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A system dynamics model to determine products mix

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CHRONICLE

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ABSTRACT

This paper presents an implementation of system dynamics model to determine appropriate product mix by considering various factors such as labor, materials, overhead, etc. for an Iranian producer of cosmetic and sanitary products. The proposed model of this paper considers three hypotheses including the relationship between product mix and profitability, optimum production capacity and having minimum amount of storage to take advantage of low cost production. The implementation of system dynamics on VENSIM software package has confirmed all three hypotheses of the survey and suggested that in order to reach better mix product, it is necessary to reach optimum production planning, take advantage of all available production capacities and use inventory management techniques.

1. Introduction

Aggregate analysis in manufacturing system design has been a popular method to detect the links between the non-feasible alternatives at earlier stages and there are various studies associated with the implementation of such method (Clark et al., 1995; Helo, 2000; Ovalle & Marquez, 2003). Stave (2002), for instance, applied system dynamics (SD) to improve public participation in environmental decisions. Tesfamariam and Lindberg (2005) presented a reusable system dynamics (SD) technique (Karnopp et al., 1976; Sterman, 2000) and the Analytic Network Process for a rapid and strategically consistent decision-making. The SD model investigates the causal relationships and interdependence of the factors, which could be simulated while the ANP is capable of providing the preferences towards the performance objectives consistent with the strategic goals. The basis for the SD and ANP is the Causal Loop Diagram (CLD), which demonstrates the relevant relationships and feedbacks among the model parameters. Kamath and Roy (2007) proposed a SD technique for detecting critical information flows based on the system dynamics model of a two-echelon supply chain. They disclosed that the delivery delay information had little impact while the loop that connected retail

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sales with production order influenced the dynamics, significantly. They claimed that the information feedback based methodology was good enough to be useful for designing decision support systems for capacity augmentation. Risch et al. (1995) described the implementation of SD tools and processed to help a major integrated forest products company develop its strategy. The company had recently acquired a major pulp and paper mill and had entered a new venture, the specialty paper business. Despite substantial amount of investment, the mill was losing money, contrary to expectations. They drew on established strategic frameworks, using SD to integrate the data created by traditional analyses and developed a representation of management's collective mental model, demonstrating the feedback processes they believed would lead to success in the specialty market. They developed a dynamic hypothesis, explicated in the form of causal loop diagrams, to describe the failure of the firm's strategy to yield profitable operation for the mill. They explained how leading team underestimated a variety of side effects of the new strategy, both at the market level and in the mill. These side effect feedbacks undercut the intended impact of the new strategy.

2. The proposed study

This paper presents a system dynamics model to determine appropriate product mix by considering various factors such as labor, materials, overhead, etc. The proposed model of this paper considers three hypotheses including the relationship between product mix and profitability, optimum production capacity and having minimum amount of storage to take advantage of low cost production. Fig. 1 demonstrates the closed loops among various components of the production system.

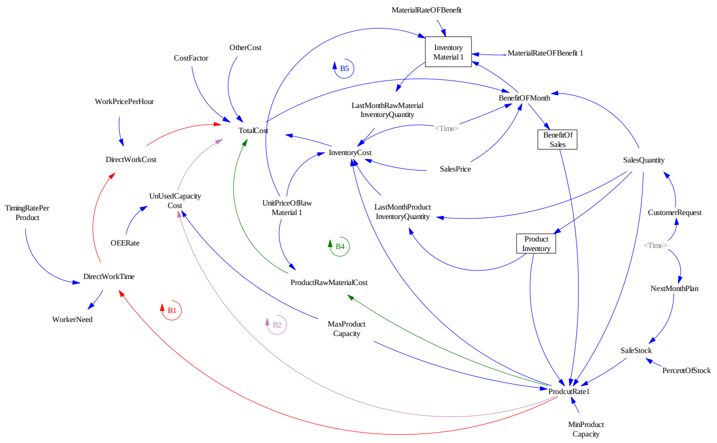

Fig. 1. The preliminary framework of the study

As we can observe from Fig. 1, there are four loops associated with production system, which are described as follows,

1. B1: The first loop is associated with direct payment, which is associated with the number of production unit. In our survey, we assume that the payment cost increases as the number of production unit increases and this has negative impact on profitability.

2. B2: The second loop is related to unused capacity of production limit, which has a negative impact on profitability.

3. B3: The third loop is associated with raw materials and when the cost of raw materials especially of a particular one, M1, increases, we may expect higher expenses on the cost of production and this will have a negative impact on profitability.

4. B4: The fourth loop is related to inventory expenses of final products. We expect to have higher expenses the cost of inventory increases and lower profit.

5. B5: The fifth look is associated with inventory expenses of raw materials and similarly we anticipate higher cost of inventory and lower profitability as inventory expenses increase.

Fig. 2 demonstrates the final model of the proposed model.

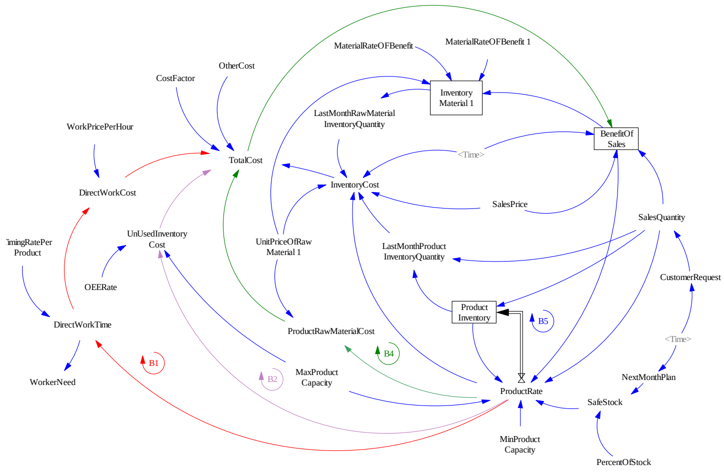

Fig. 2. The proposed structure of the proposed model

The effects of different variables are as follows,

1. The effect of raw materials: The first variable is associated with the effect of raw material, which is as follows,

   ∫ IF THEN ELSE(BenefitOfSales 2<0 , 0,(BenefitOfSales 2*MaterialRateOFBenefit 1 1/UnitPriceOfRawMaterial 1 0)+(BenefitOfSales 2*MaterialRateOFBenefit 3 /6.5))

2. Profit: Profit is an important part of the survey and has been influenced as follows,

   ∫ IF THEN ELSE(BenefitOfSales 2<0 , 0,(BenefitOfSales 2*MaterialRateOFBenefit 1 1/UnitPriceOfRawMaterial 1 0)+(BenefitOfSales 2*MaterialRateOFBenefit 3 /6.5))

3. Production rate: This variable is influenced by the increase in demand and it is modeled as follows,

   ∫ IF THEN ELSE(BenefitOfSales 2<0 , 0,(BenefitOfSales 2*MaterialRateOFBenefit 1 1/UnitPriceOfRawMaterial 1 0)+(BenefitOfSales 2*MaterialRateOFBenefit 3 /6.5))

In addition, there are some external factors influencing the production, which are as follows,

1. Market demand, inventory of final product and inventory expenses of final product: These three components are essential parts of market development and the influence profitability, significangtly. Therefore, we consider the following condition,

   IF THEN ELSE((((ProductRate0+LastMonthProductInventoryQuantity 0-SalesPrice 2)* SalesQuantity2+(UnitPriceOfRawMaterial10*LastMonthRawMaterialInventoryQuantity0)) * 0.21*Time/12)<0,0,(((ProductRate 0+LastMonthProductInventoryQuantity0-SalesPrice2) * SalesQuantity 2+ (UnitPriceOfRawMaterial10*LastMonthRawMaterialInventoryQuantity0)) *0.21*Time/12)/10000)

2. Opportunity cost: For the proposed model of this survey we assume the opportunity cost as the cost of unused capacity of equipment as follows,

   IF THEN ELSE(ProductRate 0>=MaxProductCapacity 0,0,((MaxProductCapacity 0-ProductRate0)*OEERate 0*3.5))

3. Rates of raw material

   (5.6*ProductRate 0)+(2e-005*UnitPriceOfRawMaterial 1 0*ProductRate 0*0)

4. The amount of labor equired

   ProductRate 0*TimingRatePerProduct 0

5. The rate of payment

   DirectWorkTime*WorkPricePerHour

The proposed study consideres the following three hypotheses,

1. The first hypothesis: Market demand and profitability are the most important factors influencing product mix.
2. The second hypothesis: Optimal capacity utilization plays essential role on product mix.
3. The third hypothesis: Inventory expenses of raw materials as well as final products influence profitability.

The proposed study has been applied in one of Iranian firms, which produced perfoum, shampoo and cosmetic products. Next, we present details of our findings on testing three hypotheses of the survey using SD technique.

3. The results

In this section, we present details of our findings on testing various hypotheses of the survey. Fig. 3 demonstrates the results of our investigation on the cost of direct cost and production ratio.

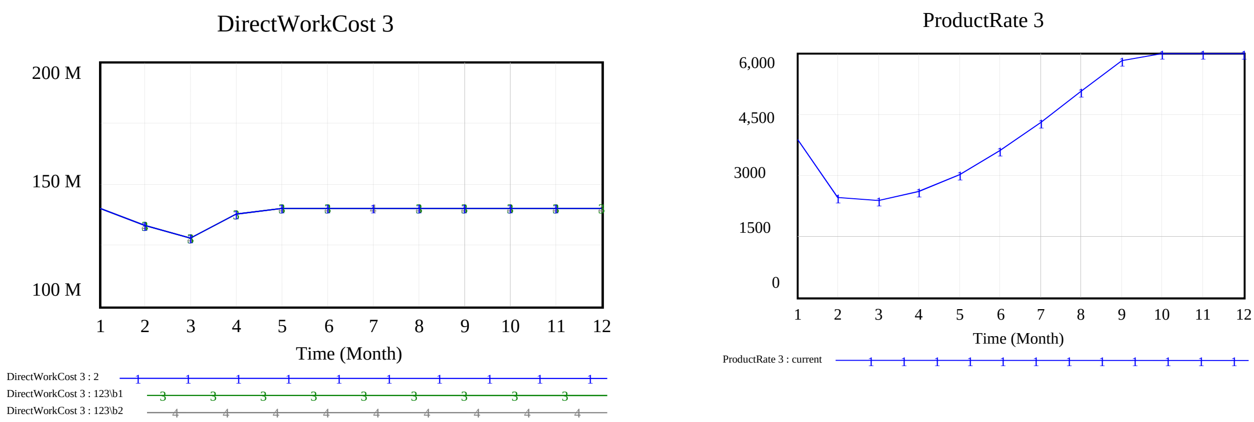

Fig. 3. The production rate as well as direct work expenses

In our survey, we have realized that the cost of final product could be reduced by replacing some cheaper raw materials. One of the primary concerns on production development is to reduce the un-used capacity. In our survey, there was a correlation between cosmetic and shampoo and we needed to find a balance between these two groups of products. Our survey indicates that moisturizing daycare cream and lipstick both need M1 raw material and we may have some adjustment on unused capacity by switching between two types of products in various months as shown in Fig. 4 as follows,

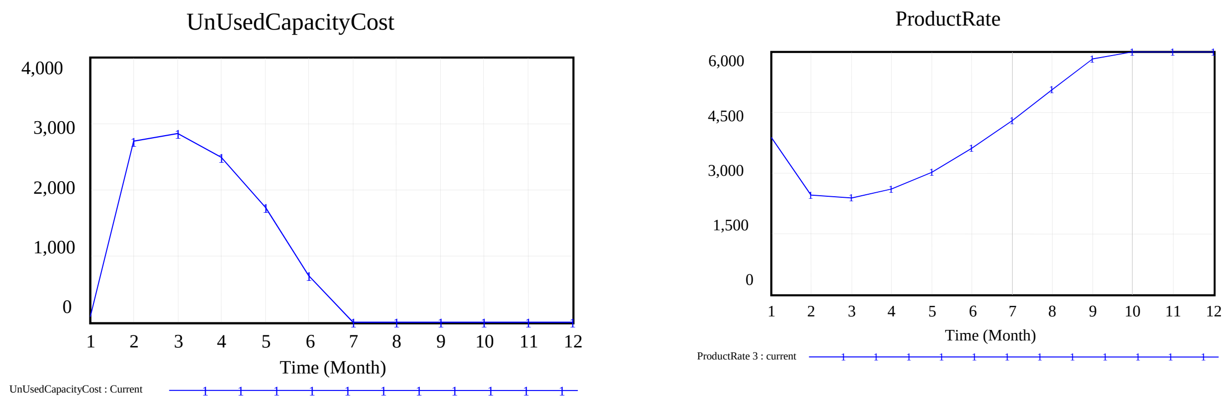

Fig. 4. The trend for unused capacity and production rate

In addition, Fig. 5 shows the production rate and unused capacity when we use some capacity for production of shampoo instead of moisturizing daycare cream.

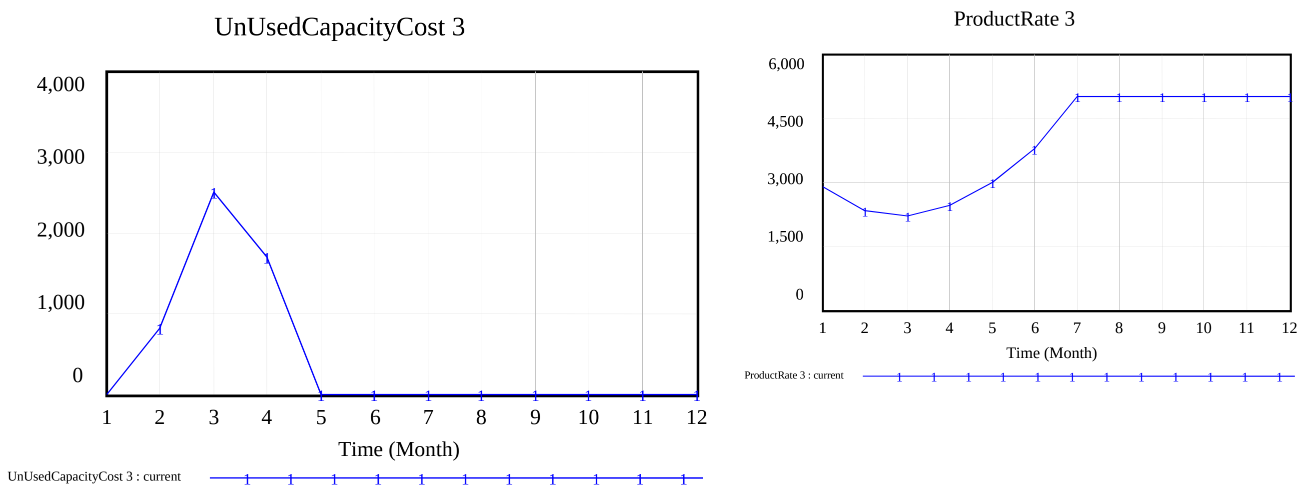

Fig. 5. The unused capacity expenses and production rate

Opportunity cost is another component of this survey and we may be able to reduce this item by increasing the production size. These observations confirm three hypotheses of the survey and suggested that in order to reach better mix product, it is necessary to reach optimum production planning, take advantage of all available production capacities and use inventory management techniques.

4. Conclusion

In this paper, we have presented an empirical investigation to study the production mix and learn more on how to increase the profitability by making some changes on unused capacity, raw materials, etc. The proposed study has been implemented in one of Iranian producers of cosmetic and sanitary products. The proposed systems dynamic has been implemented in VENSIM software package and the results have been discussed under various conditions.

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