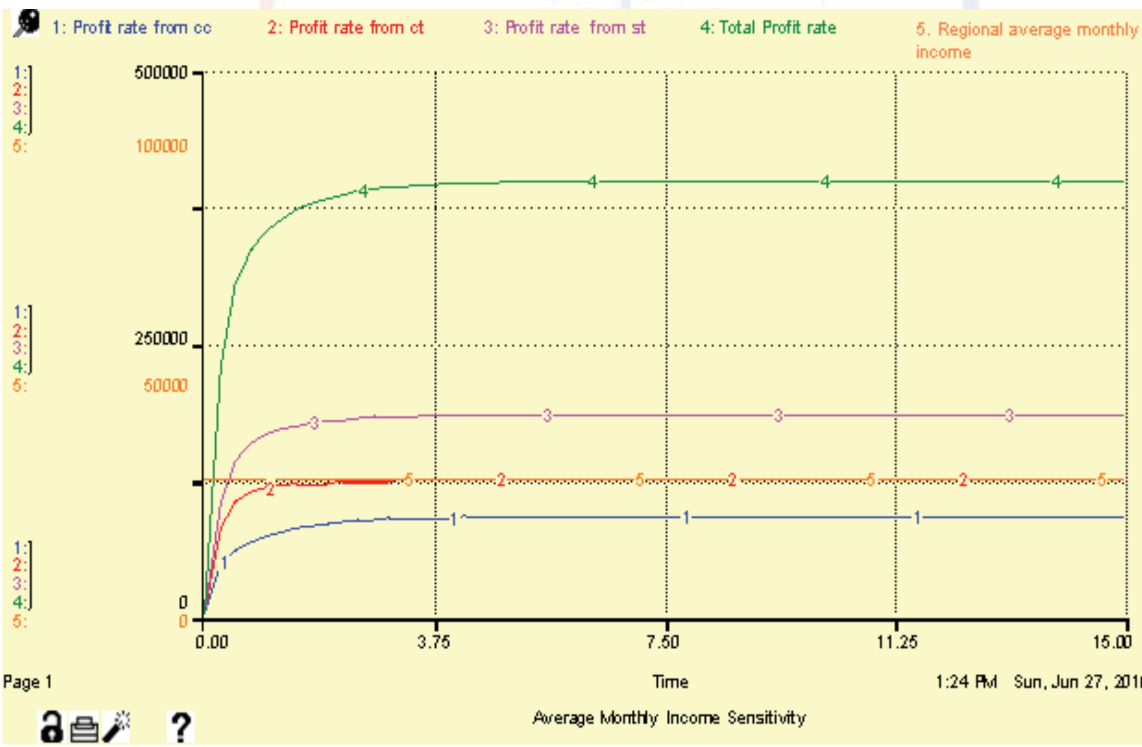
Graph 3. Cumulative Demands



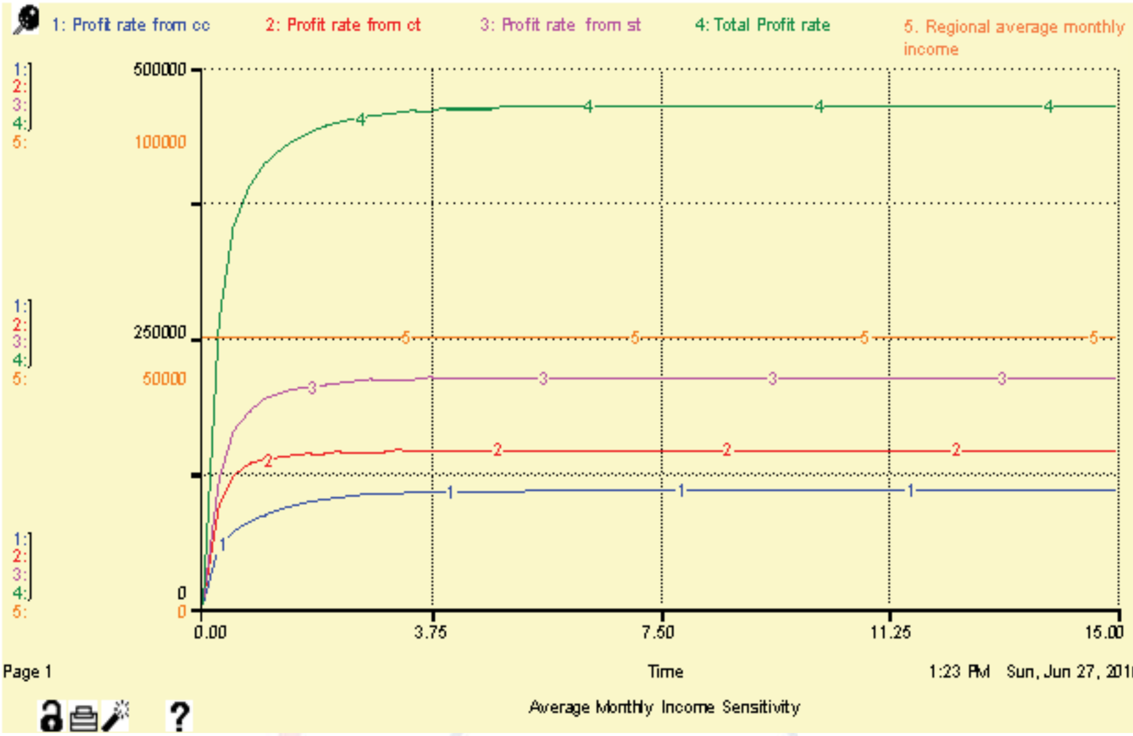
Graph 4. Shelf Spaces and Total Profit Rates



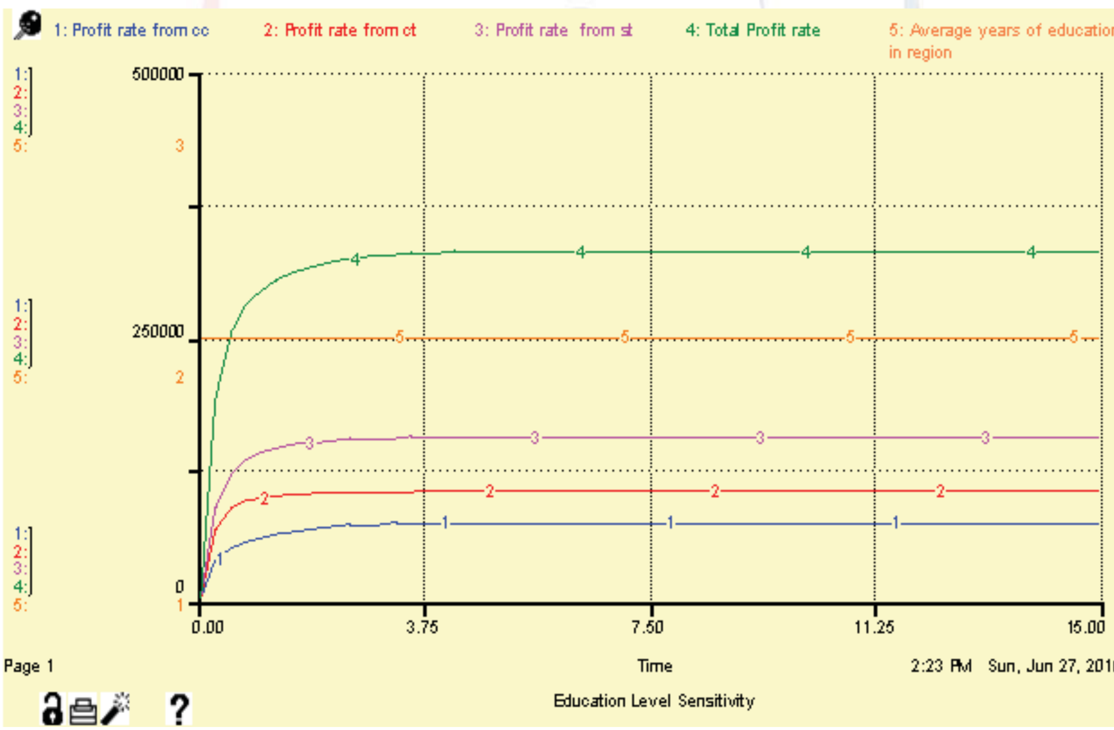
Graph 5. Sensitivity for Average Monthly Income (PKR 2000)



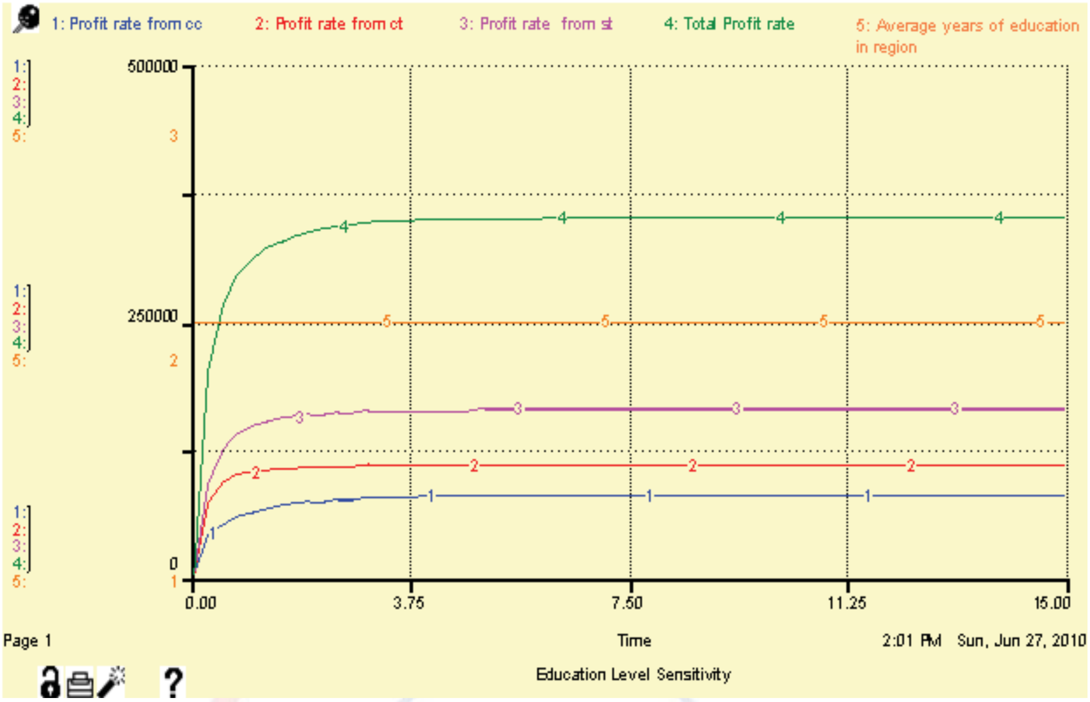
Graph 6. Sensitivity for Average Monthly Income (PKR 25000)



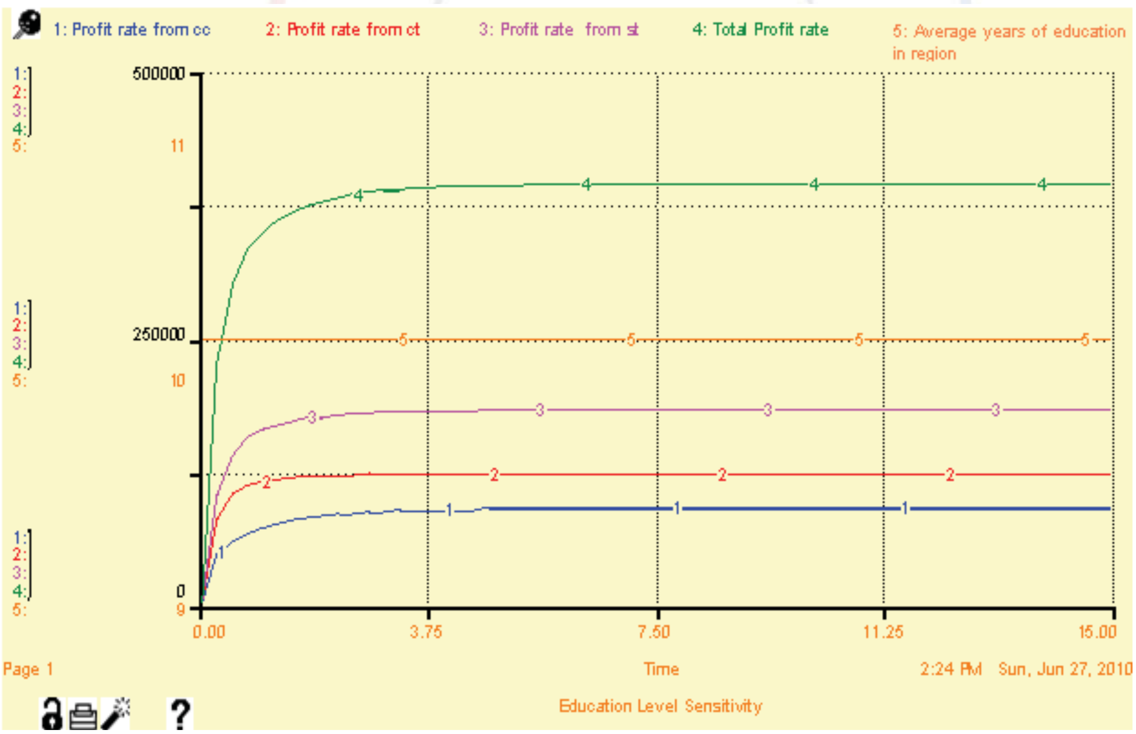
Graph 7. Sensitivity for Average Monthly Income (PKR 50000)



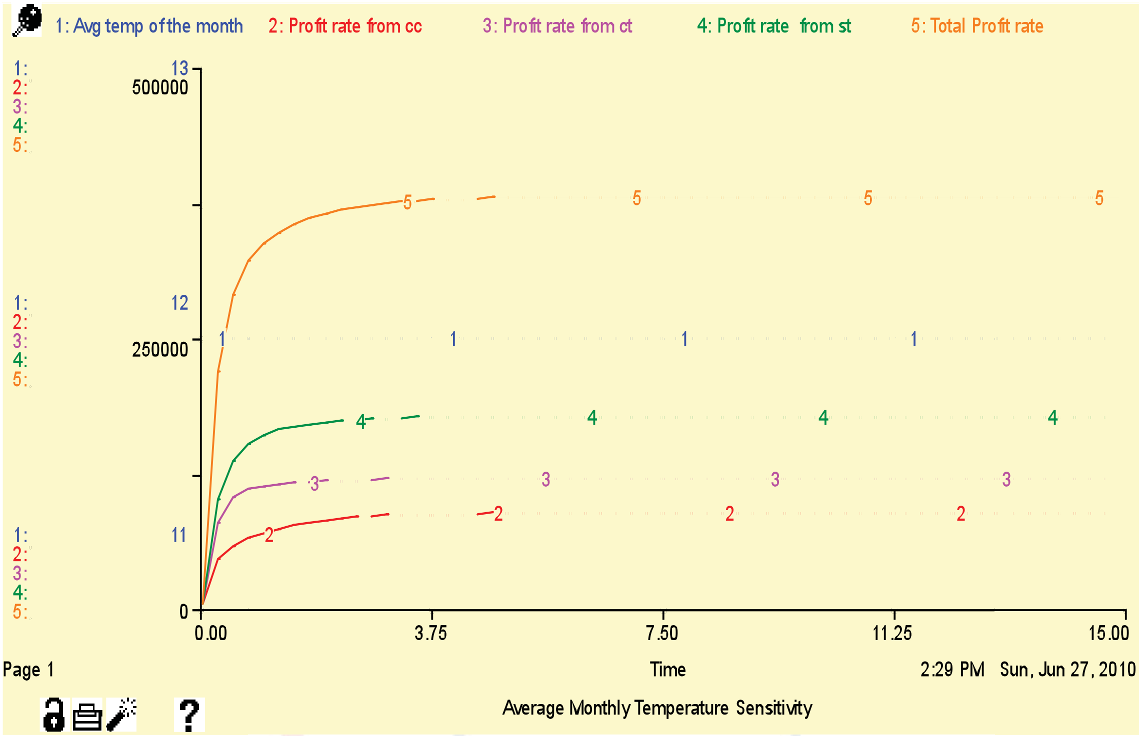
Graph 8. Sensitivity for Average Education Level (2 Years)



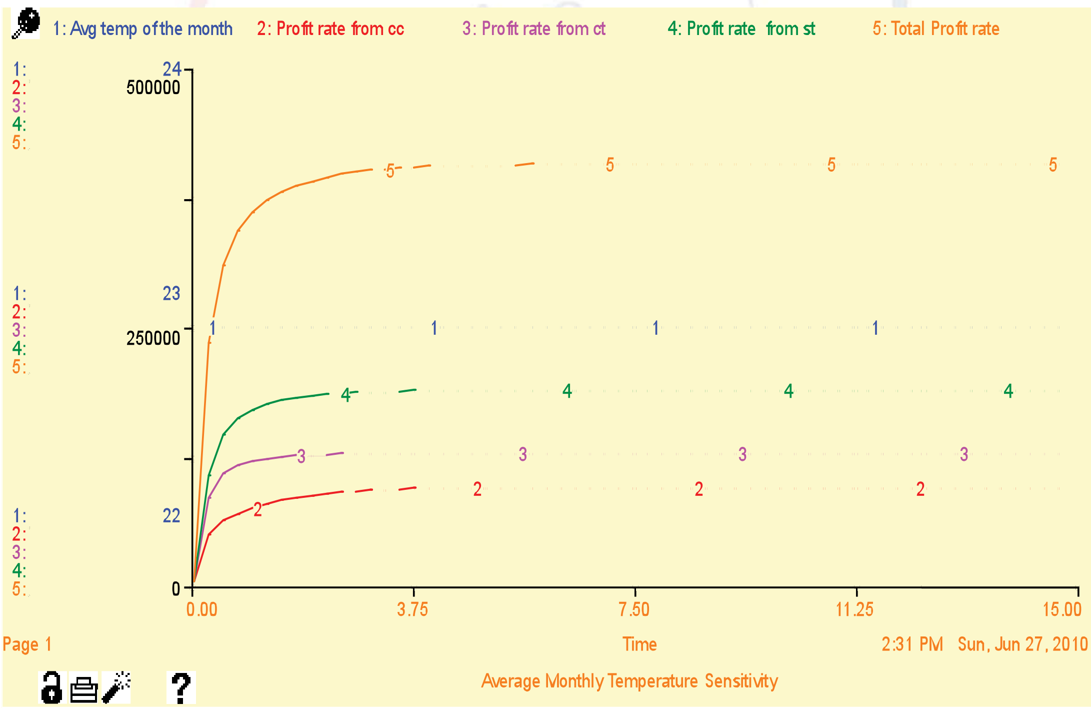
Graph 9. Sensitivity for Average Education Level (5 Years)



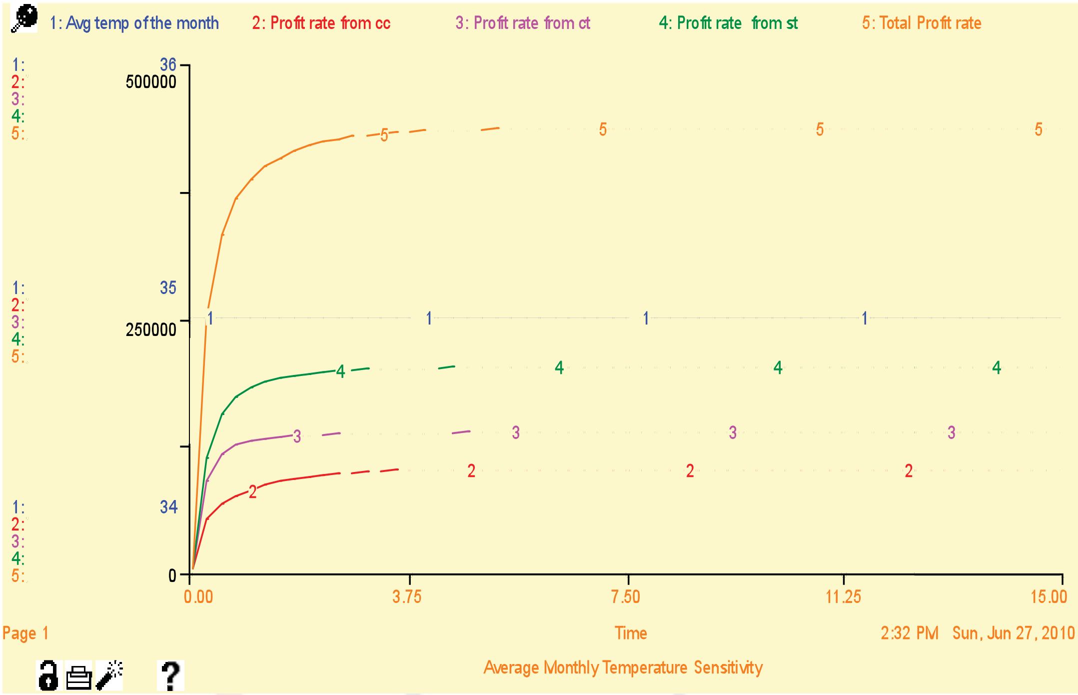
Graph 10. Sensitivity for Average Education Level (10 Years)



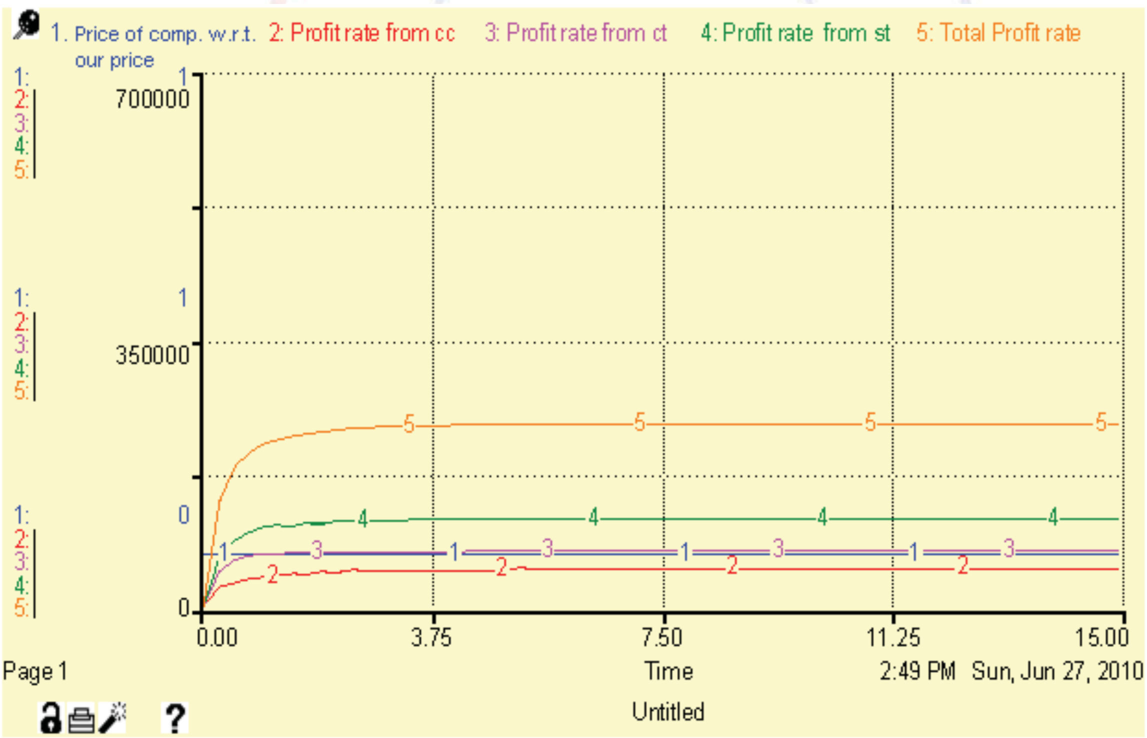
Graph 11. Sensitivity for Average Monthly Temperature (12℃)



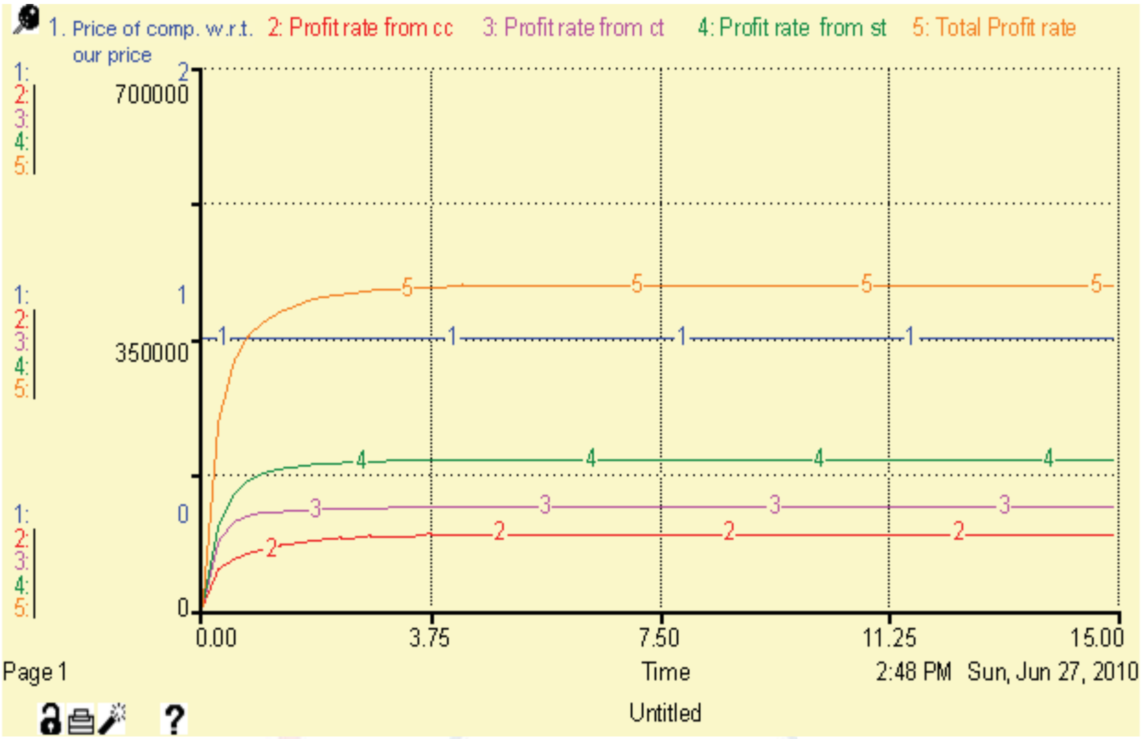
Graph 12. Sensitivity for Average Monthly Temperature (23℃)



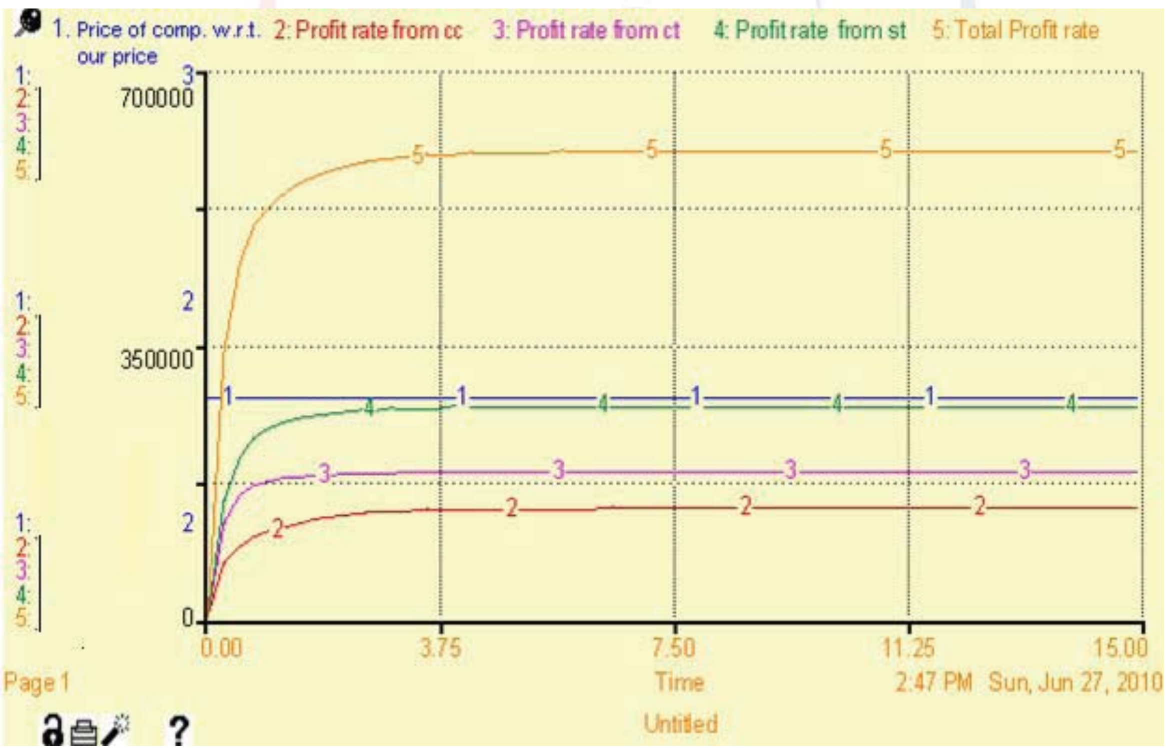
Graph 13. Sensitivity for Average Monthly Temperature (35℃)



Graph 14. Sensitivity for Price of Competition (0.1)



Graph 15. Sensitivity for Price of Competition (1)



Graph 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_due_to__education_level+Demand_due_to__economic_condition+Contribution_of__price_in_demand__rate_of_cc+Contribution_of__promotion_on__demand_rate_of_cc+Contribution_of__shelf_space_in__demand_rate_of_cc+Contribution_of__temperature__in_demand
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_due_to__education_level+Demand_due_to__economic_condition+Contribution_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

Notice

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