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RESEARCH ARTICLE

Optimizing seasonal grain intakes with non-linear programming: An application in the feed industry

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ABSTRACT

In the feed sector, 95% of the input costs arise from the supply of raw materials used in feed production. The selling price is determined by competition in free market conditions. Due to the use of similar technologies and the very small share of production costs in total costs, it is unlikely that a competitive advantage will be gained through innovations in production. Between 30% and 50% of grain products are used in feed ration analysis. Cereals can only be harvested at a certain time of the year. Due to this limited time frame, feed production enterprises have to balance their financial burdens with their operational needs while making their annual stocks. The study was carried out to cover all the relevant businesses of the company, which has feed factories in four regions of Turkey. Based on the season data of the year 2020-2021, the grain purchase planning for the year 2021-2022 was tried to be optimized with non-linear programming. While creating the mathematical model, grain prices, interest rates, production needs according to production planning, sales according to sales forecasts, factory stocking capacities, licensed warehouse rental, transportation, handling and transshipment costs were taken into account.

With this unique paper, in the cattle feed production sector, storage, transportation and handling costs will be minimized. Cost advantage will be provided with optimum purchase planning in the season. According to the grain pricing forecast and market data for the 2021-2022 season, model can provide a cost advantage of 0.7%. Model will also provide insight to the managers for additional storage space investments.

1. Introduction

Grain production is a strategic input of critical importance for both human and animal nutrition. The price of this strategic input is shaped under the influence of many factors. The most important factors affecting the price of grain products are the food industry price index, oil price, international food price, dollar and euro exchange rates, respectively [1]. Physical factors affecting harvest yield are also important in price formation. It is known that the grain group is the most important input in the content of animal feed rations. In this respect, cost items such as transportation, stock keeping and operating expenses should be purchased by considering the cost-benefit ratios. Grain prices reach their lowest level with the start of the harvest season and increase throughout the year due to the factors mentioned above. In addition, the availability of raw materials is limited and, due to seasonality, their prices and quality change over time.

Grain purchasing decisions in the feed sector are based on the experience of purchasing officials and their interpretations of market data in this direction, rather than analytical approaches. With this study, it is aimed to be affected by price changes at the minimum level during the year and to create a decision support model that will keep the financial burdens originating from stock holding at an optimal level. All constraints were taken into account while creating the model so that the dimensions encountered in business processes address real problems.

As far as we know, due to the generally accepted way of doing business in the feed industry, we have not encountered a decision support method that makes annual purchase planning within the framework of the factors determined in the mathematical model. The main contribution of this study is to fill this gap with a realistic and industry-independent purchasing planning optimization model.

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The rest of the paper is structured as follows. A literature review is provided in Section 2. The formal problem is defined in Section 3. In Section 4 mathematical model is given. Section 5 summarizes computational results reached by running the model based on grain price estimations and financial input estimations for the current year, sensitivity analyzes and insights for magement related with the possible investments are given. In Section 6, the conclusions are mentioned as well as future research directions.

2. Literature review

In the modeling studies in the literature, it is seen that the general approach encountered is to model the entire supply chain instead of planning seasonal purchases. Soysal et al. [2] analyzed the quantitative studies in the food supply chain management, found that 54% of the distribution of methods in 36 studies was mixed integer programming, 20% was analytical studies, 11% was simulation techniques, 6% was linear programming, 6% was multi-objective programming. It is been stated that the remaining 3% is solved by goal programming. Most models were constructed with linear variables, and heuristic methods are developed due to overcome the complexity.

Agent-based simulation approaches and analytical models applied to supply chain management are studied by Ge et al. [3]. In order to determine the wheat quality testing, it was tried to decide how to structure and optimize the entire wheat supply chain. The creation of the wheat supply chain with the analytical model and the simulation approach were compared. This comparison was made between solutions and procedures. While the two approaches offer different solutions, in many respects similar conclusions have been reached regarding the general testing and quality control issue in wheat processing and handling.

While presenting a new analytical model in Hosseini et al. [4], the total cost of wheat supply chain network design has been tried to be optimized. The proposed model simultaneously integrates the harvesting, production, inventory and distribution dimensions of the wheat supply chain. The role of uncertainty in the analytical optimization model is emphasized and then a robust optimization approach is used to remove the uncertainty of the parameters. It is seen that the results obtained from the robust optimization model outperform the deterministic model. The study highlights that uncertainties over demand and supply can have a direct impact on the total cost of the supply chain.

In Mirzapour et al. [5], the problem of multi-regional, multi-period, multi-product mass production planning under uncertainty is discussed. It is designed as a supply chain that includes multiple suppliers, manufacturers and customers, respectively. In the first multi-objective robust mixed integer nonlinear programming model, the cost parameters and demand fluctuations of the supply chain are subject to uncertainty. The first objective aims to minimize the total losses in the supply chain, including the cost of production, the cost of hiring, firing and training, the cost of holding raw materials and finished products, the cost of transportation and shortages. The second objective function, on the other hand, is to ensure customer satisfaction by minimizing the sum of the maximum amount of deficiency among customers' regions in all periods. The LP-metric method was used to solve the model. The results show that the designed model can fulfill a compromise approach to satisfy an efficient production planning in the supply chain.

A general production and financial planning model is introduced in Satır and Yıldırım [6]. This model is realistic and strategic because of all the divisions in a complex poultry integration (including the feed mill, breeder houses, hatcheries, broiler houses, abattoirs and distribution centres) and the relationships between these divisions. The model appears to have made it a strategic level plan for the fast moving chicken industry due to the planning horizon taken into account over the years. It is seen that linear programming is used in the model, aiming to provide valuable management understanding by making sensitivity analysis at the expense of loosening the integrity requirement on some decision variables (egg, chick, chicken, number of workers). Experiments with various end-customer demand scenarios have found that the amount of broiler chicks to be purchased at certain times over the planning horizon is the sound key decision variable in the overall system.

Mogale et al. [7] examined the entire supply chain in terms of transportation and storage of grain during the harvest season. The researchers aimed to minimize operating costs by using a mixed integer nonlinear programming (MINLP) model with a large number of binary and integer variables with various complex constraints. Due to complexity, exact algorithms could not help with the optimal solution. Therefore, it is seen that the Hybrid Particle-Chemical Reaction Optimization (HP-CRO) algorithm is used to solve the MINLP model. It is stated that the hybrid model outperforms both particle swarm and chemical reaction optimization.

Razmi et al. [8] created a dynamic mixed integer linear programming (DMILP) model by addressing the problem in three separate sections, such as facility location selection, the decision to open and close the facilities during the season, supplier selection, and determination. The problem is categorized in the large size group. For this reason, it has been preferred to use heuristic algorithms, stating that the optimal solution cannot be obtained using the exact solution procedure. The solution has been searched by genetic algorithm and it can be seen as a satisfactory approach to divide the problem into three subproblems without losing the total optimization approach. Despite the comprehensive modeling approach, it was seen that the part of determining the lot sizes was not taken into account in order to minimize the inventory costs in the study.

Nourbakhsh et al. [9] proposed an optimum network design and total system cost minimization model, taking into account unit rail transport cost, pre-processing plant capital cost, raw grain price and post-harvest losses. Some operational assumptions have been made, such as that the loss of quality during transport and handling is directly proportional to the travel time. In the model, it is seen that the loss of dry matter over time due to the effect of initial humidity and temperature is not taken into account. In addition, inventory holding costs are neglected in the model and a simplified linear assumption is made. It can be said that it is beneficial to have the harvest time frame in the model as a new dimension.

Dwivedi et al. [10] developed a MINLP model in order to minimize total transportation cost and corbon emission tax so as to maintain a sustainable network design. Genetic algorithm (GA) and quantum-based genetic algorithm (Q-GA) and LINGO are employed for problem solving. The computational experiments concede that the performance of LINGO was better than meta-heuristics in terms of solution obtained, but opposite to solution, computational time was longer analogically.

Teixeira et al. [11] developed a MINLP model to provide decision support to the relevant unit management in the planning of purchases of a business operating in the retail sector. The step functions are designed to analyze different scenarios, mathematical programming modeling language (AMPL) is used. The solution found by the KNITRO solver is compared with the current operation. It was stated that the delivery methods of the products were rearranged by meeting with the suppliers every two weeks and a cost advantage of 19.41% was achieved.

Other than MILP and MINLP models discrete optimization had been utilized for the sake of applicable decision support for the supply chain management. Smith et al. [12] proposed a methodology for developing an optimal promotional plan that maximizes total season profit, subject to promotional resource constraints and a set of possible market scenarios, by selecting from a discrete set of candidate ads and markdowns. By the use of the model, optimal planning of the inventory levels, timely usage of ads and markdowns and less operational cost had been reached.

Deciding what quantity of material to procure is critical to improving the supply chain performance. [13] Tries to solve problem of wrong time and sizing of inventory orders in bakery industry. Profitability is mainly affected by the fluctuating cost of inputs together with rising operational and maintenance costs. To overcome these challenges researchers conducted ABC inventory analysis, optimized the total holding and ordering costs where it’s suitable for the bakery industry operations as an approach which is close to economical order quantity procedure. As a result monthly purchasing quantities had been optimized with respect to monthly production forecasts. Also it includes recommendations for researchers on integrated inventory model for lead-time variability in order to cut down safety stock requirements.

The survey shows that numerical modeling is used effectively in supply chain management and provides decision support for significant profit margins and lower costs. However, lot size determination studies, except for [12], do not seem to focus on seasonal purchase planning as widely by researchers.

During the researches, only two studies were encountered that included both purchase/production lot sizes and plant storage capacities in the modeling at the same time [14-15]. Supply chain modeling/stock management with inter-facility transfers (transshipment) is covered in three related studies [16-18].

The contribution of this study to the literature can be seen as attempting to model production/purchasing lot-lot size, facility storage capacities and transfer between factories together, considering all possible alternatives in the calculations since it is designed to solve the relevant problem in real life.

3. Problem definition

Since the harvest period of grain products takes place in a limited time period and production can be made once a year, price fluctuations of the products are at a high level during the year. Successful stock management will ensure that these price fluctuations have minimal impact. Optimization of purchasing quantities is on the agenda as an important problem to be solved by purchasing decision makers, as stock holding investments are expensive and stocking can be done for a limited time. The purchases to be made during the season should include financial parameters, facility storage capacities, warehouses to be rented and the costs that will arise from these leasing transactions. Purchasing management will be an innovative approach that will allow scientific inferences to be made within the framework of the proposed decision support model, while making decisions based on market data and past experience. A model based on real-life data with all its dimensions will make it easier to make the right decisions. The problem has been evaluated in this context. As stated in the literature review in Section 2, no model was found for this purpose.

The basic approach in the model is to calculate the positioning return to be obtained by meeting the total needs with the purchases to be made in the previous monthly periods. It includes the comparison of the prices in the period when the position is taken with the estimated prices in the future periods when the need has to be met, and the comparison of this return remaining after the inventory holding costs arising from previous purchases deducted.

The company where the research was conducted has feed mill facilities in four different locations in Turkey. With the model, it is tried to find a solution about which grain type, which factory, which monthly period, in which quantity and at which unit price should be purchased. Based on this solution, it is aimed to plan external warehouse agreements, budget determination analyzes and operational actions. The healthy results of the study largely depend on the accuracy of price forecasts, interest rate forecasts and factory consumption analysis. Supply chain schema can be seen from Figure 1.

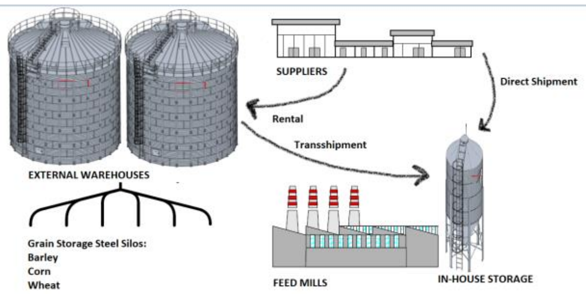

Figure 1. Supply chain schema

As can be seen from Figure 1, purchases from suppliers can be made directly to feed mills or to external warehouses. There will be rental costs in external warehouses as well as transshipment costs. Buying directly to the factory grain silos will minimize both rental fees and handling costs. For this reason, it is essential to optimize the capacity of the grain silos in the factories. To solve the problem described, the analytical model described in the next section was designed.

4. Mathematical model

As mentioned in Section 1, Frontline Analytic Solver software was used in this study to study the model designed to solve the mentioned problem in the computer environment. An NLP model is formulated for grain purchase planning and the results are analyzed using Microsoft Excel on a computer with a 2.0 GHz processor and 8 GB of RAM. All parameters and sets of the proposed NLP model are presented as follows.

Sets & parameters

f: factories = *{1,..,F}*

t: monthly periods = *{1,..,T}*

h: grain types used = *{1,..,H}*

sm^{dd}_{fht} , sa^{fb}_{fht} : for the factory f, inventory holding cost of the h type raw material in the outer warehouse in the period t, inventory transfer cost to the factory respectively.

$hm^{s}_{fht}, hm^{k}_{fht}$: for the factory f, at period t of the h type raw material, amount sold and used respectively.

av_h: Purchase deferment of h type raw material.

af_{fht}: Purchase price of h type raw material to factory f in period t.

an_{fh}: Raw material of type h received from the supplier is sent to the outer warehouse of the f factory, transshipment cost per ton.

dfn_{fh}: Per ton shipping cost of raw material h in the outer warehouse of factory f from warehouse to factory.

km_h: Rental cost per ton of keeping raw material h in an external warehouse.

em_h: Cost of handling raw material h in the outer warehouse.

dk_{fh}: Storage capacity for raw material h in factory f.

ddk_{fh}: Storage capacity for raw material h in the external warehouse of factory f.

$fo_t, dovk_{ht}$: Estimation of interest rate for period t, T.C.M.B. dollar exchange rate forecast in TL respectively.

4.1 Non-linear programming (NLP) model

The decision variables of the NLP model are defined as follows:

Decision variables

$hm^{a}_{fht}, hm^{i}_{fht}$: to factory f, the amount of raw material h type received and stocked in month t respectively.

dd^{i}_{fht} , $dd^{\text{ç}}_{fht}$, dd^{k}_{fht}: the amount of h type raw material stock, amount taken from the external warehouse to the factory f and amount stored at the outside warehouse at month t respectively.

X_{fht}: Purchase amount of raw material h for location f, in month t.

xv_{ht}: Remaining deferment of h type raw material in period t.

sfm_{fht}: Inventory financing cost for raw material h at month t of factory f/external warehouse.

PAG_{fht}: Return on positioning (early watch advantage) for raw material h at month t of factory f.

TNG_{fht}: Total net return from raw material h at factory f in month t.

The objective function and the constraints of the NLP model are presented below.

Objective function

$$\text{Maximize} \quad TNG_{fht} = PAG_{fht} - sfm_{fht} - sa^{fb}_{fht} - sm^{dd}_{fht}\ ;\ \forall t \in T\ ;\ \forall f \in F\ ;\ \forall h \in H \tag{1}$$

Constraints

$$hm^{i}_{fht\ t=1,..,T,h=1,..,H,f=1,..F} \geq 0\ ,\ \forall t \in T\ ;\ \forall f \in F\ ;\ \forall h \in H \tag{2}$$

$$hm^{i}_{fht-1} + hm^{a}_{fht} + dd^{\text{ç}}_{fht} = hm^{s}_{fht} + hm^{k}_{fht} + hm^{i}_{fht};\quad t = 1,..,T, h = 1,..,H, f = 1,..F;\ \forall t \in T\ ;\ \forall f \in F\ ;\ \forall h \in H \tag{3}$$

$$dd^{i}_{fht-1} - dd^{ç}_{fht} + dd^{k}_{fht} = dd^{i}_{fht}; \quad t = 1,..,T, h = 1,..,H, f = 1,..F; \ \forall t \in T; \forall f \in F; \forall h \in H \quad (4)$$

$$hm^{i}_{fht} \geq hm^{k}_{fht} + hm^{s}_{fht}; \ t = 1,..,T, h = 1,..,H, f = 1,..F; \ \forall t \in T; \forall f \in F; \forall h \in H \quad (5)$$

$$hm^{i}_{fht} \leq dk_{fh}; \ t = 1,..,T, h = 1,..,H, f = 1,..F; \ \forall t \in T; \forall f \in F; \forall h \in H \quad (6)$$

$$\sum_{h=1}^{H} dd^{i}_{fht} \leq ddk_{fh}; t = 1,..,T; f = 1,..F; \forall t \in T; \forall f \in F; \forall h \in H \quad (7)$$

$$\frac{hm^{i}_{fht}}{hm^{k}_{fht}} \ h \in H \leq 180; t = 1,..,T, h = 1,..,H, f = 1,..F; \ \forall t \in T; \forall f \in F; \forall h \in H \quad (8)$$

$$\frac{hm^{i}_{fht}}{hm^{k}_{fht}} \ h \in H \geq 10; t = 1,..,T, h = 1,..,H, f = 1,..F; \ \forall t \in T; \forall f \in F; \forall h \in H \quad (9)$$

$$\frac{X_{fht}}{hm^{k}_{fht}} \ h \in H \leq 365; t = 1,..,T, h = 1,..,H, f = 1,..F; \ \forall t \in T; \forall f \in F; \forall h \in H \quad (10)$$

$$X_{fht} = hm^{a}_{fht} + dd^{k}_{fht}; \ t = 1,..,T, h = 1,..,H, f = 1,..F; \ \forall t \in T; \forall f \in F; \forall h \in H \quad (11)$$

$$sm^{dd}_{fht} = \sum_{f=1}^{F}\sum_{h=1}^{H}\sum_{t=1}^{T}[(dd^{k}_{fht} * an_{fht}) + (dd^{i}_{fht} * km_{ht}) + (em_{ht} *, dd^{ç}_{fht})]; \quad \forall t \in T; \forall f \in F; \forall h \in H \quad (12)$$

$$sa^{fb}_{fht} = \sum_{f=1}^{F}\sum_{h=1}^{H}\sum_{t=1}^{T}(dfn_{fht} * dd^{ç}_{fht}); \quad \forall t \in T; \forall f \in F; \forall h \in H \quad (13)$$

$$sfm_{fht} = \sum_{f=1}^{F}\sum_{h=1}^{H}\sum_{t=1}^{T}(X_{fht} * fo_{t} * dovk_{ht} * af_{fht} * xv_{ht} * 30/36000) \quad (14)$$

$$xv_{ht} = \frac{X_{fht}}{hm^{k}_{fht}} - av_{h} \begin{cases} xv_{ht} > 0; \ xv_{ht} \\ xv_{ht} < 0; 0 \end{cases}; \quad \forall t \in T; \forall f \in F; \forall h \in H \quad (15)$$

$$PAG_{fht} = \sum_{f=1}^{F}\sum_{h=1}^{H}\sum_{t=1}^{T}\left(X_{fht}\right) * \left(af_{fht\left(t=t+\frac{X_{fht}}{hm^{k}_{fht}}\right)} - af_{fht}\right); \quad \forall t \in T; \forall f \in F; \forall h \in H \quad (16)$$

The objective function of the NLP model given in Eq. (1) maximizes the net return resulting from the operations represents the gain remaining after the return on positioning is deducted from the cost of stock financing, the cost of transferring stock from the external warehouse and the costs of holding stock. The second constraint Eq. (2) ensures that for all monthly periods t, the stocked quantity in all factories and all types of raw materials cannot be negative. The third constraint Eq. (3) guarantees that the inventories at the beginning of the period are added to the purchases in the relevant period and the amount withdrawn from the external warehouse, deducting sales and uses, and the remaining inventory is transferred to the next period. With constraint number four, Eq. (4), the amount put in the external warehouse in the relevant period is added to the stocks in the outer warehouse at the beginning of the period, the amount withdrawn to the factory is deducted, and the remaining stock is transferred to the next period. Eq. (5) maintains the amount of raw material h stocked in the f factory in period t should not be less than the amount that is envisaged to be used and sold in the same period. The constraint (6) ensures the amount of raw material h stocked in factory f in period t should not be more than the warehouse capacity allocated for this raw material. With the constraint (7) in the external warehouse of factory f, the total amount of raw material stocked in period t cannot exceed the capacity of the outer warehouse. The number of days of stocking of raw materials stocked in factory f in period t should not exceed 180 days, see Eq. (8).

The number of stock days of raw materials stocked in factory f in period t should not fall below the critical stock level of 10 days (Eq. (9)). The number of stock days cannot exceed a one-year period in proportion to the amount of raw materials purchased in factory f in period t (Eq. (10)). Dispatch planning constraint (Eq. (11)) guarantees raw material h purchased in period t should be shipped to the f feed factory or to the external warehouse of this factory. External warehouse inventory holding cost consists of intermediate shipping + rental cost + handling cost, Eq. (12). Cost of transferring inventory from external warehouse to factory f, Eq. (13). Constraint (14) defines the stock holding cost and Constraint (15) defines the remaining purchase deferment period. The last equation, Eq. (16), stands for return on positioning which can be defined as, the product of the unit gain arising from the price difference that would occur if the long-term raw material purchased when the raw material was cheap, instead of if it was purchased at the very required time t. The problem is considered as a nonlinear programming model because of the nonlinear constraints (14), (15) and (16) where decision variables are multiplied and divided by each other.

5. Case study

Experiment design includes optimization of the analytical model in the light of real-life data. The study was designed and implemented by using real-life data for the optimization of grain purchases of the enterprise, which has factories in four regions of Turkey. The model was designed to include the purchasing optimizations of all raw material items of feed mills and analyzed as a real-life problem.

Experiment design are divided into three subsections. In the first part, the data generation procedure is explained in detail. Then, the computational results of the NLP model are given in the second subsection. The third subsection includes sensitivity analyzes and the profitability of investments that can be made in the axis of these analyzes and possible decision sets.

5.1 Data generation

Making the annual grain purchase planning correctly depends on the correct estimation of the financial data, as it will directly affect the solution of the model. The financial inputs of the model consist of grain market price forecasts, exchange rate and interest rate forecasts for periods t. Apart from these, it consists of external warehouse rental fee, handling and transshipment cost, which are operational costs. Time series analysis was used to estimate the grain market prices. The actual purchase prices of the previous year's data entered into the SPSS program, the price information that may occur at the beginning of the season of the planned year and in the next twelve-month purchase period are estimated as in Table 1.

Table 1. Forecasted price data for grains (time series t, raw material h – Currency *Turkish Liras*)

Month t	*h / barley*	*corn*	*wheat*
t.1	2.700	2.600	2.550
t.2	2.500	2.600	2.550
t.3	2.600	2.450	2.600
t.4	2.600	2.300	2.650
t.5	2.700	2.300	2.700
t.6	2.900	2.350	2.850
t.7	3.000	2.400	3.000
t.8	3.100	2.600	3.100
t.9	3.200	2.800	3.200
t.10	3.400	2.950	3.400
t.11	3.600	3.150	3.550
t.12	3.700	3.300	3.650
Average	*3.000*	*2.650*	*2.983*

Another financial input is the monthly interest rate data, which is the determinant of the cost of holding stock. The rates based on the results of the market participants survey published by the Central Bank of the Republic of Turkey (T.C.M.B.) are given in Table 2.

Table 2. Interest rate estimates (monthly time series t)

Month t	InterestRate %	*Month t*	Interest Rate %
t.1	19	*t.7*	15
t.2	19	*t.8*	15
t.3	18	*t.9*	14,5
t.4	17	*t.10*	14,5
t.5	16	*t.11*	14
t.6	16	*t.12*	14

The final financial input is exchange rates, which indirectly affect market prices for substitute products. Due to the fact that imports are carried out in dollar exchange rates, estimates are given in Table 3 based on the dollar exchange rate estimates made by T.C.M.B.

Table 3. Dollar exchange rate estimates in Turkish Liras

	t.1	t.2	t.3	t.4	t.5	t.6
$ / TL	8,5000	8,5850	8,6279	8,6711	8,7144	8,7580
	t.7	t.8	t.9	t.10	t.11	t.12
$ / TL	8,8018	8,8458	8,8900	8,9345	8,9791	9,0240

Operational cost items can be specified as warehouse rental cost, handling cost, warehouse-factory transshipment cost, supplier-factory transportation costs. All parameters listed in Table 4 below include all cost items calculated per ton for the raw materials being used.

Table 4. Operational cost items

	Rental Cost TL / Ton	Handling Cost TL / Ton	Trans shipment Cost TL / Ton	Direct Shipment Cost TL / Ton
Factory f=1	10	7	50	50
Factory f=2	10	7	100	100
Factory f=3	10	7	120	120
Factory f=4	10	7	270	270

Table 5. Estimated grain usages

Grain Type Period t	Estimated Usage (Ton)			
	Factory f=1	Factory f=2	Factory f=3	Factory f=4
Barley .t1	1.006	597	556	0
Barley .t2	1.168	866	580	0
Barley .t3	1.041	558	514	119
Barley .t4	434	482	423	125
Barley .t5	425	382	416	139
Barley .t6	343	322	167	153
Barley .t7	284	168	144	168
Barley .t8	263	151	118	185
Barley .t9	254	143	270	203
Barley .t10	280	214	166	223
Barley .t11	289	212	174	246
Barley .t12	355	217	180	270
Corn .t1	1.173	746	602	0
Corn .t2	1.168	692	589	0
Corn .t3	1.041	744	682	260
Corn .t4	1.880	964	1.504	274
Corn .t5	2.409	1.146	1.480	304
Corn .t6	2.469	1.501	1.713	334
Corn .t7	2.553	1.906	1.779	368
Corn .t8	2.368	1.767	1.449	404
Corn .t9	2.290	1.387	1.310	445
Corn .t10	2.523	1.659	1.493	489
Corn .t11	2.530	1.536	1.564	538
Corn .t12	2.202	1.517	1.081	592
wheat .t1	2.011	1.412	1.223	-
wheat .t2	1.836	1.212	1.197	-
wheat .t3	1.636	1.324	1.168	-
wheat .t4	1.302	1.068	517	-
wheat .t5	709	1.091	509	-
wheat .t6	754	750	509	-
wheat .t7	780	617	529	-
wheat .t8	724	505	431	-
wheat .t9	700	765	401	-
wheat .t10	701	696	498	-
wheat .t11	723	795	521	-
wheat .t12	923	867	1.081	-

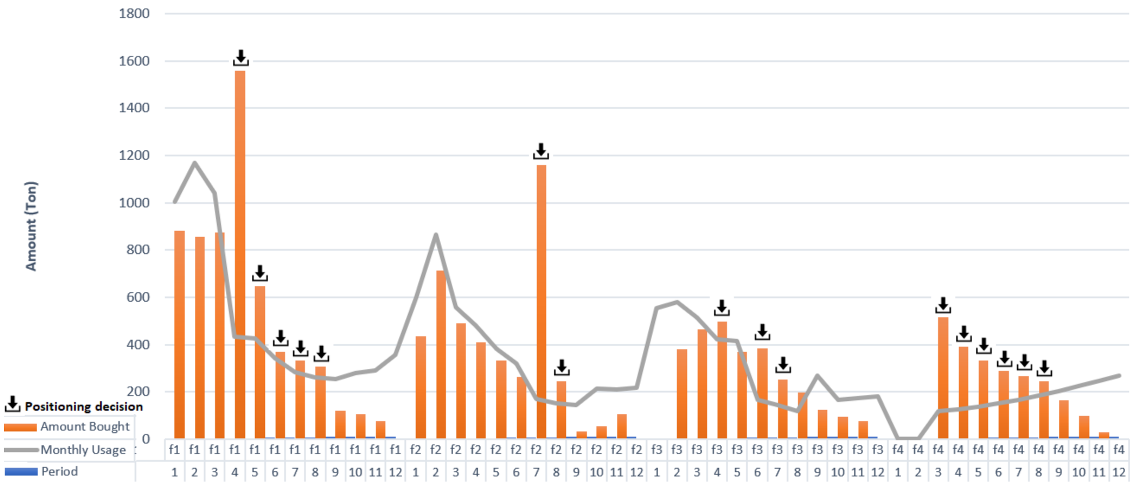

Figure 2. Purchase plan vs. monthly usage of barley

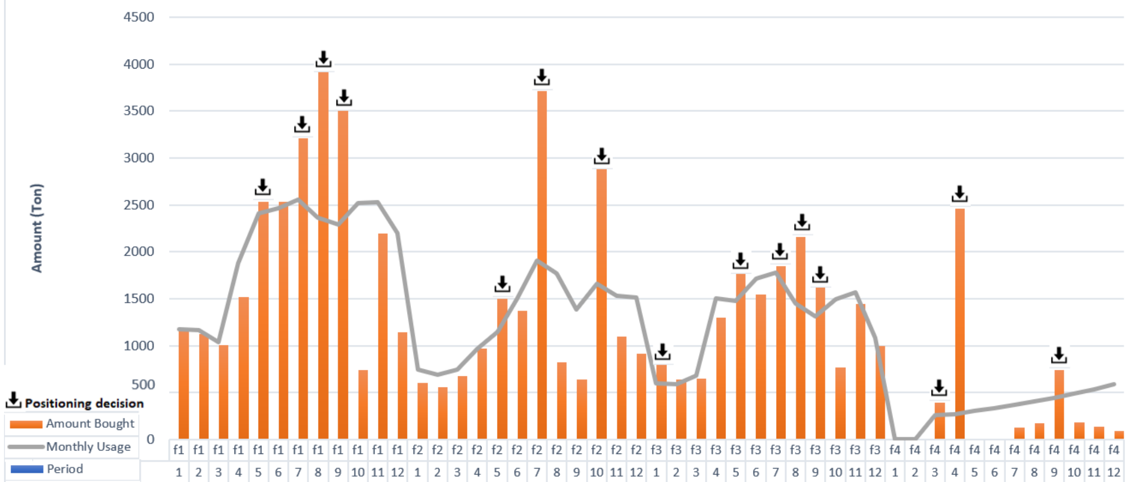

Figure 3. Purchase plan vs. monthly usage of corn

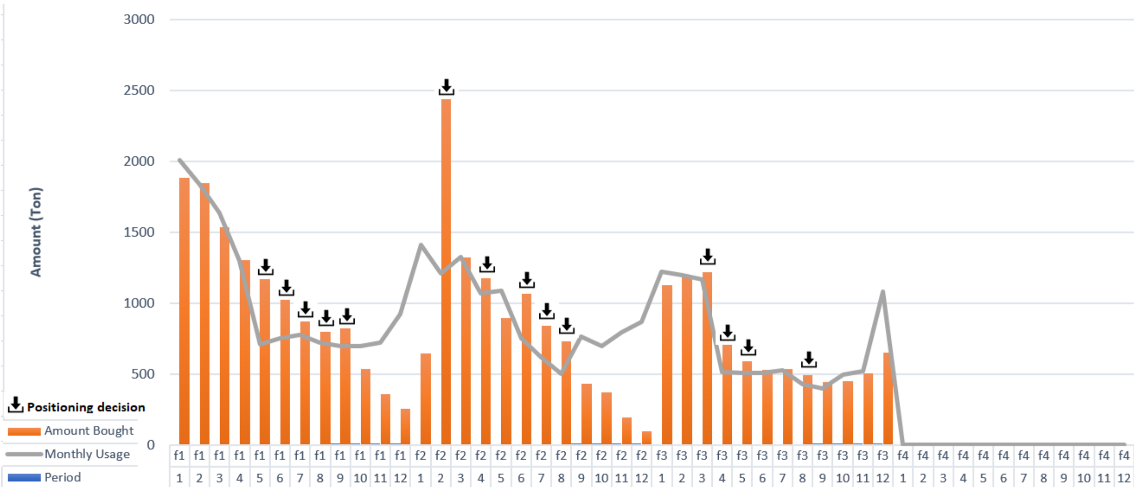

Figure 4. Purchase plan vs. monthly usage of wheat

Feed rations are prepared by the formulation department. While preparing the formula, the stock amounts of the raw materials in the existing stocks, market prices and feed target values are taken as basis. Production amounts of feeds are determined according to sales forecasts. According to the estimated grain prices, estimation recipes were prepared with the help of Brill recipe optimization program and estimated grain usage in the factories throughout the year was calculated. Estimated uses are given in Table 5.

Thus, all the necessary data for the model to provide a solution are determined.

5.2 Computational results

Model was coded in the GAMS program, in order to determine the purchase quantities and to avoid the problem of infeasibility which is eminating from start up stock quantities.

The initial stock quantities were captured. And using the initial feasible stock quantities, model solved with Excel Analytic Solver of Frontline Systems using the Gurobi engine with "General Constraint Helper Functions" available in Gurobi that will linearise the nonlinear constraints in the background. The mathematical model has 1.440 variables and 1.296 constraints. With the model, it takes an average of 4.8 seconds to reach a solution for a factory, which is a moderate time frame.

The main decision variables of the model are to determine how many tons of raw material h should be taken to factory f in which period t. The amount of raw material to be taken directly to the factory or to the external warehouse for later transfer to the factory is another variable that needs to be decided.

The values of the purchase amount decision variable on the basis of factories are given in Figures 2, 3 and 4 in comparison with the monthly usage amounts for the various grain types respectively. As it can be seen from the figures, some of the periods show some peaks in the amount bought. Those buying decisions which are higher amounts compared to the related monthly usage has some cost decreasing function. Those are positioning points. points are the optimum buying amounts just before some upward trend in the market prices of the grains. In those points, positioning gains and stock holding and handling cost are optimized.

Due to the feed usage habits in the region of the factory number 4, no wheat purchase planning has been made for this factory in the model, since wheat is not used in the ration content. This is why the purchase and estimated usage section in Figure 4 is empty. The financial results based on the purchase decisions made after the optimization are given in Table 6.

A gain of 11.6 million was achieved in return for 7.2 million TL investment, which is the sum of the storage, handling and financial costs incurred in order to take the position. 60% more return was obtained compared to the cost incurred. It is seen that the amount of return in factory number 3 is negative. Although this situation seems like a handicap in terms of the model and its solution, as can be seen from Table 7, it can be said that the negative amount would have been higher if this positioning had not been done.

Table 7. Financial results without positioning

	Factory 3
Total Amount Purchased (TON)	26.589,65
Total External Storage Amount (TON)	3.474,02
Total Purchasing Cost (TL)	72.783.925,99
Total External Storage Cost (TL)	59.058,39
Total Transshipment Cost (TL)	416.882,73
Total Financing Cost (TL)	977.537,99
Total Storage Cost (TL)	1.453.479,10
Total Gross Positioning Gain (TL)	1.304.277,17
Total Net Positioning Gain (TL)	***- 149.201,93***

The reason for the negative return in factory number 3 is that external storage solutions are needed more because the factory stocking area is lower than the stock area and usage forecast of other factories.

For this reason, the extra stocking and handling costs reduce the amount of return to a negative level. The subject will be examined in more detail in the sensitivity analysis and investment analysis section.

5.3 Sensitivity and investment analysis

Sensitivity analyzes were conducted to measure the effect of increasing the installed capacity on profitability and to determine to what extent it increased/decreased. The results are given in Figure 5.

The installed storage capacities of the factories are as given in Table 8.

Table 8. Installed storage capacities (Units in Ton)

	Factory 1	*Factory 2*	*Factory 3*	*Factory 4*	*Overall*
Barley	1.800	1.698	1.000	1.260	5.758
Corn	4.400	1.724	2.000	1.950	10.074
Wheat	1.800	2.560	1.000	-	5.360
Overall	8.000	5.982	4.000	3.210	21.192

Table 6. Financial results

	Factory 1	*Factory 2*	*Factory 3*	*Factory 4*	*Overall*
Total Amount Purchased (TON)	43.150,05	30.196,29	26.841,94	6.644,49	106.832,77
Total External Storage Amount (TON)	8.948,55	6.382,31	7.033,61	1.335,35	23.699,82
Total Purchasing Cost (TL)	115.752.441,97	81.604.833,84	73.005.150,61	17.361.083,81	287.723.510,24
Total External Storage Cost (TL)	152.125,27	108.499,21	119.571,45	22.700,94	402.896,86
Total Transshipment Cost (TL)	447.427,27	638.230,62	844.033,74	251.234,01	2.180.925,63
Total Financing Cost (TL)	1.791.119,70	1.493.840,04	1.000.196,89	363.310,53	4.648.467,15
Total Storage Cost (TL)	2.390.672,24	2.240.569,86	1.963.802,07	637.245,47	7.232.289,65
Total Gross Positioning Gain (TL)	3.876.989,97	2.915.465,10	1.820.547,54	3.006.571,78	11.619.574,39
Total Net Positioning Gain (TL)	***1.486.317,73***	***674.895,24***	***- 143.254,54***	***2.369.326,31***	***4.387.284,74***

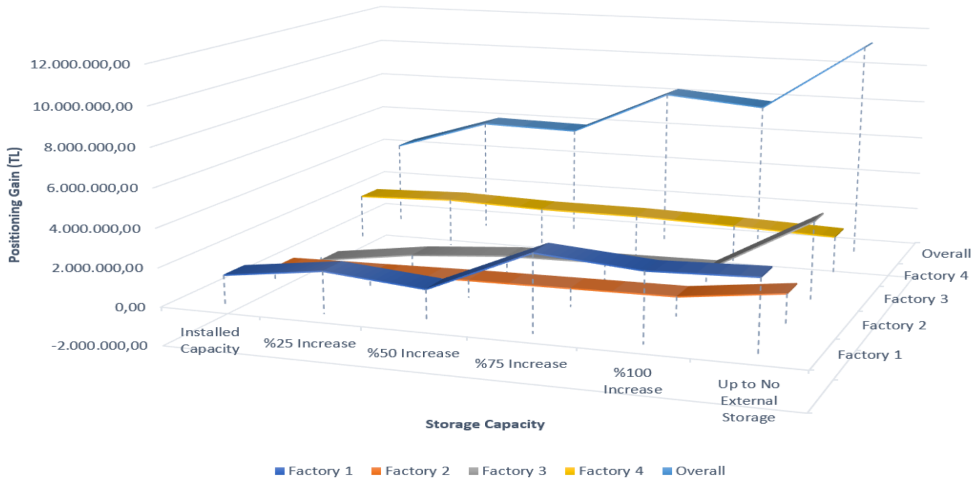

Figure 5. In-house storage capacity increase vs. positioning gain increase

In the model operated with the installed storage capacities, a positioning return of 4.3 million TL was achieved, while sensitivity analyzes of 25%, 50%, 75%, and 100% in-house capacity increase were performed, and it was observed that the return on positioning reached up to 7.8 million TL. The maximum achievable return installed capacity constraint was changed with a Big M number, and the model was revised, which provides a solution without the need for external storage. It has been observed that the maximum positioning return that can be achieved is 10,9 million TL.

Although the installed capacity is changed with a large number, the limits of the model have been determined due to the limitation that the maximum number of instant stock days cannot exceed 180 (constraint number 8) and the seasonal purchase cannot exceed a one-year period (constraint number 10). The required installed capacity determinations for the upper limit of the model are given in Table 9. Required extra storage space investments are given in Table 10.

Table 9. Maximum in-house capacity requirement (Units in Ton)

	Factory 1	*Factory 2*	*Factory 3*	*Factory 4*	*Overall*
Barley	1.800	1.698	1.666	1.260	6.424
Corn	8.575	4.043	7.302	2.573	22.493
Wheat	3.320	3.092	2.420	-	8.832
Overall	13.695	8.833	11.388	3.833	37.750

Table 10. Required Storage Space Investments (Units in Ton)

	Factory 1	*Factory 2*	*Factory 3*	*Factory 4*	*Overall*
Barley	-	-	666	-	666
Corn	4.175	2.319	5.302	623	12.419
Wheat	1.520	532	1.420	-	3.472
Overall	5.695	2.851	7.388	623	16.558

The investment return rate analysis for the determined steel silo requirements can be made as given in Table 11.

Table 11. Return on investment analysis

Steel Silo Investment Analysis	Unit	Amount
Investmet Cost (906,66 x 16.558)	**TL**	**15.012.476**
Positioning Gain Return / Yearly	TL	6.590.695
Interest Rate	%	19
Financial Cost	**TL**	**2.852.370**
Total Cost	**TL**	**17.864.847**
Total Savings (Useful Lifetime)	**TL**	**52.725.560**
ROI		**1,95**
Useful Lifetime	**Year**	**8,00**
Annual Savings of Investment	**TL**	**6.590.695**
Investment Cost Payback Time	**Month**	**32,53**
Return on invested capital	**%**	**36,89**

Although there is no consensus in the literature about the ideal figure for the return on investment [19] or minimum acceptable return rate, suggestions [20] have been made ranging from 9% to 22.5%. The company where the study is conducted sees investments with a return period of less than three years, starting with a return above the annual interest rate value, as low risk and is decided as acceptable. As a result of the analysis, the return period of the investment is determined as 32.5 months and the return rate is 36.89%, which is more than 19%, which is the current annual interest rate, thus meeting the investment feasibility conditions.

6. Conclusion

This study transforms the seasonal grain purchasing studies, which are generally carried out according to the market comments of the purchasing managers experienced in the feed industry, into an analytical non-linear optimization model in which experience is taken into account. In this way, it has been tried to develop an institutional tool that allows the simulation of different scenarios and alternatives. In the current situation, it is seen that the organization, which is the whole of the four enterprises, needs to increase its installed capacity as soon as possible.

As the first harvest period is approaching, it is not possible for the investment to be done this year. But it is beneficial to make an investment decision so that more positioning returns are possible to be reached. It is beneficial to make an investment decision so that the positioning gain is not low due to external warehouse leasing and transshipment fees. Hence cost-effective purchases can be provided in the future.

Since the model created enables the purchase planning of the grain types separately, it provides the opportunity to examine both the purchase and additional storage space investment for each grain type in detail. With simple changes that can be made in the model, a solution can be provided for all raw material inputs that can be used in feed content. With the model, it can be said that a useful tool has been created for the use of purchasing and planning executives in the feed sector.

The aspect of the study that is open to improvement is that the part where instant factors and free market conditions determine raw material prices in an environment of uncertainty is based on forecasts. Our suggestion for future studies may be to add to the model to allow price determinations with stochastic variables.

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