A DECISION SUPPORT SYSTEM FOR GENERATING OPTIMAL RAW MILK MANAGEMENT STRATEGIES IN A DAIRY SUPPLY CHAIN

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A DECISION SUPPORT SYSTEM FOR GENERATING

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IN A DAIRY SUPPLY CHAIN

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Thesis Abstract

Burak Gül, "A Decision Support System for Generating Optimal Raw Milk Management Strategies in a Dairy Supply Chain"

The main supply of the dairy business, raw milk, is one the most volatile supplies in fast-moving goods businesses since there are many areas that cause complexities. Raw milk has a high supply seasonality that contradicts with the demand; there is a harsh competition for supply that forces long-term contracts and, inventory alternatives are very limited due to perishability. Moreover, the demand is also volatile and highly sensitive to lost sales. Therefore, it is necessary to utilize an optimal mix of supply, production and inventory strategies that takes all of the items described into account; however, such optimization practices are not common and the strategy mix is usually determined by experience and intuition, being likely to provide a suboptimal solution. The goal of this study is to eliminate the trial-and-error methodology of strategy determination process by implementing a mathematical model of the whole raw milk management system and the relevant strategy options as the basis of a Decision Support System (DSS) to automate the strategic raw milk planning process in an actual dairy company. In addition to modeling and optimization, this study focuses on the user interface design in DSS development for practical use by providing an example with incorporating the new generation Microsoft Ribbon interface.

Tez Özeti

Burak Gül, "Sütlü Ürünler Tedarik Zincirinde Eniyi Çiğ Süt Yönetim Stratejilerini Oluşturmak için bir Karar Destek Sistemi"

Sütlü ürünler endüstrisinin temel girdisi olan çiğ süt, hızlı tüketim sektöründeki en değişken girdilerden biridir, zira karmaşıklık yaratan birçok nokta bulunmaktadır. Çiğ sütün, talep ile ters orantılı yüksek bir arz mevsimselliği bulunmaktadır ve sütün kolay bozulabilir yapısı nedeniyle stok tutma seçenekleri kısıtlıdır. Aynı zamanda, arz için, uzun süreli sözleşmeleri zorunlu kılan sert bir rekabet ortamı söz konusudur. Müşteri tarafında da değişken ve satış kaybına oldukça duyarlı bir talep yapısı mevcuttur. Bu nedenle, bütün bu unsurları bir arada hesaba katabilen, tedarik, üretim ve stok planlaması için optimal bir strateji bileşiminin bulunması gerekli olmuştur. Buna karşın, bu tür eniyileme uygulamaları yaygın değildir ve stratejiler, genellikle deneyim ve sezgiler ile belirlenerek optimale tam ulaşmayan sonuçlar elde edilmektedir. Bu çalışmanın amacı, deneme yanılmaya dayalı strateji belirleme sürecini; bir karar destek sistemine temel oluşturacak şekilde, çiğ süt yönetim sisteminin ve ilgili karar seçeneklerinin matematiksel bir modelini oluşturarak, gerçek hayatta kullanılacak otomatik bir çiğ süt stratejik planlama sistemine dönüştürmektir. Bu çalışma, eniyileme modellemesinin yanı sıra, hayata geçirmeye uygun bir örnek teşkil edecek şekilde yeni nesil Microsoft Ribbon arayüzünü kullanarak karar destek sistemlerinde kullanıcı arayüzü tasarımı konusuna da değinmektedir.

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CHAPTER 1

INTRODUCTION

The nature of the milk is different from the supplies of other types of businesses and there are many areas that cause complexities. Raw milk has a high seasonality, and this seasonality is actually the opposite of the demand seasonality. In summer, the cows produce more milk, but the demand is reduced. However, as the academic semester starts in autumn, in the “back-to-school” season, demand suddenly increases but supply decreases due to weather conditions.

The gap between demand and supply cannot simply be managed by getting less milk in summer and more milk in winter. There are long-term contracts with the milk supplying villages and farms and all milk must be acquired no matter what the actual need is.

The only way to cover this gap is to find a way to store the milk until the need arises, but the life of raw milk is only 2 days and it is not possible to store it for a long time unless it is processed. There are only two types of milk products that can be stored long enough: long life milk and milk powder. Their shelf lives are 6 months and 12 months respectively. Long life milk is stored to be sold where there is milk shortage and milk powder is used to produce dairy products with less raw milk consumption. Other dairy products such as yoghurt or desserts are perishable products and their shelf lives are even less than a month, eliminating any inventory buildup option.

Therefore, external sources of milk (such as purchased milk powder or short-term contracted raw milk sales/purchases from/to other companies) must also be considered for raw milk management. In the long run, the objective is to meet all customer demands when there is milk shortage and to manage excess milk with the least cost when there is excess. A long-term milk strategy must be generated for achieving these objectives. Some common strategies can be listed as follows:

- Store milk powder/long life milk and manage the seasonality with the help of inventory.
- Get new sources of milk when there is a need and break contracts when there is excess milk.
- With promotions and price adjustments, manage the seasonality by managing demand.
- Create new product recipes with alternative milk replacers such as milk powder.

Each strategy has its own set of risks and difficulties; thus costs. Higher inventories mean higher costs and if the sales are more than the forecasts, the company may need to purchase additional milk/milk powder at higher costs in low milk season or if the sales are less than the forecasts, the company may face the spoilage risk of the items in inventory.

Getting new sources in low milk season may be difficult, costly, or even impossible, which creates a supply risk. Similarly, breaking contracts in high milk season is not preferable because it creates a bad reputation about the company among suppliers, which in turn makes them more reluctant to sell their milk to that company.

Demand management is a complex issue because accurate forecasting is required. If the prices are reduced significantly, then the company loses profits and faces lost sales or if the prices are too high, the company may be unable to sell its excess milk. Both for traditional products such as yoghurt and for value added products such as desserts, the market is highly sensitive to price and does not depend on brand loyalty.

It is necessary to utilize an optimal mix of these strategies. In current situation, their mix is usually determined by experience and intuition. The strategy determination is based on trial and error and it is likely to obtain only a suboptimal solution.

A literature survey indicates that there are not many studies that approach the supply chain management from such a broad view together with an optimization approach. The general tendency is to optimize only a portion of the dairy system, such as production or supply or to analyze the whole system without any quantitative approach. The significance of this study is that it blends the two conflicting activities of supply and processing in a single mathematical model and tries to find an optimal strategy for the entire system from supply to production.

Moreover, by making use of new trends in software development, this study is aimed to develop a new decision support system that replaces the current trial and error methodology of developing raw milk management strategies.

The organization of the thesis is as follows: In Chapter 2, background information about the dairy supply chain and general information about the company in study is presented. In Chapter 3, a literature survey about the dairy supply chain, raw milk management and the ribbon interface is introduced. In Chapter 4, a mathematical model of the system is constructed. In Chapter 5, the model is integrated into a DSS and the architecture, development and the operation of the system is depicted. In Chapter 6, the model and the DSS is evaluated with real life scenarios and comparisons with the current situation. Chapter 7 closes the study with a conclusion and a summary.

CHAPTER 2

DAIRY SUPPLY CHAIN

General Information

Turkish dairy business is a traditional business and there are both small and large number of companies most of which are formed many years ago as family businesses. Some companies stood out and they became not just national but also international producers of milk and dairy products. Yet, they are still run with the conventional methods. Although the company in study is an international company, it entered the market with the help of a Turkish partner and with acquisitions of some long-established dairy companies. Moreover, dairy business has unique characteristics in each country and for competition, it is usually necessary to run the business as suggested by the local industry. The acquisitions of local companies also brought in local experience. After gaining sufficient experience, the company broke its partnership with the Turkish partner and acquired 100% ownership of the shares. Although there are improvements in operations, the dairy supply chain of the company is still managed with conventional methods and it is an example of a typical Turkish dairy business.

Products and Market Structure

The products of the company can be categorized into two types. The first is fresh dairy products, which consist of products with short shelf lives, 30 days in average. They consist of more than half of the sales volume and they require cool conditions in all phases of the supply chain. The range of fresh dairy products includes traditional, flavored or functional yoghurts, desserts and fresh cheese for children.

The second is long-life products, which are more like commodity products and can be kept in room temperature. Their average shelf life is 6 months, which is much higher than fresh dairy products, but compared with other types of food products, it is still relatively low. The range of long-life products includes plain or flavored milks.

These two types of products have somewhat different production processes. For instance, the heating temperature of milk is different and most fresh dairy products are fermented, which are the main reasons of difference in shelf lives. Briefly, the production process can be summarized in following steps: pasteurization/sterilization of raw milk, addition of flavors/fermentation/various processing, and then filling by automatic filling machines.

The receipt of raw milk and other materials can be considered as common supply chain processes for both product types. The supply chains are separated into two after the production phase as the cold chain and the regular chain. In terms of profitability, there are more value added products among fresh dairy and the sales of fresh dairy is more important for the company, but its supply chain is more demanding in terms of management.

Because milk and most dairy products are among basic sources for nutrition and production is relatively simple, there is a fierce competition in the market. With the added effect of family tradition, especially for non-value added products such as plain yoghurts, the number of competitors is high and they are in various sizes.

The profits for these traditional products are very low and even negative in some cases. Due to the high consumption per capita, even a small price difference can make a large difference. Therefore, the customers are highly price sensitive and brand loyalty is not present. Moreover, some companies are manipulating the market by price adjustments, which even complicate the situation more. The demand is very difficult to predict and customer behavior cannot be foreseen properly. Forecast accuracy is relatively low, but both the cost of loss sales and overstocking is high. Because there is no customer loyalty, the customers get whatever they find in a store and they do not look for a specific brand if it is not present. However, the customers also want fresh products so that they can consume it before the expiration date and overstocking causes product freshness to decrease, which results in decreasing sales along with expired products, which get to be scrapped.

Compared to traditional products, the value added dairy products are very profitable, but without an offering of standard milk products, a company cannot survive only with value added products since their sales volume is low and they occupy very little shelf space, whereas visibility of a brand is more important than other types of marketing activities. It should also be noted that even in value added products, some portion of customers are price sensitive and can easily switch brands.

The sales forecasts are done at monthly level for each product category and then disaggregated to weekly, daily and sku levels. Forecasting is done by assigning some monthly weight to all activities and factors, such as marketing campaigns, product launches, price increase/decreases, etc. After weights are assigned, a base volume is determined from the past data by removing all effects. This base volume only contains seasonality information, which is assumed to be constant every year. Then, for the future, weighted activity effects are added to the base volume. The important thing is to identify the activities that may cause a permanent increase in the base volume so that their effects are not remove but carried on instead. The whole forecasting process in done in meetings that seek consensus of sales, marketing and planning departments and is based on insights. Time and sku splits are also found by looking at the past data.

In such a volatile market, supply chain management is difficult and many decisions are made by intuition and experience, but they are not necessarily the optimal decisions.

Supply Chain Operations

Raw milk is the most important input of the company and the supply chain starts from milk sourcing.

Most of the raw milk in Turkey is produced by villagers who have just a couple of cows. There are milk collection centers in each village and each producer brings their milk to these centers to be stored in a common tank, waiting for collection. A little percent of raw milk is collected from milking farms, where cows are milked by automatic machines and the milk is again stored in a collection tank.

Then, a milk tanker comes in and receives the milk from the tank. There are many villages and farms like this. In average, a milk collection point (village or farm) provides only 1-2% of the all milk supply. They are dispersed around a geographical location close to the plants and the raw milk needs of each plant differ every day. The milk collection operation is done every day regardless of anything.

The number of collection points is high, they are dispersed, and daily milk needs of each plant vary from day to day. Therefore, a new vehicle routing and allocation problem is solved every day for determining which tanker will collect the milk by which route and bring it to which plant. A tanker collects milk from at least 5-10 locations depending on the milk supply of that location. Any revisions in milk needs during a day causes the optimal vehicle plan to become infeasible or at least nonoptimal and the milk requirements plan must be fixed at least from the previous day, reducing the flexibility in terms of supply.

At this point, the daily variability of milk quantities must also be taken into account. At each milk collection point, it is asked what might the next day's quantities be and together with the past data, these figures are used to forecast next day's supply amount. This is necessary to make the vehicle plan such that the tanks are filled fully but also no milk is left at the collection points.

Milk collection operation is managed by a third party logistics vendor. The milk planner of the company reports daily milk needs and then the vendor is responsible from creating vehicle routes to collect all milk from all locations. The collection vehicles are also owned by the logistics vendor but to ensure the accuracy of the vehicle plans, they are also checked by the transportation responsible of the company. This is an outsourcing relationship and the objective of the vendor is to deliver the planned milk on time with the least cost. The cost of outsourcing is determined by the mileage of the vehicles plus a fixed service cost. The main supply chain driver is transportation in raw milk collection.

In strategic level, things are more complicated. Having so many different collection points mean that the company has many suppliers each of whom needs to be managed separately. Village milk is contracted by auctions held by village unions, which all producers attend. Farms milk is contracted by giving separate offers to farms.

The daily milk needs are determined according to the planned production amounts. Raw milk must be used in 48 hours, so each day; milk for the next day's production is brought to the plant. The production plan is done by combining daily finished goods inventory reports with the daily forecast report, which includes the daily forecasts with a monthly horizon for each product.

Combining the stock information with forecasts, it is decided how many tons of products must be produced to supply the demand. Because the products have low shelf lives, plans are revised every day with the new forecasts and there is little safety stock keeping. This also forces machine capacity to be taken into account when planning.

Each product has a specified milk usage determined by protein and fat content but raw milk protein and fat content changes. After the production plan is made, milk requirements are calculated taking into account the next day's protein and fat estimates.

First, the milk requirement of the fresh dairy products is planned and then long life milk products are used as the buffer for managing the remaining milk. If there is even more milk that is excess or as the strategy requires, the milk can be directed to milk powder production as well.

During both the milk collection and production, the milk must be stored cold and the preservation of the cold chain is important starting from the beginning. This brings additional complexities and costs to the supply chain. The temperature and the microbiological status of the milk must be checked continuously and spoilage risk must be avoided since milk from different sources are stored in same tanks and even a tiny bit of spoilage affects the whole storage tank. In that case, there is no choice but scrap the milk in whole tank.

Such issues emphasize the importance of facilities as an important driver in a dairy supply chain. The milk can only be collected from locations close to the plants. Another important issue is that during production, milk is heated for sterilization and to achieve economies of scale in heating processes, large tanks are required, which require large facilities. The decision at this point is either to build large, centralized facilities to have cost reduction in production or to build smaller facilities to reduce milk transportation costs. In this company's setting, the first option is more viable because of the demand volatility and the objective of achieving greater control in terms of keeping the high quality. Moreover, once milk enters into the production system, it never gets in contact with external environment and setting up such a facility with full of pipelines and control mechanisms has very high costs, so set up costs must also be considered for facility decisions.

After a product is produced, it is not immediately ready for shipment. Initially, all products are kept under quarantine and released only after a period of time. During this period, some tests are conducted both microbiologically and sensually (taste, texture, packaging, etc.). If they are found to be conforming to the standards, then they are released for shipment; otherwise, they are scrapped.

Quality control is crucial but it actually makes things more complicated. Because the shelf lives of products are low, only a small amount of safety stocks can be held, but if the products get to be scrapped for quality reasons, usually a whole batch from the same tank is scrapped. If the scrapped amount is high, this may cause loss sales due to the absence of sufficient safety stocks. There is a trade-off between facing loss sales versus shipping products with closer expiry dates.

After release from quarantine, the products are transferred to distribution centers. Then from these locations, products are sold to distributors as the next tier in the supply chain. Having distribution centers allows shipments to be combined and because the fresh dairy products are carried with "cold trucks", transportation costs are higher and there is an important saving in full truck shipments.

Except safety stocks, there are no additional inventories and the majority of these inventories are held in the distribution centers. For fresh dairy products, inventory turnover is very high; every day, there are shipments from the plant to the distribution center and from the distribution center to a set of customers, but the frequency of shipments to a specific customer depends on the sales of that customer. For larger cities, there are shipments almost every day, but for some cities, it can be as low as two days per week. Distributors place orders and the company fulfills distributor orders. However, for large national and local key accounts, direct shipments are made. For other sales points, distributors make shipments every day with smaller trucks or at least every other day.

Typically, each distributor has to have its own cold warehouse, but in cities where the company has distribution centers, these warehouses also serve as distributor warehouses, the small sales trucks of the distributors come directly to these warehouses and they are loaded from here. Because these cities have the highest sales and the highest number of distributors, aggregating the inventories and removing an intermediate step has many advantages for all parties.

For distributors, setting up and maintaining a special refrigeration system for a warehouse is an expensive and difficult task and they avoid such a burden and direct shipment means more fresh products. For the company, demand management is easier since aggregated inventories allow more flexibility with less amount of inventory held. In addition, the company has more control over shipments, which makes this setting more similar to a vendor managed inventory scheme.

In many other businesses, retailers carry the highest amount of stocks; but in fresh dairy, retailer stocks are relatively low. Retailers receive frequent shipments and the inventories are aggregated in higher tiers, which is necessary to provide more fresh products.

Considering the supply chain characteristics presented above, dairy supply chain has various unique complexities, which require novel approaches and more complicated solutions than common supply chain practices.

Although this study primarily focuses on raw milk management, it cannot be isolated from the rest of the dairy supply chain and the sought approach is expected to take into consideration all aspects of the supply chain.

CHAPTER 3

LITERATURE SURVEY

Raw Milk Management

As indicated previously, the studies involving the dairy business mostly focus on a specific part of the supply chain and studies tend to cluster around three specific areas:

i. Focusing on the whole system only with a qualitative approach – providing a general overview and an analysis with recommendations only, no specific solution
ii. Focusing on farmers with an economic viewpoint – prices, cooperation, cattle management
iii. Focusing on producers with a production viewpoint – optimization of daily operations only

Due to the seasonal and volatile nature of the raw milk supply and prices, this field of study has been within interest of agricultural economists for a long time and the studies in the first category provide a structured guideline for viewing the entire supply chain. Yet, they only provide recommendations for generating a supply chain strategy, not the strategy itself and this study extends the notion of previous studies with a quantitative, global optimization approach.

Although the milk supply and demand is almost fully domestic in Turkey (Tasdan et al. 2009), the structure and the dynamics of the dairy business is similar around the world. Issar (2004) analyzes all tiers in the Australian dairy supply chain and discusses the strategies for all the parties in this chain. Popovic (2009) provides an overview of the Serbian dairy supply chain with less emphasis on strategies. Vilella et al. (2008) discuss the limitations for growth in Argentinian dairy supply chain, focusing more on milk producers. While these studies rely on similar research methodologies like interviews and publication research, Hockmann et al. (2007) take on a quantitative approach to determine the market power in Hungarian dairy supply chain.

The studies describe the similar supply chain structure in different countries, only with minor differences. The supply chain includes the following actors: producers (farms), processors and retailers. The first tier in the supply chain, the producers, consists of small farms working with traditional methods. Therefore, producers lack the means to prevent unwanted seasonality in supply and have little control over the market price, which is determined by the seasonality in supply and demand. Although there is a trend to build up larger farms with new technologies, this is a highly small percentage of all producers. In Turkey, for instance, 85% of the farms have less than nine animals (Tasdan et al. 2009).

Being in a disadvantaged situation despite the large number of members, the producers became the focus of various studies, which can be placed in the second category described previously.

These papers focus on raw milk prices and seasonality to seek possible actions to bring supply closer to demand or optimization of farm management.

For farm management, there are multiple studies focusing on optimization, however, these studies strictly discuss micromanagement of farms and not the supply chain. Aryal et al. (2008), Kerr et al. (1999), Congleton (1983) and Reyes et al. (1980) proposes models and decision support systems for managing cattle and milk supply by using inputs like cattle types, farm size, feeding methods, etc. Although these studies about farm management provide insight about inner workings of dairy farms, they are out of scope of this study due to the specificity and micro viewpoint. Moreover, the dairy farming in Turkey is not actually considered as an economic profession and the farms are so small (Tasdan et al, 2009) that the approaches mentioned in the studies may have significant limitations for real life application.

From a broader point of view, Weldon et al. (2003) and Kaiser et al. (1988) discuss the implementation of a pricing scheme that can reduce the milk production when demand is low and increase production when demand is high. Both papers conclude that with the right price, it is possible to reduce the seasonality, but in US, the government subsidies are limited; therefore, the improvement is limited. Yavuz et al. (2002) makes a similar analysis for Turkey, pointing out the regional differences in milk quantity and proposes a price premium scheme to reduce the quantity differences between regions.

The main limitation in these similar proposals is that instead of focusing on reducing the total cost of the supply chain, an interference to the free market price of the milk is preferred. By offering premiums, the costs are not reduced but actually shifted from the producers to the governments or processors, so it may actually have unforeseen adverse effects in the next tiers of the dairy supply chain.

Another alternative for more market power for raw milk prices is cooperation. Abdulai et al. (2008) and Artukoglu et al. (2008) indicate that when producers work collectively, they get more negotiation power as well as reduced transactional costs. In terms of consideration of the full supply chain, this is a viable proposal since it also allows producers to be informed about the market environment.

Uzmay et al. (2006) brings in a different view and focuses the raw milk pricing form producer point of view. One of the remarkable findings of this study is that for determining raw milk price, large dairy companies has significant power, but for determining finished good price, large companies are not powerful at all.

This fact is crucial for modeling the right environment for the dairy supply chain. Unlike producers, which are mainly small, the processors have a mixed structure. The number of players is high and the largest players do not have domination over the market, creating a competitive environment both for supply and demand and adding another level of volatility to a market that is already volatile. The third tier, the retailers, gains the upper hand from this competition among processors and pushes the processors for lower prices.

However, as indicated by multiple raw milk market reports by Turkish Competition Authority, the processors have no control over the raw milk price either. For more than ten years, producers have been periodically filing complaints that processors are manipulating the raw milk prices to keep the prices lower. However, all investigations made by the Competition Authority indicate that no evidence is found for the producers’ claims and recommends solving the problem of low raw milk prices by government subsidies.

Facing pressure from both sides of the supply chain as the middle tier, the processors are seeking ways to reduce costs internally since they have limited control over input costs and output prices. The third category described previously includes studies that aim to improve the way of working using quantitative methods.

Milk processing is a typical example of continuous, process-based production and there are different studies with different methodologies for improving the processes.

Leewattanayingyong et al. (2007) explicitly considers the production, without considering any other parts of the supply chain. A single-period MIP model is proposed for determining the optimal production mix. Although the model is relatively less comprehensive with single period, it provides a guideline for production planning.

Wouda et al. (2002) focuses on a single period location-allocation model of a dairy supply chain. The model determines the optimal locations, numbers and product portfolio of plants. The study also presents a sensitivity analysis of the solutions, which provide an insight by considering the full supply chain.

Bei et al. (2006) provide a broader view and considers both production and distribution. The model presented in the study makes a trade-off between customer satisfaction and cost, providing a notable insight about demand by assuming it as a sine function, which is close to reality. A similar study by Bancheva et al. (2007) considers the objectives of customer satisfaction, vendor satisfaction and cost in a multiobjective model. Although the conflicting objectives in the dairy supply chain justify the need for multiobjective optimization, the approach is not commonly used. Besides the previous study, Yandra et al. (2007) also utilize multiobjective genetic algorithms to optimize the agroindustrial supply chain. The model is more of a general model that can be applied to different industries after modifications; therefore, further study is needed for the application of such a model for dairy industry.

Two most relevant studies were done by Li et al. (2008) and Mellalieu et al. (1983). Li et al. (2008) discuss the implementation of a DSS for daily planning from raw milk collection to production. The DSS uses a simulation-based system to make plans based on random supply and demand with the objective of reducing the difference between supply and demand. Yet, they only consider a single day as the scope and long-term planning is not possible. Mellalieu et al. (1983) provide a broader view with a network model that contains milk supply, transportation and production. With the network covering all points from global supply to global demand, the model is more suitable for long-term planning than the studies mentioned previously. "Traveling salesman" is an accurate representation of the dairy supply chain with transportation and product allocation. The only missing point is that the model considers each period as a separate network and although long-term planning is possible, it has the risk of being stuck with local optima.

Essentially, this is the general missing point of the studies in this field, as they focus on short-term operations with limited attention to time dimension, also indicating that time sensitive variables such as inventories are not considered. In overall, raw milk management is a complex issue and a broader study is needed.

Consequently, this current study is expected to go beyond the previous studies by considering a longer time horizon in a multiperiod manner with emphasis on a broad section of the dairy supply chain, if not all.

Ribbon Interface

DSS development is a common practice and applied by most studies mentioned in the previous section. However, Microsoft Ribbon interface is relatively a new technology introduced in 2007 that is expected to replace the traditional toolbar and menu based user interface designs. Yet, it has not gotten too much scholarly attention, especially in DSS development.

Dostal (2010) provides a qualitative assessment of the Ribbon user interface, concluding that more experienced users are less satisfied, but there is no loss in user experience with switch to the Ribbon interface.

Since the newer generation office software is shipped with this interface, it is becoming more commonly used in workplaces, so to provide a more coherent user experience, developers may start to consider using the Ribbon interface.

Rice et al. (2006) indicates that the ribbon interface replaces the current complicated system with a simpler system. This new interface is expected to increase the user efficiency. It is more visual, which increases the discoverability of commands and commands can be executed with less number of clicks than the previous system. Moreover, it is dynamic and provides more flexibility to the developer to build creative solutions for improving the user experience.

Since no similar study has been published yet, this current study is expected to provide a reference point in this field with the development of a DSS with the Ribbon interface.

CHAPTER 4

MODEL DEVELOPMENT

Since the focus of this study is to find optimal raw milk strategies, an optimization-based approach is sought to develop a model. In this section, the problem is identified, a suitable mathematical model is developed and then the model is refined for real life application.

Problem Definition

In the current situation, there is already a strategy determination process in place, but this process is not formalized and it is partially structured; therefore, optimization is not an element in the current situation. The supply and production plans are generated iteratively with the involvement of multiple users and with multiple spreadsheets specifically prepared for this purpose and the decisions are dependent on the personal insights of the raw milk planner.

However, by implementing a mathematical model, it is possible to optimize the supply, production and inventory plans by a more efficient decision process and reduce dependency on people. An expected drawback is that building a mathematical model may require some compromises from the system to create a solvable model.

Figure 1 below shows a graphical representation of the whole system:

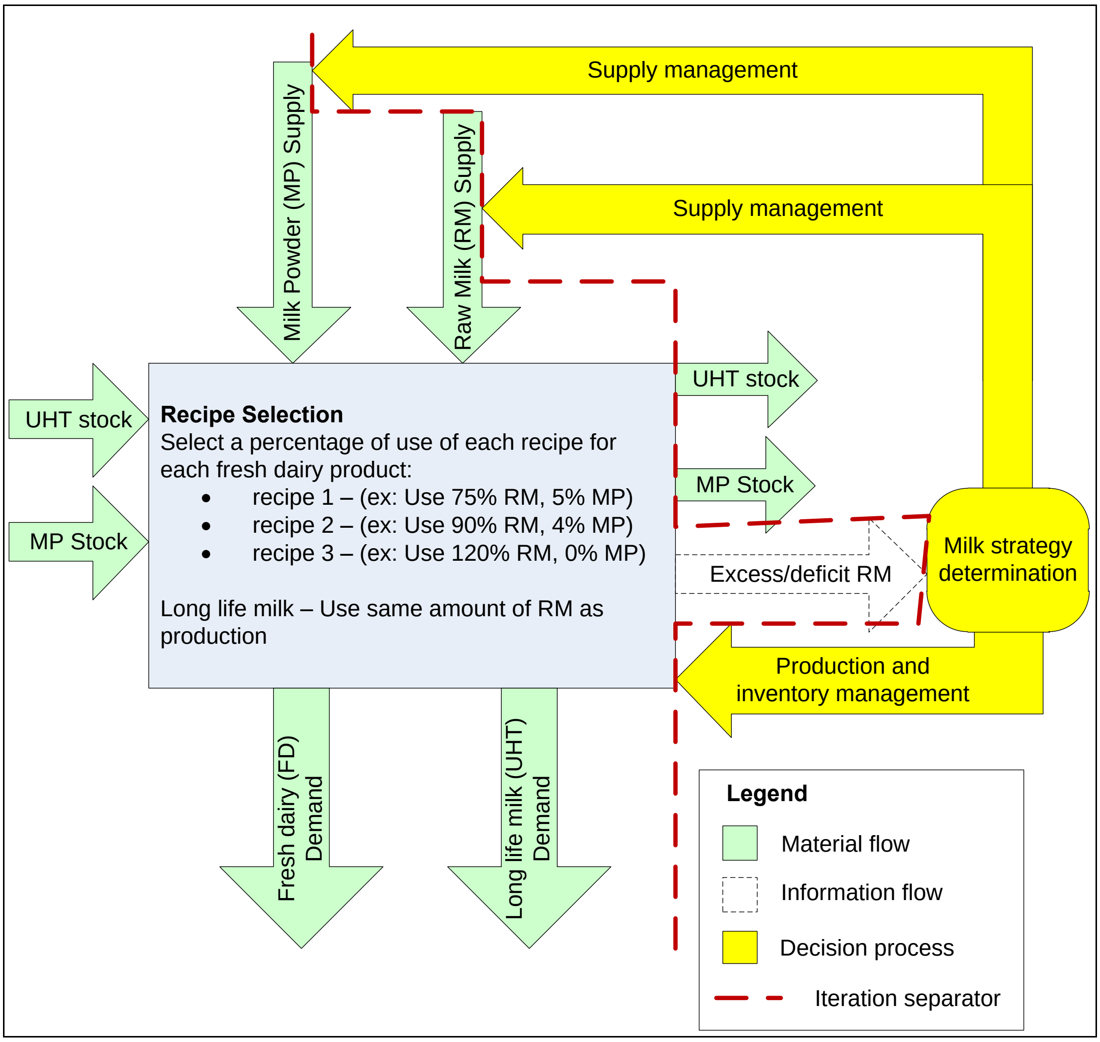


Figure 1: Raw milk management process in application in current situation

As seen in Figure 1, there are various flows in the system and these flows in the current process can be explained with the following steps that also provide guidance for creating a mathematical model:

For the initial iteration, only the left side of the separator is considered. The inputs of the production system are the raw milk (RM) and the milk powder (MP) and the outputs of the system are fresh dairy products (FD) and long-life milk (UHT). Among these, MP and UHT can be inventoried, whereas RM and FD cannot be stored due to their perishabilities. With the same reasoning, the production quantities of the perishable outputs are set to the customer demand level in a period in order to avoid inventory keeping.

During the production process, an initial arbitrary recipe selection is made to determine the amount of RM and MP required to produce the demand of FD products. Actually, in a dairy system, the protein and fat content of the RM fluctuate throughout the year mostly due to environmental or seasonal factors. Noting that the minimum protein and fat requirements in the final products are defined by the legislation (food codex), the usage proportion of each recipe should be updated periodically.

After the initial recipe selection, the amount of excess or deficit RM is determined and in the next step, supply and production decisions are updated to manage this excess/deficit milk amount. Then the process moves to the right of the separator in Figure 1, where there are two main phases for management.

The first phase is the production and inventory management. In this option, the RM requirements are adjusted by selecting alternative recipes, which replace RM with other sources of protein such as MP. After the RM and MP consumptions are updated by the new recipe selection, the final inventories are checked. If there is still excess/deficit UHT after the adjustments, the remaining amount is managed by increasing/decreasing UHT inventories.

However, due to the perishability of UHT, which limits the inventory build-up, it may be necessary to manage the supply as well. Supply management is the second phase in strategy determination.

For managing supply, there are three options: purchase milk with long-term or short-term contracts or produce MP.

It is possible to change supply by “adding or dropping” milk that means contracting new farms/villages or breaking contracts with current farms/villages. As explained previously, there are serious risks in breaking contracts and seasonal difficulties in getting new contracts; thus, the hidden costs of these options are required to be taken into consideration for a more accurate representation of the problem by the model. In the current process, this is done by intuition and experience, but in the mathematical model, a numerical representation, such as a penalty cost, is required.

The second alternative in supply management is selling milk as RM or getting “short-term contracted” milk for a higher price. In addition to higher price, short-term contracted milk has other disadvantages such as unreliability in terms of delivery quantities, timings and quality. Similarly, selling milk also has problems. In high supply season, all companies tend to have excess milk. Therefore, it is difficult to find a buyer unless the offering price is lower than the purchase (market) price, which creates additional costs. Moreover, in extreme cases of excess, it may be impossible to sell excess milk even with a loss.

The third alternative is to send excess milk for MP production and then consume this MP when there is milk deficiency. Although this alternative is rational, MP production is costly due to additional transportation and processing of milk. In the iterative process, this alternative is selected only if there is no other alternative.

After both phases of the strategy determination is done, the process moves back to the left side of the separator in Figure 1 to check the results of the strategy.

The cost is not considered at this point, only the alternatives are selected and a solution is found accordingly with the objective of keeping UHT inventory coverage between 10 days and 30 days. 10 days is the safety stock level and 30 days is due to the shelf life restrictions. Therefore, long life milk should be considered as a buffer more than an item to rely on for milk management.

If the UHT inventory is within bounds, then the process is complete and the strategy is determined with a local optimum, but if the inventory is out of bounds, the process restarts with a new iteration until the inventory is kept within bounds. The production and inventory and the supply is adjusted back and forth with each iteration.

As the strategy determination tool for the current process, all data explained above are entered into a spreadsheet; different scenarios are created by adjusting the variables and their costs are compared to find the least costly scenario which is not necessarily optimal.

With the implementation of a mathematical model for the optimization of the strategy, the decision point indicators can be expanded as shown in the following Figure 2 (cost aspect is not included in the figure) so that the strategy is found in a single step by having a full view of the big picture.

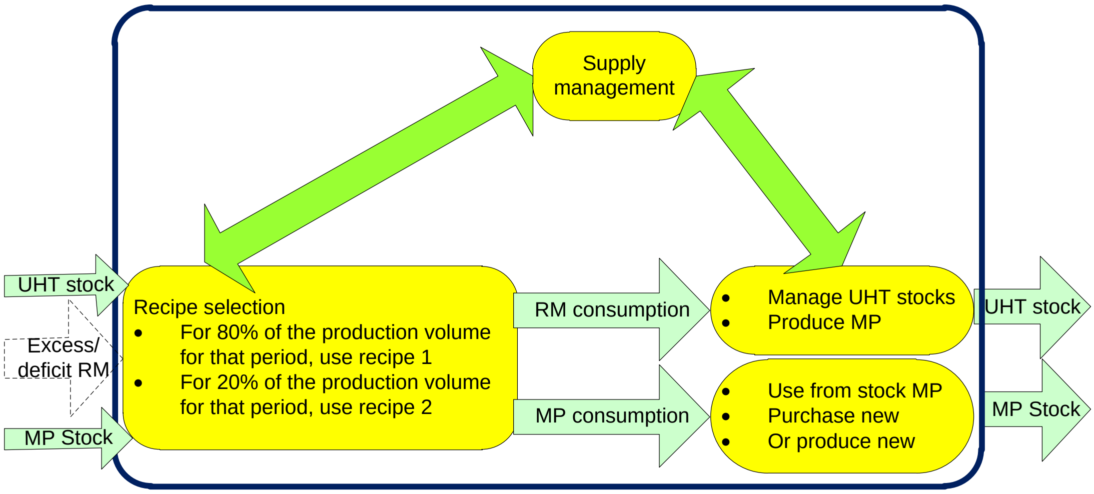


Figure 2: Strategy determination process after the model implementation

The optimization model is expected to contain the variables and constants explained in the steps above and the cost dimension is required for the creation of an objective function.

In the current situation, strategy determination process is repeated every month for the next twelve months in a rolling horizon manner with previous month's inventories being the input for the current month. For the mathematical model, a similar approach is followed, where the number of periods is set as twelve months and the model is rerun each month with the new data.

Initial Mathematical Model – NLP

The strategy determination process considers 12 months, in which the full seasonal cycle for both supply and demand are completed. Therefore, the mathematical model is a multi-period model, which aims to minimize cost by determining the optimum strategy for a full cycle.

Indices

i: index for product type, $i = 1,2,\cdots,7$

$i = 1$ - Long-life milk

$i = 2$ - Dessert

$i = 3$ - Plain yoghurt

$i = 4$ - Fruit yoghurt

$i = 5$ - Fresh drink

$i = 6$ - Fresh cheese

$i = 7$ - Other products

j: index for recipe type, $j = 1,2,3$

t: index for periods, $t = 1,2,\cdots,12$

Parameters

Process Related Parameters

M_{ijt}: milk usage for product i for recipe j in period t

N_{ijt}: milk powder usage for product i for recipe j in period t

D_{it}: demand for product i in period t

S_t: seasonality coefficent for supply from period $t-1$ to t

G_t: milk to milk powder conversion coefficent in period t

Cost Parameters

C_t: purchase cost of long-term contracted raw milk in period t

$(TL/1000\ kg/period)$

U_t: purchase cost of milk powder in period t

$(TL/1000\ kg/period)$

V_t: additional cost upcharge for milk powder production in period t

$(TL/1000\ kg/period)$

W_t: sales price of short-term contracted raw milk in period t

$(TL/1000\ kg/period)$

Q_t: purchase cost of short-term contracted raw milk in period t

$(TL/1000\ kg/period)$

R_t: inventory holding cost per 1 TL of product $(TL/TL/period)$

J_t: penalty cost due to a newly added long-term contractor $(TL/1000\ kg)$

L_t: penalty cost due to a broken long-term contractor $(TL/1000\ kg)$

Z_{ijt}: cost of production per unit of product i with recipe j in period t

$(TL/1000\ kg/period)$

Initialization Parameters for Period Zero

x_0: initial milk supply in period 0

k_0: initial milk powder inventory at the end of period 0

i_{i0}: initial inventory for product i at the end of period 0

Bounds

$InvLB_{it}$, $InvUB_{it}$: Lower and upper inventory bounds for product i in period t

The lower bound for inventory is set according to the quarantine period of that specific product. As indicated previously, all products are kept under quarantine and released only after a period of time for quality reasons. If the products are scrapped, safety stock is needed until the next batch of products are produced and released from quarantine. The upper bound for inventory is set in a level to avoid scrapping of products.

$PrdLB_{it}$, $PrdUB_{it}$: Lower and upper production quantities for product i in period t

The lower bound specifies the minimum production quantity required due to the processing requirements and the upper bound specifies production capacities.

$ImpLB_t$, $ImpUB_t$: Lower and upper inventory bounds for milk powder in period t

For milk powder, the inventory bounds are determined in a similar manner with products, where there is a quarantine period before the usage of milk powder and the milk powder also has a shelf life, which creates the need for an upper bound to avoid scrapping of the milk powder.

$PmpLB_t, PmpUB_t$: Lower and upper production quantities for milk powder in period t

Similar with products, the lower bound specifies the minimum production quantity required due to the processing requirements and the upper bound specifies production capacities.

$StsUB_t, StpUB_t$: Short-term contracted milk sales and purchase upper bounds in period t

These bounds are set in accordance with market situation, where it may be impossible to sell too much raw milk in high milk season or to purchase raw milk in low milk season.

If the bounds are exceeded for a reason, then the problem is considered infeasible and the parameters must be adjusted, such as reducing or increasing the demand or capacity if possible.

Decision Variables

Supply Variables

x_t: adjusted milk supply in period t

a_t: increase in milk supply with new long-term contracts in period t

b_t: decrease in milk supply with broken long-term contracts in period t

e_t: short-term contracted milk sales in period t

o_t: short-term contracted milk purchase in period t

f_t: milk sent to milk powder production in period t

h_t: milk powder purchase in period t

k_t: milk powder inventory at the end of period t

Production Variables

y_{ijt}: ratio of recipe j usage for product i in period t

i_{it}: inventory for product i at the end of period t

p_{it}: production quantity of product i in period t

Objective Function

The objective is to minimize the total costs over all periods ($\sum_t$) and the objective function has three cost components.

The first component is the cost of supply and supply management:

$$[C_t x_t - W_t e_t + Q_t o_t + J_t a_t + L_t b_t + U_t h_t + V_t(G_t f_t)] \quad (4.1)$$

This expression is the sum of base milk cost $(C_t x_t)$ and short-term sales/purchase cost $(W_t e_t + Q_t o_t)$ and long-term contracted milk add/drop penalty $(J_t a_t + L_t b_t)$ and MP purchase/production cost $[U_t h_t + V_t(G_t f_t)]$.

The second component is the cost of production:

$$\textstyle\sum_i [p_{it} \sum_j (Z_{ijt} y_{ijt})] \quad (4.2)$$

This expression is summed over products i with production quantity (p_{it}) times the sum of unit cost of production for each recipe j multiplied with the usage percentage of that recipe $(Z_{ijt} y_{ijt})$.

The third component is the holding cost of inventory:

$$R_t \sum_i [i_{it} \sum_j (Z_{ijt} y_{ijt} + C_t M_{ijt} y_{ijt} + U_t N_{ijt} y_{ijt})] + R_t U_t k_t\} \quad (4.3)$$

This expression has two parts. The first part is the inventory cost of products with inventory holding coefficient (R_t) multiplied by the amount of inventory of each product (i_{it}) times total product cost, which is summed over recipes as the sum of production cost $(Z_{ijt} y_{ijt})$ and milk consumption cost $(C_t M_{ijt} y_{ijt})$ and milk powder consumption cost $(U_t N_{ijt} y_{ijt})$. The second part of the expression is the milk powder inventory holding cost $(R_t U_t k_t)$.

Then the objective function can be expressed as minimizing the sum of expressions (4.1), (4.2) and (4.3).

Min total costs = Min

$$\sum_t \{[C_t x_t + W_t e_t + Q_t o_t + J_t a_t + L_t b_t + U_t h_t + V_t (G_t f_t)] + \sum_i [p_{it} \sum_j (Z_{ijt} y_{ijt})] +$$

$$R_t \sum_i [i_{it} \sum_j (Z_{ijt} y_{ijt} + C_t M_{ijt} y_{ijt} + U_t N_{ijt} y_{ijt})] + R_t U_t k_t\}$$

<u>Constraints</u>

<u>Equations</u>

$$x_t = S_t x_{t-1} + a_t - b_t \quad \forall t$$

$-$Milk supply balance with seasonality effect in period t

This equation indicates that the base milk quantity from the previous period (x_{t-1}) is multiplied by the seasonality coefficient (S_t) to obtain the initial amount of base milk in that period. Then this initial amount is adjusted by adding new long-term contracts (a_t) or breaking the current long-term contracts (b_t) to obtain the final base milk amount for that period. (x_t)

$$\sum_i [p_{it} \sum_j (y_{ijt} M_{ijt})] + f_t = x_t - e_t + o_t \quad \forall t$$

−Raw milk consumption in period t

The left hand side of the equation indicates raw milk consumption and the right hand side indicates the raw milk supply for a given period. The first element of this expression is the sum over products i with production quantity (p_{it}) times the sum of milk usage coefficient for each recipe j multiplied with the usage percentage of that recipe ($M_{ijt} y_{ijt}$). Then for total consumption, amount of milk sent to milk powder is added (f_t), which is equal to the base milk amount (x_t) adjusted with short-term milk sales (e_t) and short-term milk purchases (o_t).

$$i_{it-1} - D_{it} + p_{it} = i_{it} \quad \forall\, i, t$$

−Inventory balance equation for product i in period t

Although this is a standard inventory balance equation, backorders are not included since they are not allowed due to the market structure. If a customer cannot find a specific brand on the shelf, the customer just buys another brand and the sales are lost.

$$k_{t-1} - \sum_i [p_{it} \sum_j (y_{ijt} N_{ijt})] + G_t f_t + h_t = k_t \quad \forall t$$

−Inventory balance equation for milk powder in period t

For milk powder, sales to market can also be considered as an option, but due to the additional upcharge of transportation of raw milk to the milk powder producer, the produced milk powder has a higher cost than the market price, which makes it impossible to sell the milk powder without a loss. Therefore, milk powder sale is not included in the model.

$$\sum_{j} y_{ijt} = 1 \quad \forall i, t$$

−Sum of recipe usage percentages for product i in period t

Bounds

$$InvLB_{it} \leq i_{it} \leq InvUB_{it} \quad \forall i, t$$

$$PrdLB_{it} \leq p_{it} \leq PrdUB_{it} \quad \forall i, t$$

$$ImpLB_{t} \leq k_{t} \leq ImpUB_{t} \quad \forall t$$

$$PmpLB_{t}, \leq G_{t} f_{t} \leq PmpUB_{t} \quad \forall t$$

$$e_{t} \leq StsUB_{t} \quad o_{t} \leq StpUB_{t} \quad \forall t$$

Variable Types

all variables ≥0 $\quad y_{ijt} = [0,1] \quad \forall i, j, t$

Revised Mathematical Model – LP

Although the initial model is a full representation of the system, it is not suitable for real life application since there are multiple occurrences of nonlinearity in both the constraints and in the objective function. The primary reason for this is that the main element of the model, the milk and milk powder consumption, is the product of two decision variables, production quantity (p_{it}) and recipe usage percentages (y_{ijt}).

$$\text{milk consumption for product i} = p_{it}\sum_{j}(y_{ijt}M_{ijt})$$

Therefore, it is crucial to remove the nonlinearity without losing the correspondence to the real life. For scenario analysis, it is expected to solve a high number of optimizations in a small amount of time and with such a large model, nonlinearity has a negative effect on the solution times. Moreover, the solver engine has more strict variable and constraint limitations for nonlinear problems than linear problems and to avoid the need for reduction in number of variables, the model is needed to be linear for solving larger problems.

For removing nonlinearity, it is necessary to take out either production or recipe usage percentage out of the variables and actually, depending on the product, this is possible with minimum effect.

As explained previously, the demand is volatile and most customers do not have brand loyalty. Since dairy products are common goods and consumed quickly, If a customer cannot find a specific brand on the shelf, that customer is likely to purchase another brand without waiting for the missing product to arrive, indicating that stock out orders cannot be backordered. This is especially important for national key accounts, to whom direct shipments are made. Key accounts cover a high percentage of sales. As well as backorders, inventory buildup is not an option as well, due to the limited (less than one month) shelf life of most products.

With these facts in mind, it can safely be assumed that the production quantity for fresh dairy products is equal to the demand since inventory buildup would directly result in spoilage and stockout situations would directly result in lost sales.

This assumption affects three elements in the model: Raw milk consumption $\{\sum_i[p_{it}\sum_j(y_{ijt}M_{ijt})]\}$, milk powder consumption $\{\sum_i[p_{it}\sum_j(y_{ijt}N_{ijt})]\}$ and inventory cost $\{\sum_i[i_{it}\sum_j(Z_{ijt}y_{ijt} + C_tM_{ijt}y_{ijt} + U_tN_{ijt}y_{ijt})]\}$, where production (p_{it}) and inventory (i_{it}) quantities are fixed.

However, there is one product with inventory option, long-life milk and although it is possible to make the same assumption for lost long-life milk sales, it would not reflect the real life application if the production quantity of long life milk is set equal to the demand. Consequently, production quantity for long-life milk is kept as a decision variable, requiring a different assumption to remove linearity, which is conveniently enforced by the regulations.

Since fresh dairy products have protein values higher than the protein content of raw milk, the milk powder used in these products are diluted with milk only, no water is added. Yet, for long-life milk, the raw milk is sterilized and packaged directly. In the food codex, it is strictly forbidden to use milk powder in packaged milk since it would require addition of water, creating “non-genuine” milk.

Considering these points, the recipe usage percentage for long-life milk is set to 100% with a single type of recipe, eliminating nonlinearity.

This assumption again affects three elements in the model: Raw milk consumption $\{\sum_i[p_{it}\sum_j(y_{ijt}M_{ijt})]\}$, milk powder consumption $\{\sum_i[p_{it}\sum_j(y_{ijt}N_{ijt})]\}$ and inventory cost $\{\sum_i[i_{it}\sum_j(Z_{ijt}y_{ijt} + C_tM_{ijt}y_{ijt} + U_tN_{ijt}y_{ijt})]\}$, where recipe usages ratios (y_{ijt}) are fixed.

Then, the model can be converted to a linear model with the following assumptions:

$$p_{it} = D_{it}\ and\ i_{it} = 0\ where\ i \neq \text{long-life milk}, \forall t$$

$$y_{ijt} = 1\ where\ i = \text{long-life milk},\ j = 1, \forall t$$

As a result, a linear programming model is created and the model is solved using Premium Solver Platform version 9.5. As reported by the solver engine, the model has 336 variables and 528 constraints when the model is created for twelve periods for seven products and three recipes for each product.

CHAPTER 5

DSS DEVELOPMENT

DSS Design

In the current situation, a spreadsheet-based planning tool is used for strategy generation. This tool is updated by the planner with inputs from multiple sources. With the development of the DSS, this manual process is also expected to be eliminated so that every input provider is responsible from their own section and data are automatically updated from the relevant sources.

There are multiple input fields in the current solution and these fields can be divided into two categories. Some of these are fairly constant, whereas some are required to be changed once or twice a month.

The constant fields are milk and milk powder usages throughout the year for all products. Unless a completely new product line is included or a completely new product recipe is created, these fields are untouched and can be classified as the master product data.

At this point, it may be asked if the user can use this part as a decision making tool as well by playing with recipes to increase/decrease milk consumption. However, this is not possible since the relationships between the inputs are complicated. There are upper and lower limits for protein, fat, non-fat dry matter that come in different amounts from different ingredients, and there are sensory requirements such as taste and texture, so the user takes these milk usages as given. Yet, if necessary, new recipes can be requested from the product development team.

In this portion of DSS, a similar approach with the current solution is followed. Milk usage data is taken from a database to avoid any errors. The relevant database tables can only be edited by the recipe owner and in the interface; the user has limited control over the file with viewing permission only.

The second type of field is supply and demand forecasts. Usually, it is sufficient to update these fields once a month.

In the volume fields, the products are categorized into product groups and for each product group, monthly sales volumes are included. For raw milk planning purposes, single products are not important since product packaging size or flavor does not change milk requirements.

In the DSS, volumes are updated automatically from an external database, but at times, the user may be required to work with different volume scenarios, so the interface includes mass volume manipulation tools.

Like volumes, milk quantities are regularly updated each month with seasonality data, but unlike volumes, their values are not changed during input since they have a specific section in strategy determination part of the system. In the DSS, the external database is used for initial values.

It should also be noted that in the current solution, the prices are not taken into account and the DSS introduces a new input section for prices. Since the objective is to reduce the cost, the model is very sensitive to changes in costs and the user has full control over the prices. The user is given the option to obtain the price data from an external file or enter manually so that detailed sensitivity checks and scenario analyses are possible.

After all inputs are collected, values are entered in a trial-and-error manner in the spreadsheets in the current solution, but with the DSS, the user can find the optimal strategy automatically with the only requirement being the input of bound constraints by the user.

The complete data flow diagram for the DSS is exhibited in Figure 3 below:

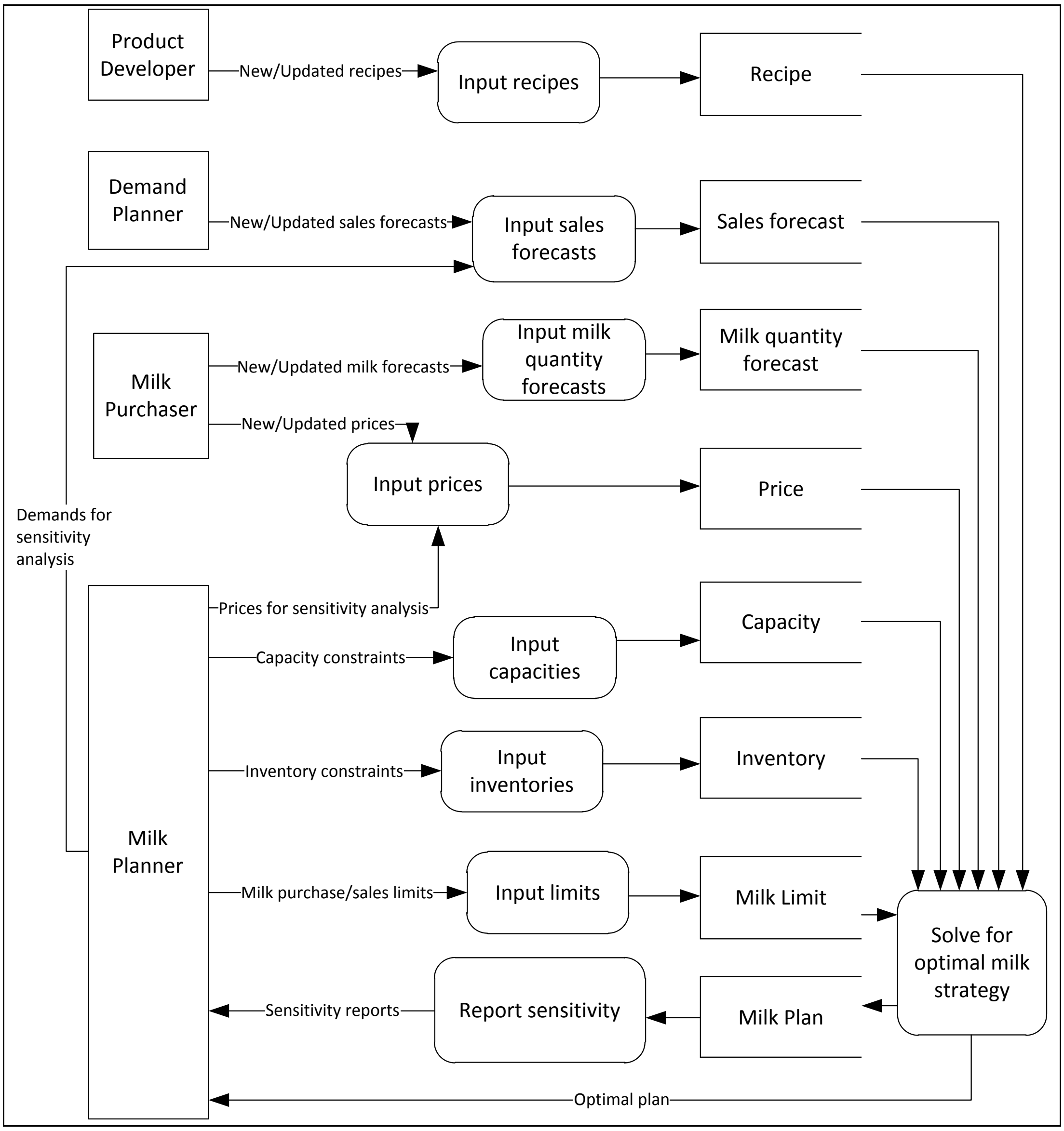


Figure 3: Data flow diagram of the DSS

In this diagram, the user roles are defined as product developer, demand planner, milk purchaser and the key user is the milk planner. All inputs are stored for solving for optimal milk strategy and the output is the optimal plan along with the sensitivity reports.

DSS Architecture

To exploit the users' familiarity with productivity software as well as to ensure the real life applicability, the DSS is based on commercially available software. The DSS itself is a Visual Basic application in an XML based XLSM worksheet as the container, which opens with Microsoft Excel.

The application has two layers, the interface and the solution engine.

The interface is designed from scratch using the new generation Microsoft Ribbon technology. This technology is the new user interface standard in Windows platform and it replaces the traditional toolbar & menu interface. Currently, it is used in all applications in the latest version of Microsoft Office and in productivity applications in the latest version of Microsoft Windows as well as other commercially available software.

Although Ribbon interfaces are becoming widespread in various applications, this study is one of the first to implement it in an academic setting. As well as ease of use and consistency in user experience with other productivity applications, using the ribbon technology provides full compatibility with the container software, Microsoft Excel.

As the solution engine, Premium Solver Platform is selected to handle large problems with high number of variables and constraints. Although there are similar platforms available even with more powerful optimization capabilities, this software has practical advantages over other solution engines for better applicability.

The user is expected to be familiar with the Solver feature of Microsoft Excel, which is actually a trimmed down version of Premium Solver Platform, reducing the learning curve of users. Moreover, unlike other solution platforms, it is fully integrated with Microsoft Excel, so it does not require additional things like accessing the command line or running an external executable file. Along with this out-of-the-box integration, availability of an object oriented API of Premium Solver enables access to the optimization model itself so that programmatically model manipulation is possible via a custom user interface.

For deployment, there are no special requirements. The user only needs to have Microsoft Excel and Premium Solver Platform installed.

Interface Development

Since the ribbon technology is relatively new, there is only one tool for generating interfaces within XML based spreadsheet files, which is the Custom UI editor for MS Office. Basically, a new generation XML based spreadsheet file is a compressed file consisting of multiple XML files for various elements of the document. This editor extracts the user interface component and allows editing of the user interface with XML codes.

It should also be noted that although Ribbon technology was introduced with Microsoft Office 2007, it lacked any kinds of Ribbon interface customization options for the end user. It was only after the release of Microsoft Office 2010 where Ribbon interface became more mature and the users had the chance to change the commands freely on the application ribbon.

The primary advantage of the ribbon technology over the traditional toolbar setting is that buttons are not the only type of controls that can be used. Checkboxes, option boxes, list boxes, etc. can also be used in a ribbon user interface. This reduces the need for designing forms when more sophisticated inputs are required from the user and provides a more consistent interface.

Therefore, it is possible to design an interface from scratch within Microsoft Excel, which allows retaining all spreadsheet experience while minimizing the feeling that the user is within a Microsoft Office application. Yet, built-in application commands can be presented alongside with custom commands and built-in button images can be used for custom buttons.

There is one missing point, which is the inability to combine add-in controls (such as Solver Platform) with custom controls. For this problem, this study provides a different solution, which is to modify the primary user interface customizations file of Microsoft Excel upon launch of the application and then revert it back after quitting. This requires checking the operating system version and locating the UI customization file in the profile location. Then the file is modified to display the necessary controls from the add-in. This is crucial since reporting features of the solver engine should be made available directly to the user whereas features that can be used to change the model should be disabled.

Although the ribbon technology has reached to a certain level of maturity, especially in the user experience side, it still has some weaknesses from the developer side. There is no visual editing options and previewing of the changes requires saving and reloading the file. Besides the difficulty in development, the ribbon interface is very error-sensitive. In the Visual Basic application, the interface can only be called from the XML file during the initial loading of the file. Once called, it is possible to interact with it by function calls referencing to the interface and with variables that define states of controls like checkboxes.

The custom interface is defined as an IRibbonUI variable

```
Public MyRibbon As IRibbonUI
```

Then during the loading of the built-in ribbon interface, it is replaced with the custom one:

```
Sub RibbonOnLoad(ribbon As IRibbonUI)
Set MyRibbon = ribbon
```

The function names to run in button clicks are defined in the XML file and in the application; the functions are defined with a specific input variable type of IRibbonControl. Just like the example below, the function call can also include information about the state of the control.

```
Sub PricesPressed(control As IRibbonControl, ByRef
pressed)
```

The interface can only be controlled in a limited manner during runtime and if any errors occur in the Visual Basic application, the control interface can be "lost". The only way to gain control of it is closing and reloading the file. Therefore, error handling is important when developing with the ribbon interface. In the DSS, this is a major issue due to the fact that the application uses its own file management routines to avoid the files to be opened outside of the application. The files are actually saved as standard XLSM files, so they can be opened directly from Microsoft Excel, providing a problematic user experience. To avoid this issue, the files are protected with a password and given a specific extension called "Raw Milk Plan" or "RMP".

Figure 4 describes the final design of the DSS ribbon interface:

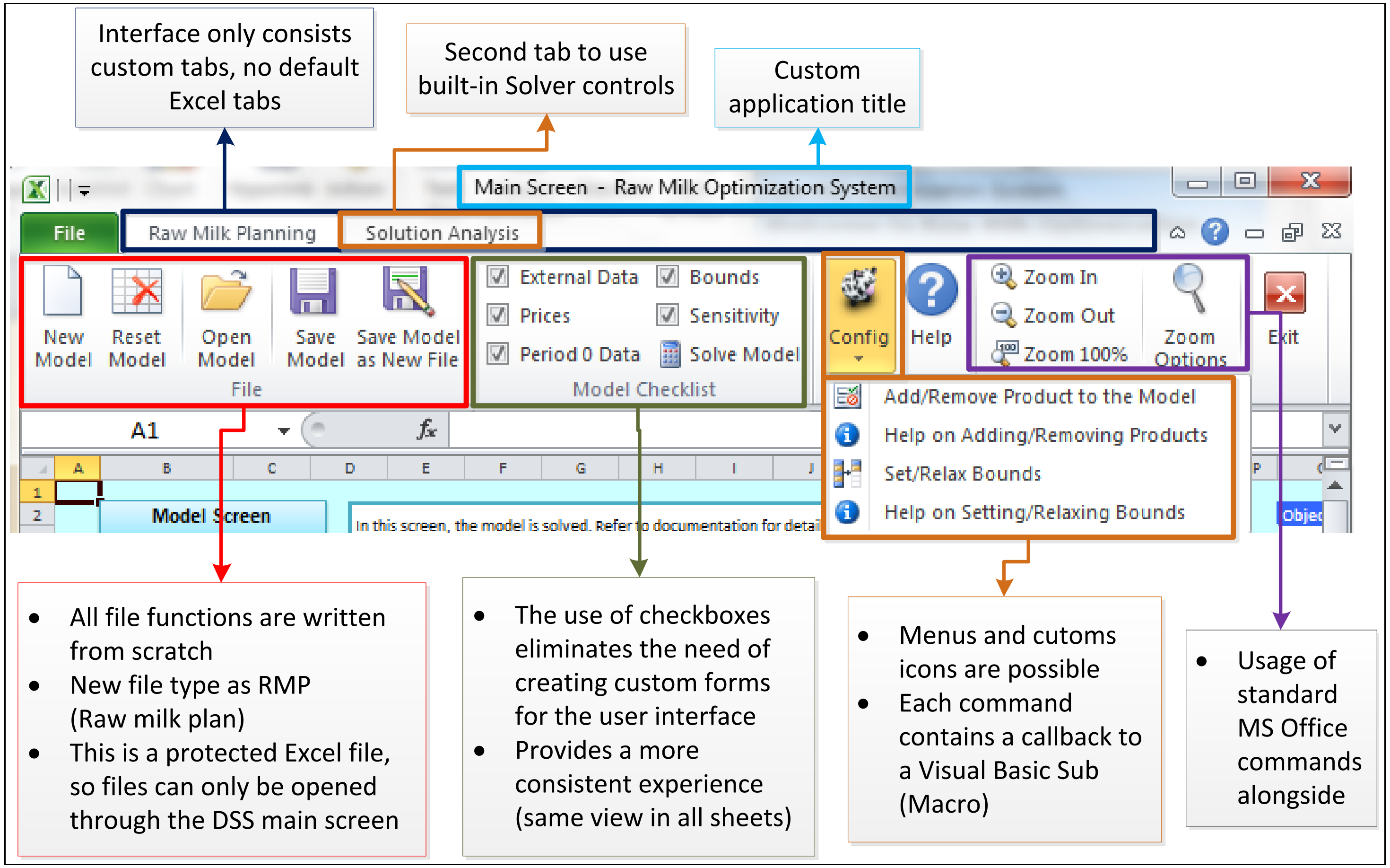
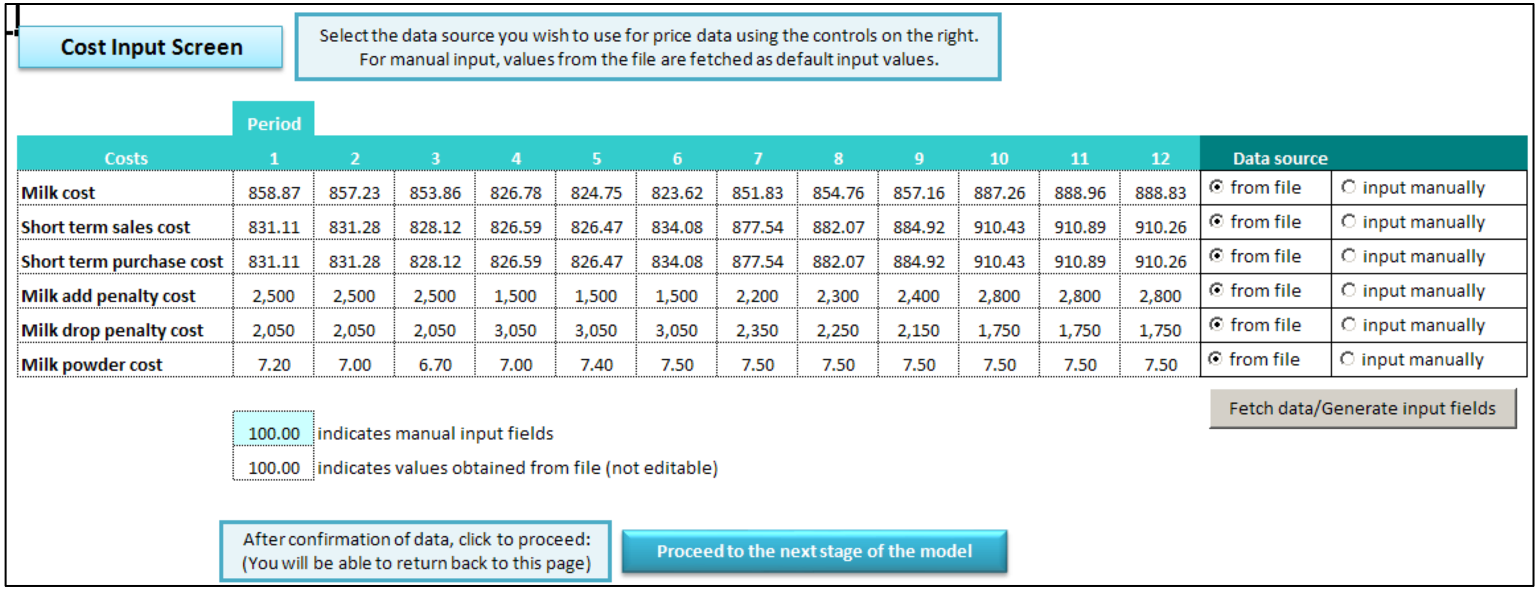


Figure 4: Ribbon interface of the DSS

For the model display interface, all model elements are presented in a single screen for convenience. There are only two additional visible screens (sheets), which are the welcome screen and manual price input screen. The remaining sheets are fully protected and they are used for fetching information from the database. However, they are intentionally left visible for the user to check raw data if necessary.

Although most of the controls are in the ribbon interface, there are some "backup" controls in the model screen so that the user has choice if there is a comfort issue with the ribbon interface. The model screen is color coded for distinguishing the model elements and the user has input access to specific cells, other cells can be selected for copying purposes but they cannot be modified to prevent the user accidentally breaking the model.

The final designs of different types of screens are shown in Figure 5 (price input screen), Figure 6 (external data viewing screen) and Figure 7 (main model screen). It can also be noted that except price screen, all external data screens such as recipes and volumes use a pivot table layout and they are similar to the one shown in Figure 6.



	Period													
Costs	1	2	3	4	5	6	7	8	9	10	11	12	Data source	
Milk cost	858.87	857.23	853.86	826.78	824.75	823.62	851.83	854.76	857.16	887.26	888.96	888.83	from file	input manually
Short term sales cost	831.11	831.28	828.12	826.59	826.47	834.08	877.54	882.07	884.92	910.43	910.89	910.26	from file	input manually
Short term purchase cost	831.11	831.28	828.12	826.59	826.47	834.08	877.54	882.07	884.92	910.43	910.89	910.26	from file	input manually
Milk add penalty cost	2,500	2,500	2,500	1,500	1,500	1,500	2,200	2,300	2,400	2,800	2,800	2,800	from file	input manually
Milk drop penalty cost	2,050	2,050	2,050	3,050	3,050	3,050	2,350	2,250	2,150	1,750	1,750	1,750	from file	input manually
Milk powder cost	7.20	7.00	6.70	7.00	7.40	7.50	7.50	7.50	7.50	7.50	7.50	7.50	from file	input manually

Figure 5: Cost input screen of the DSS

	Period												
Data	1	2	3	4	5	6	7	8	9	10	11	12	Grand Total
Sum of MilkSeasonality	1.064973978	0.98383788	1.169037388	1.014437317	1.063235944	0.868942529	0.96411129	0.966544996	0.942329084	1.006055939	0.952987725	1.053308346	12.04980242
Sum of MPProdSeasonality	0.083132352	0.081672493	0.081672493	0.081554091	0.081452484	0.081241097	0.080439584	0.080885352	0.08100683	0.081260269	0.081670826	0.082055356	0.978043227

Figure 6: Seasonality data viewing screen of the DSS

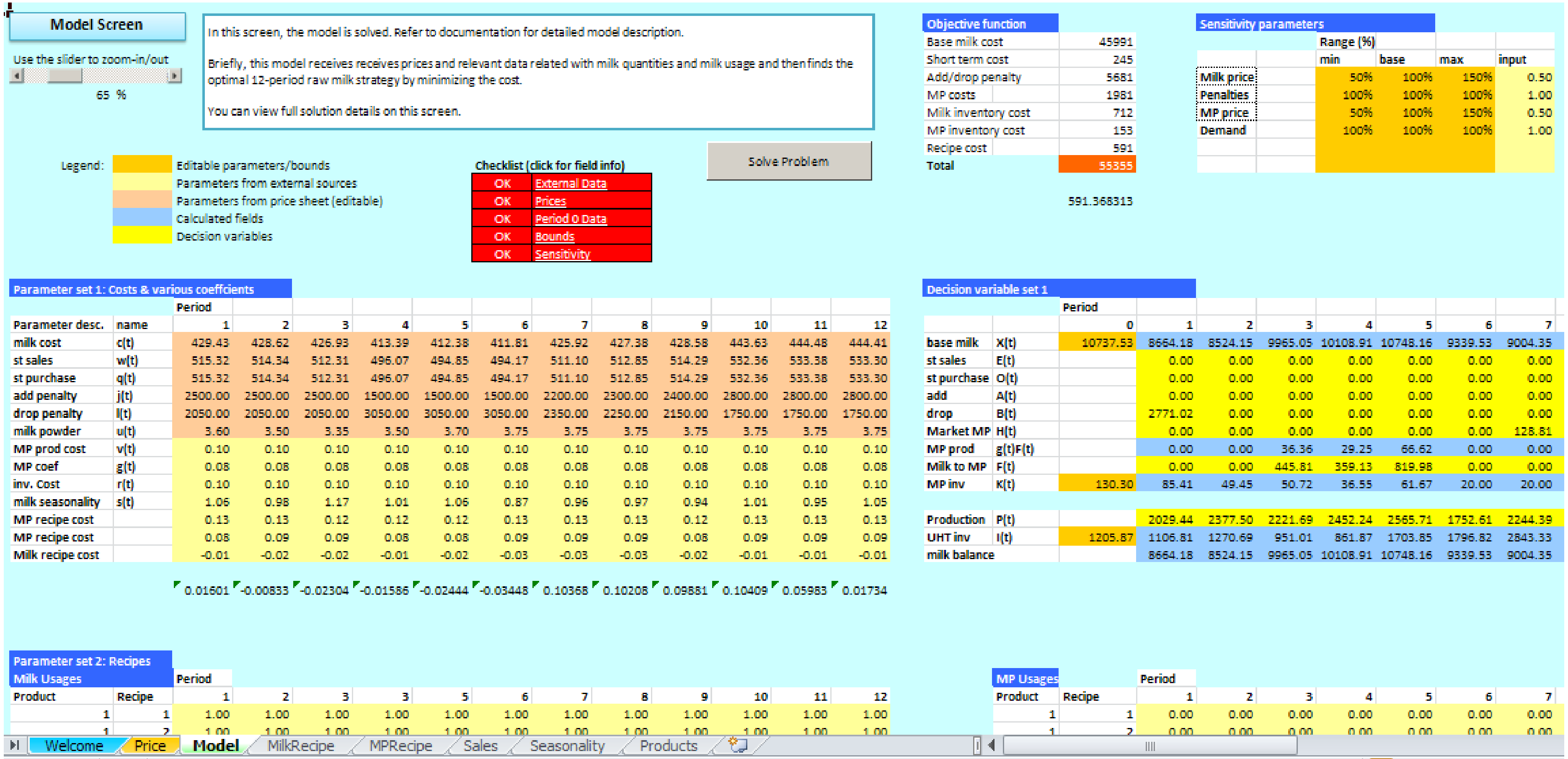


Figure 7: Main model screen of the DSS

CHAPTER 6

DEMONSTRATION OF THE DSS ENVIRONMENT

The study focuses on two main components, mathematical model for strategy generation and the DSS for the solving the model. Each component is expected to have improvements over the current solution that they are replacing and since the current solution is already in place, it is possible to test the system in a real life setting with actual data.

The strategy determination process is done monthly, where strategies are revised with a new batch of data. Usually, the whole process takes a week from collecting data to finding a suitable strategy.

In the first part of this section, the optimized results from the model are analyzed with respect to the results from the current system.

In the second part of this section, the DSS is analyzed in terms of improving the strategy determination process itself.

To assess the robustness of the usage of a linear model, a virtual machine is created on VMware with a single core CPU, 512 MB RAM and Windows XP as the testing environment. The DSS is expected to be deployed on a machine with a much better performance, but since multiple optimizations and scenario analyses will be done, stress testing on a machine with a modest performance is important for reliability.

Model Results

Although the strategy is revised every month, the most crucial time of the year for strategy determination is during the budget negotiations for the next year. General company strategies are directly related with raw milk strategies and vice versa.

For this reason, budget estimations for the year 2011 are selected for implementation and comparison of results. The budgeted strategy for 2011 had been determined in August 2010. For comparison of the determined strategy with the results of the mathematical model, the model is solved using the same data.

The main difference between the optimization model and the current process is the inclusion of prices and costs and the success of the model is evaluated depending on the reduction of costs as well as reliability of proposed strategies.

Table 1 lists the costs used in the solution. The supply and demand seasonality can be seen from the fluctuation of costs. As preliminary analysis, on Figure 8, the seasonality effect is visualized by comparing the sum of demand (left axis) and initial base milk quantity (right axis), where seasonality coefficients are directly applied starting from the period zero milk quantity.

Table 1: Costs for Model Analysis

Parameter desc.	Param. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Milk cost	c(t)	859	857	854	827	825	824	852	855	857	887	889	889
Short-term sales price	w(t)	1031	1029	1025	992	990	988	1022	1026	1029	1065	1067	1067
Short-term purchase cost	q(t)	1031	1029	1025	992	990	988	1022	1026	1029	1065	1067	1067
Long-term add penalty	j(t)	2500	2500	2500	1500	1500	1500	2200	2300	2400	2800	2800	2800
Long-term drop penalty	l(t)	2050	2050	2050	3050	3050	3050	2350	2250	2150	1750	1750	1750
Milk powder cost	u(t)	7,20	7,00	6,70	7,00	7,40	7,50	7,50	7,70	7,70	8,00	8,00	8,00

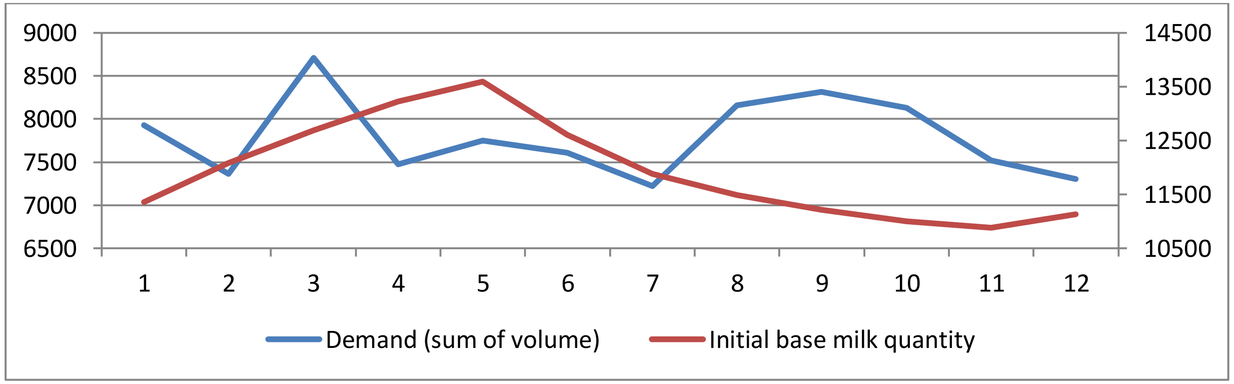


Figure 8: Chart showing the trend in demand and initial base milk quantity before strategy determination

Among the costs in Table 1, the penalty costs require the most attention. The current process is dependent of intuition and experience and although the optimization model and the DSS automate the whole process, experience is still required for the determination of penalty costs and the user is not discarded entirely.

Other costs are determined by market conditions, whereas the penalty costs are determined by the user to keep the model in control. If penalty costs are too low, then the model will opt in to manage the supply by long-term contracted milk every period, which is not realistic considering the long-term nature of these contracts.

The proposed strategy by the model when penalty costs are zero can be seen in Table 2.

Since there is no penalty, the model meets the exact demand every month by using the cheapest source, which is the long-term contracted milk. However, this strategy is not realistic, if a company is to adjust long-term contracted milk in such a manner; it is very likely that the raw milk producers would stop supplying milk to that company. Similarly, breaking such a high amount of milk contracts in April and getting a close amount back in August is not possible.

On the other hand, if the penalty costs are too high, then the model may be unable to prefer management of long-term contracted milk, but adjustments with long-term contracted milk is needed especially when there is a shift in demand.

Consequently, penalty costs are important to guide the model to the right direction for determining the optimal strategy.

Table 2: Optimal Strategy when Penalty Costs are Zero

Decision var.	Var. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Short-term sales	E(t)	0	0	0	0	0	0	0	0	0	0	0	0
Short-term purchase	O(t)	0	0	0	0	0	0	0	0	0	0	0	0
Long-term addition	A(t)	0	145	481	0	297	426	0	1276	547	0	0	201
Long-term dropping	B(t)	3513	0	0	1370	0	0	211	0	0	198	845	0
Market milk powder purchase	H(t)	0	27,8	36,3	43,7	43,0	43,3	147,5	42,1	31,7	26,5	22,7	24,1
Milk to milk powder production	F(t)	0	0	0	0	0	0	0	0	0	0	0	0
Long-life milk production	P(t)	2029	2378	2222	1813	1692	1429	1753	2246	2228	2238	1969	2068

However, the determination of the right penalty costs may be tedious, depending on the user's familiarity with the seasonality of relationships between the processor and the milk producers. As a starting point, the penalty costs can be considered to follow a similar seasonality with price since it is difficult to break contracts in spring when there is excess milk in the market and it is difficult to make new contracts in fall when there is milk scarcity in the market.

At this point, the solver platform provides a notable remedy for the trial and error based task of determining penalty costs. Once the initial costs are determined, it is possible to set a percentage interval over which the costs will be changed and multiple optimizations can be solved within this interval to determine how the penalty costs affect the strategy generation.

For initial penalty costs for new long-term contracts, an arbitrary selection is made as two times the short-term contracted milk prices that can be seen in Table 3.

Then these penalty costs are smoothed and fine-tuned to reflect the experiences of past years, which can be seen in Table 4.

After new contract costs are obtained, it is sufficient to apply a reversing methodology for the penalty costs of broken contracts since new contracts and broken contracts are inversely related with each other. For reversing, two times the average of new long-term contract penalty costs are obtained, which is 4550. Then the costs of each month are subtracted from this figure to obtain the costs in Table 5.

Table 3: Initial Selection of Long-term Contracted Milk Addition Penalty Costs

Parameter desc.	Param. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Long-term add penalty	j(t)	2061	2057	2049	1984	1979	1977	2044	2051	2057	2129	2134	2133

Table 4: Adjusted Long-term Contracted Milk Addition Penalty Costs

Parameter desc.	Param. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Long-term add penalty	j(t)	2500	2500	2500	1500	1500	1500	2200	2300	2400	2800	2800	2800

Table 5: Long-term Contracted Milk Dropping Penalty Costs Determined from Milk Addition Penalty Costs

Parameter desc.	Param. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Long-term drop penalty	l(t)	2050	2050	2050	3050	3050	3050	2350	2250	2150	1750	1750	1750

In the final step, multiple optimization reports are obtained using the related command in the Solution Analysis tab of the DSS. Whenever needed, the user can use this functionality to revise and check the accuracy of penalty costs as well as conducting similar sensitivity analyses on milk price, milk powder price and demands.

Figure 9 shows the selection screen for multiple optimization analysis for penalty prices, where they are set in an interval from 0% to 200% with 200 optimizations to solve. Due to the linear nature of the model, such a heavy task takes less than a minute to complete even in the low-performance testing environment.

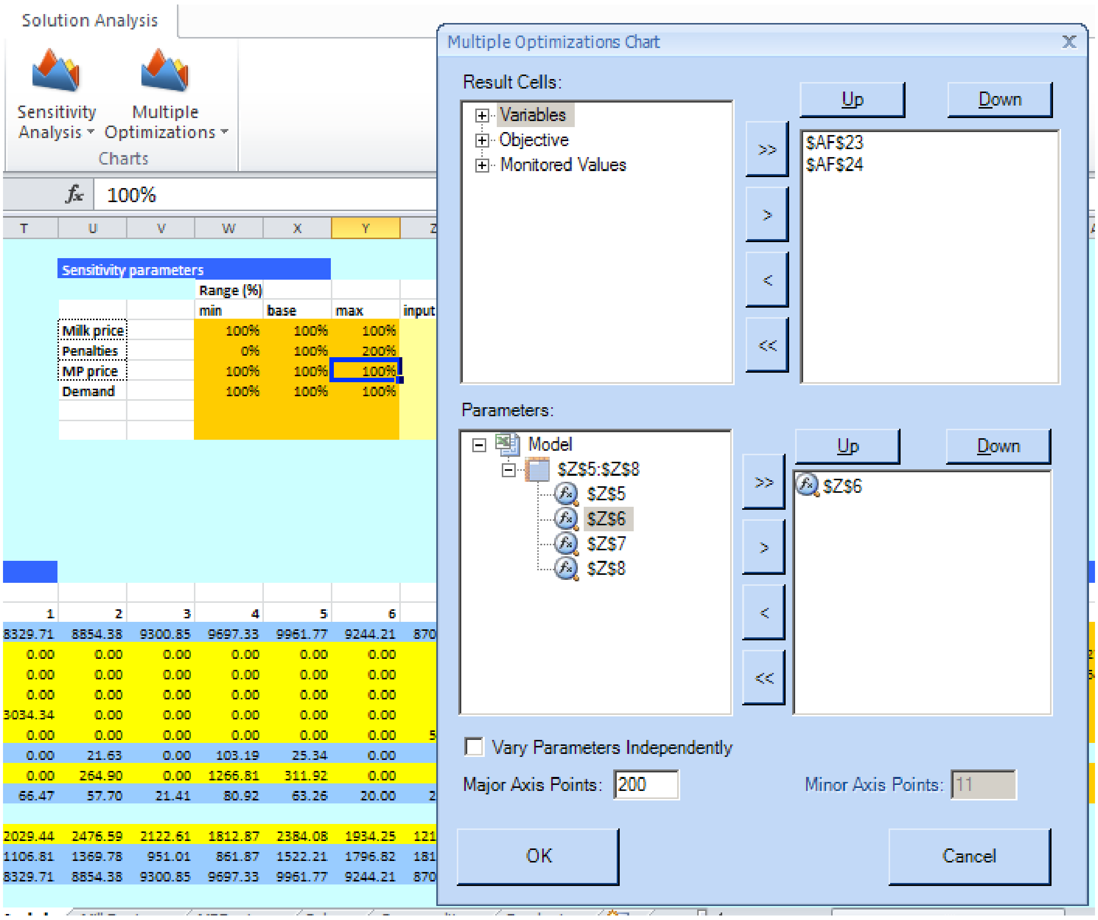


Figure 9: Selection screen for options for penalty cost analysis

The chart in Figure 10 shows the change in total dropped milk (AF24) and total added milk (AF23) over the change in penalty costs. This chart provides two primary insights. When the penalty costs exceed the value of 25% of the current, adding milk is no more an option for the model, but even when there are very high penalty costs for dropping milk, long-term contracts for around 3000 tons of milk must be broken in any case, since there is a certain amount of excess in the system.

This finding coincides with the real life situation, where at the beginning of the year, one of the private label customers is switching to another supplier and there is a strong downwards shift in the demand. In the current strategy determination process, it was decided to break contracts for 3225 tons of milk. This shows that the model is capable of obtaining applicable strategies if the penalty costs are set right.

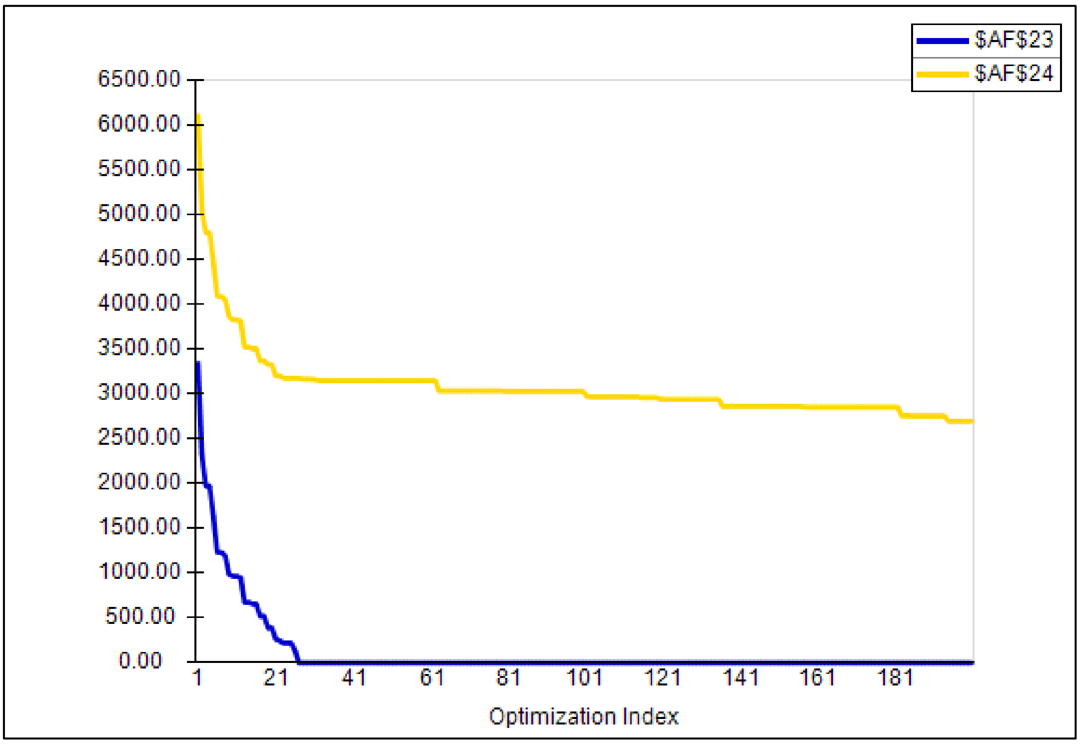


Figure 10: Change in added and dropped milk amounts depending on penalty costs

As a result of these findings, three levels of penalty costs are decided to be used for comparison of the model results with current strategy. The first is the 10% point, where the pace of reduction in added milk in the above graph becomes steadier. The second is the 25% point, the point where the graph reaches stability. The third is the 100% point, the initial penalty costs.

For the manually determined strategy, the strategies can be found in Table 6. The objective value of these strategies excluding the penalty costs are: 95,642 kTL.

For the first (10%) case, the penalty costs can be found in
Table 7 and the optimal strategy can be found in Table 8. The objective value of these strategies excluding the penalty costs are: 93,887 kTL. When penalty costs are included, the objective value of the optimal strategy is 94,894 kTL, whereas the value for manually determined strategy is 96,419 kTL.

For the second (25%) case, the penalty costs can be found in Table 9 and the optimal strategy can be found in Table 10. The objective value of these strategies excluding the penalty costs are: 94,391 kTL. When penalty costs are included, the objective value of the optimal strategy is 96,099 kTL, whereas the value for manually determined strategy is 97,584 kTL.

For the third (100%) case, the penalty costs can be found in Table 11 and the optimal strategy can be found in Table 12. The objective value of these strategies excluding the penalty costs are: 94,750 kTL. When penalty costs are included, the objective value of the optimal strategy is 100,860 kTL, whereas the value for manually determined strategy is 103,412 kTL.

Table 6: Manually Determined Strategy

Decision var.	Var. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Short-term sales	E(t)	750	0	0	0	0	0	0	0	0	0	0	300
Short-term purchase	O(t)	0	0	0	0	0	0	0	0	0	0	0	0
Long-term addition	A(t)	0	0	0	0	0	0	527	0	0	0	0	0
Long-term dropping	B(t)	2945	280	0	0	0	0	0	0	0	0	0	0
Market milk powder purchase	H(t)	0	78	37	43	0,0	0	15	147	0	0	0	0
Milk to milk powder production	F(t)	0	0	0	0	900	600	0	0	0	0	0	0
Long-life milk production	P(t)	2029	2477	2123	1813	2384	1934	1211	1883	2020	2153	1969	2068

Table 7: Penalty Costs for 10% Penalty Costs Case

Parameter desc.	Param. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Long-term add penalty	j(t)	250	250	250	150	150	150	220	230	240	280	280	280
Long-term drop penalty	l(t)	205	205	205	305	305	305	235	225	215	175	175	175

Table 8: Optimal Strategy for 10% Penalty Costs Case

Decision var.	Var. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Short-term sales	E(t)	0	0	0	0	0	0	0	0	0	0	0	0
Short-term purchase	O(t)	0	0	0	0	0	0	0	0	0	0	0	0
Long-term addition	A(t)	0	0	0	0	0	33	0	936	0	0	0	0
Long-term dropping	B(t)	3513	322	0	0	0	0	0	0	0	0	0	0
Market milk powder purchase	H(t)	0,0	68,5	127,7	43,7	43,0	43,3	147,5	82,2	111,2	96,2	22,7	24,1
Milk to milk powder production	F(t)	0	0	0	0	0	0	0	0	0	0	0	0
Long-life milk production	P(t)	2029	2378	2222	2170	1762	1100	1655	2281	2193	2238	2068	1969

Table 9: Penalty Costs for 25% Penalty Costs Case

Parameter desc.	Param. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Long-term add penalty	j(t)	625	625	625	375	375	375	550	575	600	700	700	700
Long-term drop penalty	l(t)	513	513	513	763	763	763	588	563	538	438	438	438

Table 10: Optimal Strategy for 25% Penalty Costs Case

Decision var.	Var. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Short-term sales	E(t)	0	0	0	0	0	0	0	0	0	0	0	0
Short-term purchase	O(t)	0	0	0	0	0	0	0	0	0	100	0	0
Long-term addition	A(t)	0	0	0	0	0	0	0	135	0	0	0	0
Long-term dropping	B(t)	3183	0	0	0	0	0	0	0	0	0	0	0
Market milk powder purchase	H(t)	0,0	0,0	39,1	0,0	0,0	43,3	50,0	71,8	111,2	104,0	30,5	50,8
Milk to milk powder production	F(t)	0	0	0	1064	0	0	0	0	0	0	0	0
Long-life milk production	P(t)	2029	2612	1987	1843	2519	1770	1056	1967	2006	2238	1969	2068

Table 11: Penalty Costs for 100% Penalty Costs Case

Parameter desc.	Param. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Long-term add penalty	j(t)	2500	2500	2500	1500	1500	1500	2200	2300	2400	2800	2800	2800
Long-term drop penalty	l(t)	2050	2050	2050	3050	3050	3050	2350	2250	2150	1750	1750	1750

Table 12: Optimal Strategy for 100% Penalty Costs Case

Decision var.	Var. name	Period											
		1	2	3	4	5	6	7	8	9	10	11	12
Short-term sales	E(t)	0	0	0	0	0	0	0	0	0	0	0	0
Short-term purchase	O(t)	0	0	0	0	0	0	0	0	0	34	0	0
Long-term addition	A(t)	0	0	0	0	0	0	0	0	0	0	0	0
Long-term dropping	B(t)	2981	0	0	0	0	0	0	0	0	0	0	0
Market milk powder purchase	H(t)	0,0	0,0	0,0	0,0	0,0	0,0	20,4	42,1	111,2	104,0	24,3	44,5
Milk to milk powder production	F(t)	0	382	0	1329	436	0	0	0	0	0	0	0
Long-life milk production	P(t)	2029	2417	2183	1813	2324	1994	1268	1688	2073	2238	1969	2068

These results indicate that as penalty costs increase, the model favors alternatives that are more expensive instead of managing supply with long-term contracted milk. Yet in all cases, there is an improvement over the manually obtained strategy. In the first case, the improvement is 2% and in the last case, the improvement drops to 1%. These improvements are when penalty costs are excluded, the improvement is higher when penalties are considered.

The manually determined strategy is very close to the optimal results. One reason for this is that being the next year’s budget, these strategies were fine-tuned more than the regular monthly strategies and had undergone a higher number of iterations. Another reason is that the user had three years of experience in generating strategies and having seen three full seasonal cycles, the user was able to make highly accurate predictions.

However, still the improvement provided by optimization is notable. These changes may seem small, but raw milk is the primary cost item and even 1% cost reduction is nearly equal to 1 million TL, indicating a significant improvement in the profit margin. Although exact profit figures cannot be provided due to confidentiality of data, it can be said that this saving figure signifies double-digit percentage increase in the profits.

Besides the quantitative improvements with the implementation of an optimization model, implementation of a DSS environment generates improvements in the strategy determination process and the user experience as well.

In the current situation, all data are collected by email from all parties and then entered into a single spreadsheet by the user, where some of the data is copied and pasted into a sheet and some data is obtained using links in the main spreadsheet. This is a time-consuming process and especially, copying and pasting is prone to errors. With the DSS, manual data entry is eliminated. All data is automatically fetched from a database, only external file requirement is the prices file, for which the user also has the flexibility of entering some of the prices manually.

Another improvement in data collection process is the checklist. Taking advantage of the ability to use checkboxes and interact with them in the ribbon interface, the model can only be solved when all the checkboxes are checked. For convenience, there is another checklist in the model sheet as well and both checklists are synchronized, so the user has the choice to use either of them. As the application ribbon is persistent in all screens, the checklist is always visible for the user to see all the input requirements and the steps throughout all operations with the DSS.

Figure 11 shows a screenshot of the checklists with the incompletion warning.

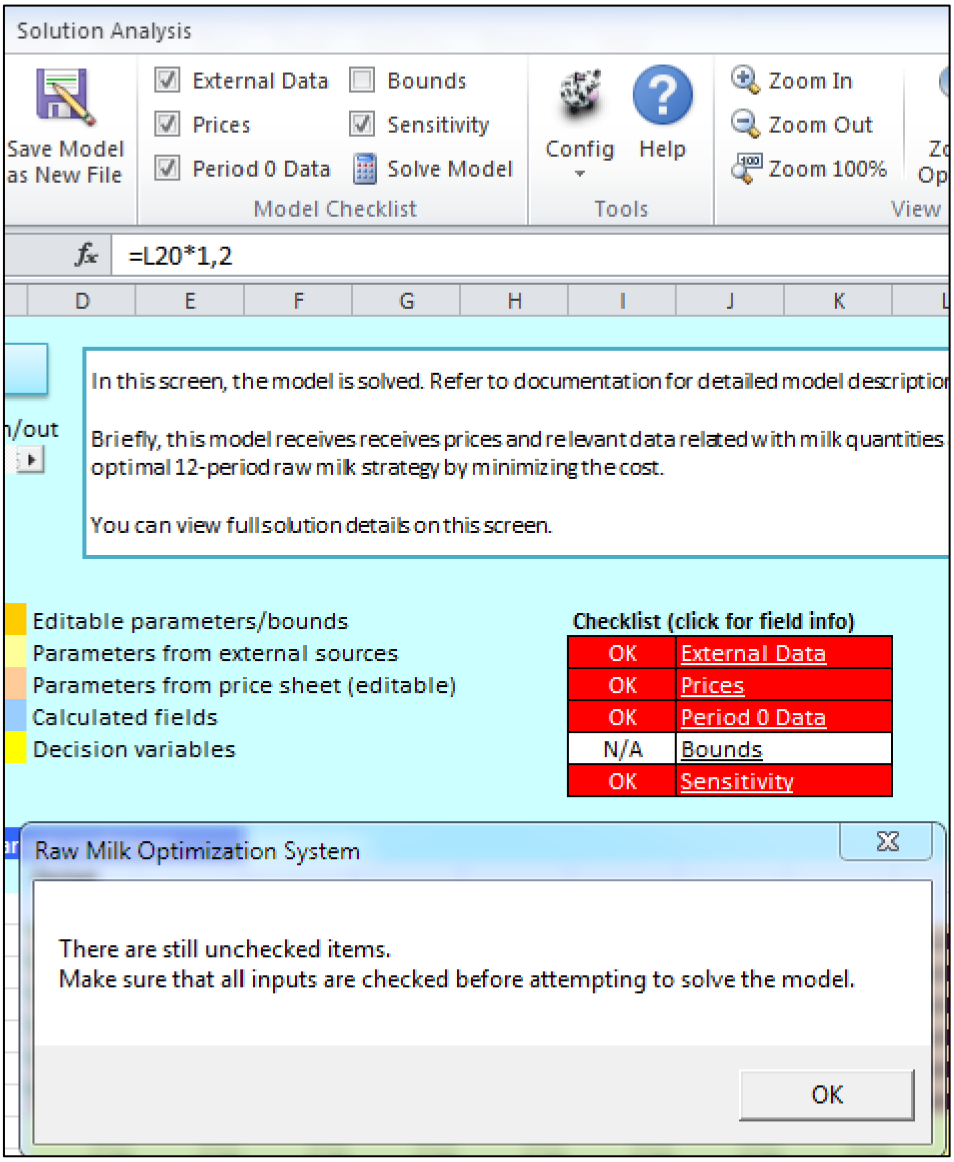


Figure 11: Checklists and incompletion warning

Moreover, the checklist is not just a cosmetic tool, when the user clicks on an item, the application guides the user what to do. For instance, Figure 12 shows an example guidance by the application; a message box that appears when the user clicks on External Data button in the Model sheet.

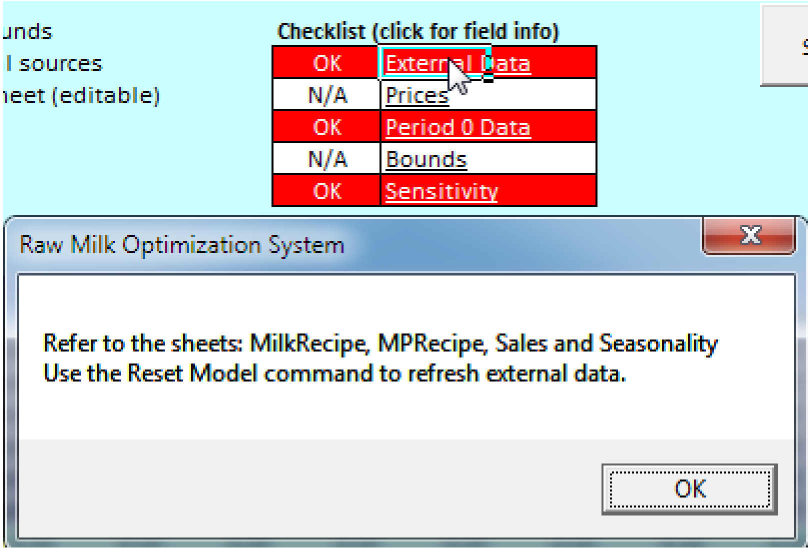


Figure 12: Example of user guidance through the checklist

With these data collection features of the DSS, the possibility of error and time required to collect data is reduced. A spreadsheet contains standard commands, but the DSS interface contains commands that are only related with milk strategy management.

The second improvement is the model sheet to control all of the strategies from a single screen. In the current situation, there are separate sheets for recipes, volumes, milk quantities and general strategies. Figure 13 exhibits a screenshot of the current spreadsheet solution. The spreadsheet is not very tidy, adding another layer of difficulty to the already tedious strategy determination process. If the user is not familiar with the locations of the data within the spreadsheet and which cells to adjust to determine the strategy, the formulas in the cells may become erroneous or links between different sheets may be broken.

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Product 1		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	
2	Strategy		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	1000
3	Product 2		100%	70%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
4	Product 3		40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	40%	250
5	Product 4		30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	30%	TOTAL
6	Milk Commitment		16.980	16.160	18.728	18.817	19.966	17.785	18.402	17.788	16.799	17.019	16.287	17.222	211.956
7	Sold/Rested		150	0	0	0	0	0	0	0	0	0	0	60	210
8	UHT Initial Demand		719	674	800	606	604	606	522	792	783	729	700	610	8.145
13	FD Demand		21.809	21.529	27.920	26.542	29.162	29.157	29.752	25.952	26.986	26.120	23.431	24.729	313.089
14	Milk Status		-218	406	-221	1.072	230	-568	641	-256	-912	-360	-43	315	85
15	UHT Build-up		-218	406	-221	1.072	230	-568	641	-256	-912	-360	-43	315	85
25	FD SMP Consumption		85	61	20	19	21	21	21	20	19	19	18	19	343
28	3rd Party SMP Production		0	0	0	0	73	49	0	0	0	0	0	0	122
29	Milk to 3rd party SMP						900	600							1.500
30	UHT Demand		1.684	1.724	1.724	1.756	1.671	1.593	1.671	1.717	1.647	1.675	1.692	1.683	20.238
33	Budget		921	1.058	792	717	2.060	1.587	2.120	908	946	917	832	666	13.524
34	UHT Closing Inv.	1206	1.945	2.282	2.098	2.990	3.182	2.709	3.242	3.029	2.270	1.970	1.935	2.197	
35	Days of Inventory		11	14	15	33	37	40	28	26	15	12	14	n/a	
36	UHT Production		3.181	4.360	3.862	4.950	3.253	1.817	3.060	3.416	2.115	3.186	3.595	3.412	
37	UHT Sales		3.543	3.685	4.230	3.166	2.869	2.763	1.994	3.843	3.633	3.785	3.667	2.889	
38	Days of Inv.		11	14	15	33	37	40	28	26	15	12	14	N/A	
40	Market SMP Procurement		0	65	31	36	0	0			0	0	0	0	132
41	BUDGET		42	42	43	180	308	371	362	287	201	101	43	21	2.000
42	SMP Closing Inv.	130	27	28	29	28	52	56	27	113	85	61	40	18	565

Recipes | Milk Supply | Pivot | milk movement | STRATEGY | 2011 volume | Summary | milk quantity | 2011 supply

Figure 13: A screenshot of the current spreadsheet solution

The DSS interface is more streamlined with zoom controls and color coding, whose legend can be seen in Figure 14**.**

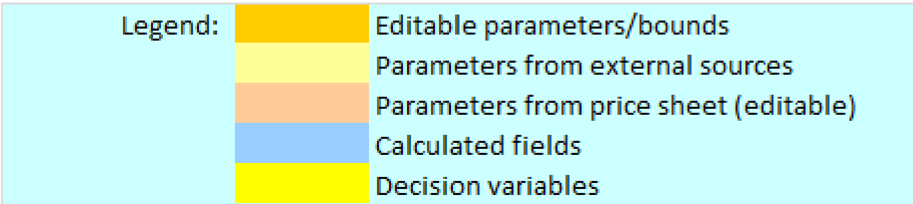


Figure 14: Color coding legend of the DSS

In the current situation, for strategy evaluation, due to the iterative nature of this process, the user needs to share these scenarios with the finance department to be evaluated and waits for feedback. If anything needs to be changed, the process starts again. On the other hand, as the cost component is embedded into the optimization model; with DSS, the user can find the optimal strategy with one click, eliminating dependency on other parties.

As explained previously, the model is linear and in the low-performance testing environment, problem parsing time is around 1 second and problem solving time is around 0.3 seconds. When multiple optimizations are conducted, the solving times reduce to values less than 0.1 seconds. Solutions can be obtained very quickly, meeting the rapidness requirements of the decision making process.

Another problematic area in the current situation is the scenario analysis. It is necessary to adjust the parameters manually and every scenario must be evaluated separately. There is no way to make a scenario analysis within an interval, so there is a mess of scenario files for discrete decision points and each file is sent separately for evaluation. Considering the combinations of strategies, scenario analysis is a serious issue and the spreadsheet solution provides limited insight besides general strategy generation.

The DSS makes use of the comprehensive parameter and optimization analysis features of the solver engine to fulfill the need of scenario analysis.

The user can set specific intervals to change the values of parameters. Figure 15 shows the adjustable selection cells for a scenario analysis of milk and milk powder prices set between 50% and 150% of the initial value.

Sensitivity parameters					
		Range (%)			
		min	base	max	input
Milk price		50%	100%	150%	0.50
Penalties		100%	100%	100%	1.00
MP price		50%	100%	150%	0.50
Demand		100%	100%	100%	1.00

Figure 15: Scenario analysis selection cells

In the input column there is a special formula using the function `PsiOptParam`, which is recognized by the solver engine. This function indicates that when optimization analysis is conducted, the related parameters are changed between lower and upper values. On Figure 16, the input screen of this function is displayed. This screen is not visible to the user and is used by the developer to determine the input cells and parameters for analysis. The user does not need to be familiar with the solver engine, these functions are already defined in the DSS and the user only fills in the values required. Whereas, in the current situation, if the user needs to change the values for scenario analysis, the values must be changed manually with a primitive method like paste special to multiply with the copied value.

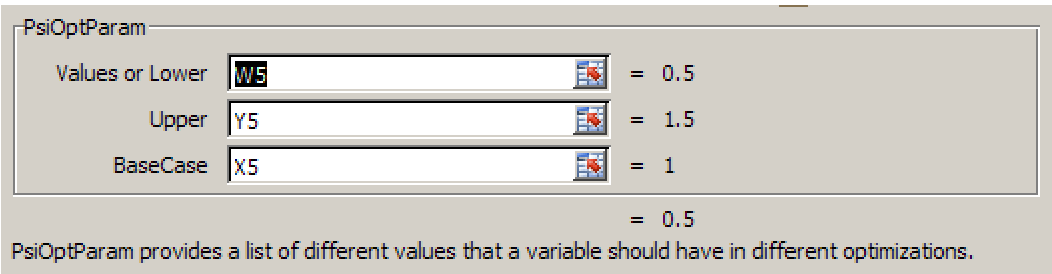


Figure 16: PsiOptParam function input screen

The objective value is not the only output that can be traced during multiple optimizations. The objective values and single variable values can be traced by default, but with the function `PsiOptValue`, other values can be defined for tracing over multiple optimizations. Again, in the DSS, this function is already set for each set of decision variables as the sum over all periods. It is sufficient for the user to specify the variable of interest in the selection screen.

An example scenario analysis can be found in the previous Model Analysis section of this study, where changes in penalty costs versus long-term contracted milk quantities are analyzed using these facilities.

Although these are already serious improvements over the current situation with these features, the solver engine is capable of addressing even more complicated scenario analyses. In the spreadsheet solution, only a single parameter can be changed at a time to see the effects independently, but the solver engine allows two dimensional parameter analysis with independent variability. The linearity of the model brings in two advantages at this point; the speed at which the multiple optimizations are solved and the ability to conduct detailed parameter analyses.

As a demonstration, the relationship between the milk powder price and the milk price is analyzed versus the total amount of milk sent for milk powder production.

Sensitivity parameters for milk and milk powder prices are set between 50% and 200%. Previously, it was decided to use the 10% point in penalties and it is fixed. The inputs are shown in Figure 17.

Sensitivity parameters					
		Range (%)			
		min	base	max	input
Milk price		50%	100%	200%	0.50
Penalties		10%	10%	10%	0.10
MP price		50%	100%	200%	0.50
Demand		100%	100%	100%	1.00

Figure 17: Sensitivity values selected for demonstration

In the next step, multiple optimization options are specified. The selection screen is shown in Figure 18.

Two parameters and an output value are selected for multiple optimizations, with each parameter is set to vary independently over 12 points. Since they are independent, this selection requires 144 optimizations to be run. Total amount of milk sent to milk powder is set in the cell AF27, milk price change interval is set in the cell Z5 and milk powder price change interval is set in the cell Z7.

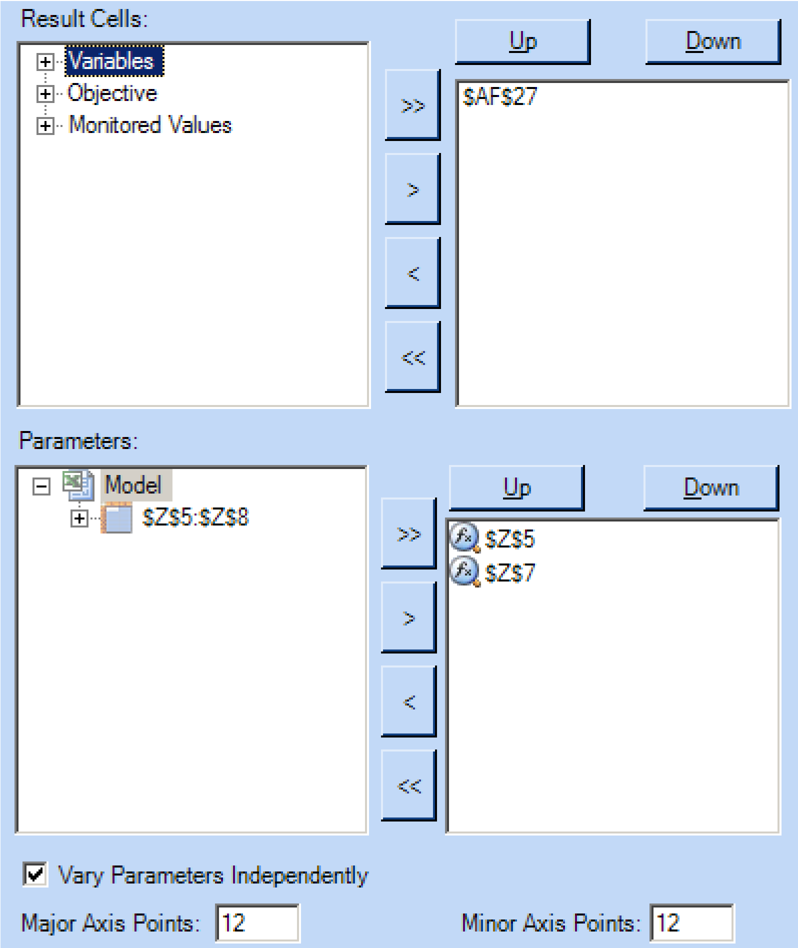


Figure 18: Multiple optimization options selected for demonstration

For analysis, the user has the option to view the results on a table or on a chart. The solver engine creates a new sheet with the data or launches a special chart viewing application. The drawback is that the chart is not a native Excel chart and can only be used like an image with limited customization options.

The data table of the results of 144 optimizations is shown in Table 13 and the surface chart of the same dataset is shown in Figure 19.

Table 13: Multiple Optimization Analysis Results of the Demonstration

Data: Total amount of milk sent to milk powder in each optimization point												
	Milk powder price %											
Milk price %	50%	64%	77%	91%	105%	118%	132%	145%	159%	173%	186%	200%
50%	1157	1873	2394	3918	3918	3918	3918	3918	3918	3918	3915	4169
64%	0	1064	1792	2096	3202	3918	3918	3918	3918	3915	3915	3915
77%	0	0	536	1353	1873	2551	3593	3915	3915	3915	3915	3915
91%	0	0	0	0	1064	1792	2542	3200	3915	3915	3915	3915
105%	0	0	0	0	0	958	1792	1963	3069	3915	3915	3915
118%	0	0	0	0	0	0	536	1260	1792	2693	3378	3915
132%	0	0	0	0	0	0	0	357	1261	1794	2278	3248
145%	0	0	0	0	0	0	0	0	0	790	1261	1879
159%	0	0	0	0	0	0	0	0	0	0	289	1261
173%	0	0	0	0	0	0	0	0	0	0	0	0
186%	0	0	0	0	0	0	0	0	0	0	0	0
200%	0	0	0	0	0	0	0	0	0	0	0	0

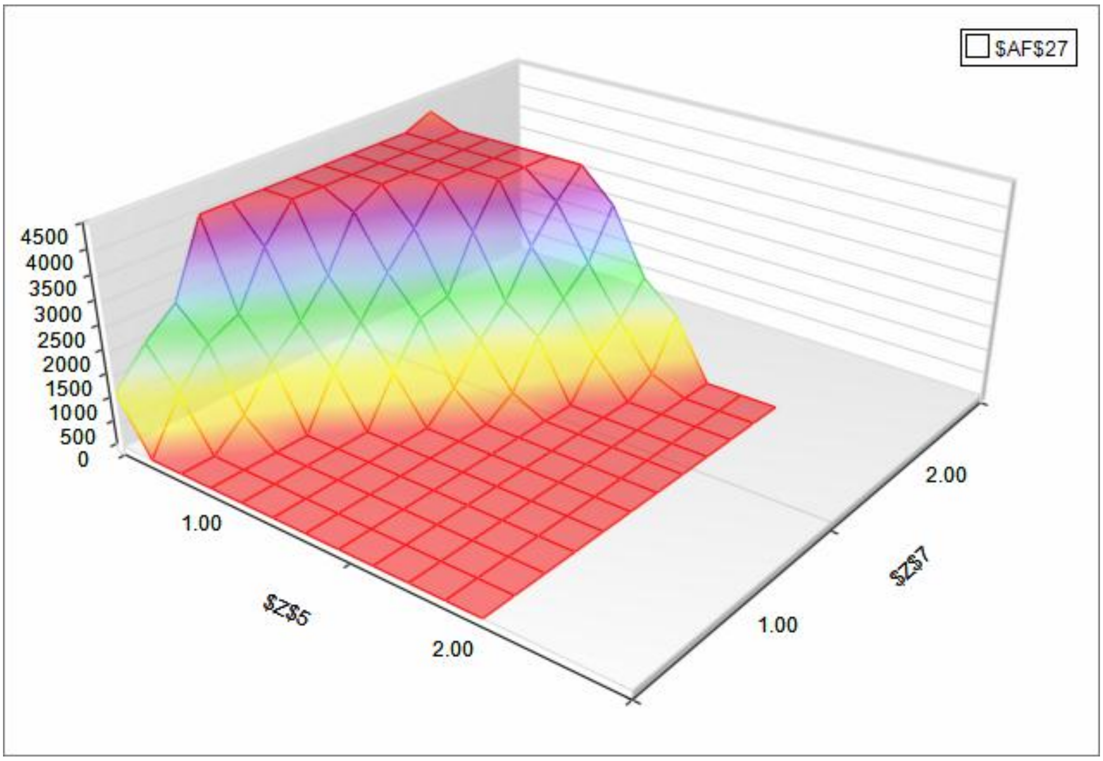


Figure 19: Multiple optimization analysis chart of the demonstration

On the chart in Figure 19, Z5 represents the changes in milk price and Z7 represents the changes in the milk powder price. Z-axis is the total amount of milk sent for milk powder production.

It can be inferred from the chart that milk and milk powder prices are dependent on each other for determining the strategy. Above a specific ratio, producing milk powder is not preferable and milk powder needs are met from market purchases, but below that line, there is a steep increase in milk powder production. Since the milk is cheaper, the model prefers milk powder production for two reasons, to meet the milk powder requirement with a less costly alternative than the market price as well as converting excess milk to milk powder.

Similar multiple optimization analyses can be conducted with various combinations of parameters and within various intervals for various variables using the DSS. The ribbon interface alone is just a facilitator and the solver engine alone requires training and experience. The strength of the DSS is to combine both elements to provide a user-friendly way to carry on demanding strategy determination and scenario analysis tasks.

With all these additional features of the DSS, both the user experience and the strategy determination process are improved. From data collection to scenario analysis, the process is more structured and the steps are more visible with the guidance of the DSS. The user has a better control over the inputs and the outputs; yet the dependence on the experience and the intuition is reduced in general.

Previously, the user was required to focus on generating the main strategy, but now, operational tasks are automated and the optimization model determines the main strategy. In the current situation, strategy determination process may take as much as a week from collecting data to finding a suitable strategy. With the implementation of the DSS, whole process can be completed in a day. If the data are ready, it will take only seconds to find a suitable strategy, whereas previously, the user had to wait for the finance department for one or two days to evaluate the potential strategies.

The user can concentrate on more sophisticated tasks like scenario analysis and fine-tuning the strategy, where experience and intuition are used for more value added tasks.

CHAPTER 7

CONCLUSION

This study focuses on an area that has not been extensively explored within the realm of dairy supply chain studies. Due to the inverse seasonality of supply and demand in dairy, as well as the unique complexities in raw milk supply, long-term planning of the raw milk supply is crucial; however, since there are still many areas to explore for improvement in the operational level, management in the strategic level is generally overlooked. Moreover, the dairy business is a traditional business and the way of working is dependent on experience and intuition. This study proposes a solution for both issues; an optimization based approach with a mathematical model of the dairy supply chain for strategic raw milk management and a DSS to automate the way of working for reducing the dependency on the adeptness of the decision maker. Another focus of the study is implementing the new generation Microsoft Ribbon interface, which is rarely seen in academic studies despite offering new opportunities for improving the user experience in application interfaces.

For the model to be created and implemented into a DSS, an analysis of the dairy supply chain of a Turkish dairy company is made and then the current strategy determination process is examined. A nonlinear mathematical model for raw milk management is created and then based on the findings of the supply chain analysis; the model is refined to be a linear model for practical purposes. For the strategic raw milk management DSS development, the improvement areas in the current tools used in strategy determination process are identified along with user requirements and a special interface is created based on the Ribbon technology.

As a demonstration and a pilot study, the performance of the optimization model is compared with the manually determined strategies and the user experience of the current tools is compared with the user experience of the DSS.

In the current situation, if the user is experienced in strategy generation, the manually determined strategies can be very close to the strategies found by the optimization model. Yet, being the primary input, the raw milk is also the primary cost item in the system; therefore, even a small improvement in raw milk management has a notable impact in costs, which translates to double-digit percentage increases in profit margins. Similarly, the DSS automates most of the manual labor, reducing the time required for strategy generation process from one week to one day. After the data are ready, generating strategies only take seconds, allowing the user to focus on more value added tasks such as detailed scenario analysis, which is only partially possible in the current situation.

For further research in modeling, supply management through price management can be implemented; however, there are certain obstacles related with milk producers for price management to be practical. As an alternative for reducing nonlinearity, recipe index can be added to production and inventory variables, defining the variables as production/inventory of product i with recipe j in period t: (p_{ijt}) and (i_{ijt}). In this case, proper aggregation of the variables is important.

As for further studies in DSS, the interface can be made even more sophisticated by using various types of controls available in the ribbon interface such as drop down boxes, multi-level menus and galleries; eliminating the need of buttons or other controls on the other parts of the application. Since the familiarity of the users with the ribbon interface is still limited, constant feedback from the users is important for the improvements in the DSS interface.

The novelty of this study in the field of dairy business and in DSS development indicates that in a traditional business like dairy, there are always new areas to explore and provide considerable contributions by focusing on overlooked areas and by taking advantage of new technologies. What is done at this point is just the tip of the iceberg of the complex dairy supply chain.

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