Methods of sales forecasting and modeling of supply chains. Case study: Atlas Chimie Algeria

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Abstract: In this article, we tend to show the effective role played by the sales forecasting methods to manage an extremely important function for the firm which is the supply chain management. Moreover, we point the way to use the data of forecasting in the mathematical modeling for the supply chain which is distinguished by the multi purposes objectives. This can be modeled by Lot-sizing models and resolved by multi criteria methods (Compromise programming). In addition, we will try to apply them on ATLAS Chimie specialized Algerian firm in producing oil.

Keywords: Forecast, Sales, Supply chain, Mathematical modelling, Multi criteria methods

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1. Introduction

To remain competitive, organizations must be able to anticipate and adapt to changing market conditions. This is to ensure that relevant information is available to all participants in the supply chain.

Software Solutions Supply Chain Management (SCM) can help manage customer demand, monitor inventory levels and be warned in advance about delays in production and distribution.

The logistics has emerged, not only as the heart of enterprises strategies, but also to be the very root of their performance in carrying out daily operational tasks. Logistics is complex because it is diffuse and multifaceted [Paché G., Sauvage T. (2004)]. The nature of the products, company history, its legacy, and its current markets, are the determining factors for the strategies chosen to retain lead logistics solutions [Giard V. (2003)].

The latter is based mainly on sales forecasting and integration of its components seeking to reduce the time needed for the supply process, stock levels early in the beginning of each season, as well as reducing risks to meet customer demand.

To achieve these objectives it is necessary to use a comprehensive package of technical methods such as sales forecasting and multi criteria methods applied to an Algerian company.

2. Definition of supply chain management

Colin, Mathé and Tixier have proposed the following definition: “Logistics is the strategic process by which the company organizes and supports its activities. As such, are identified and managed material and information flows associated, internal and external, upstream and downstream”. The logistic function will designate also the management of physical flows of commodities and products as well as information flow, i.e. the transport, storage, computing ... In the current, logistics activities are integrated in the life of the company (there is even talk of supply chain that is opposed to stewardship services).

There are many definitions of supply chain management which lead scholars to try to find a single definition. Such a definition is supposed to contain the main components of supply chain management. These components are [Stadtler H., Kilger C., (2000, 2002)]:

– The group targeted

- The objectives
- Appropriate means to achieve these objectives.

3. Definition of sales forecasting

Sales forecasting is an attempt to estimate the level of future sales through the use of previous and current information available about the phenomenon under study (sales). It is an attempt by the company to know the future based on past and present. Definitely, this does not lead to a precise calculation predicting the future but it helps to estimate the future through using technical and scientific methods [Bourbonnais R., Usunier J.C. (2004)].

The forecast is a series of calculations used to estimate future; it combines art, science and individual contributions for the study and determination of the assumptions on which the forecast is made. This is so important knowing that the forecasting is a key behavioral indicator of business administration once making future plans [Doriath B., Gouget C. (2002)].

4. The role of sales forecasting in the supply chains management

Sales forecasting plays an important role in supply chain management. Arguably the latter is responsible for the strategic management of material and products flows within and outside the company as well as their stocking [Breuzard J.P., Fromentin D. (2004)].

On the second partial process of supply chains, its purpose is to implement the needed plans to achieve integration between the company’s different activities [Pimor Y. (2005)].

Accordingly, the sales forecasting is considered as an essential and indispensable basis for the supply chains management.

5. Methods of sales forecasting and modeling of supply chains

There are several methods of forecasting sales that vary in their ease of application and in terms of their result accuracy.

There exist such simple and easy qualitative methods, which do not require much skill and experience. These methods are based mainly on intuitive perception and the induction of future imagery from statistical data. Other methods are based on market research by using the method of treating a range of sampling to determine consumer demand forecasting based on field experience. The shortcomings of these methods lie in the fact that they are based on intuition and conjecture.

Quantitative methods using econometric techniques are also used for understanding the behavior of certain variables in the past and predict their behavior in the future such as the exponential smoothing method, the method of Box and Jenkins, the goal programming, compromise programing, programing using the functions of satisfaction etc.

We use the following three methods: the method of Box and Jenkins (sales forecasting), Lot-sizing models (modeling of supply chains) and the method of compromise programming (resoling the model).

5.1. The method of Box and Jenkins

Box and Jenkins (1976) proposed a prediction technique for unvaried series based on the notion of ARIMA process. This technique has three steps: identification, estimation and verification. This method is used to obtain a model explaining the fluctuations of a series based solely on the past conduct and then extrapolate the values of the variable. If the series suggests a pattern that repeats fairly regularly, the choice of this method makes sense [Dor E. (2004)].

- The first step is to identify the ARIMA (p, d, q) which could cause the series. The series should be transformed first to make it stationary and then identify the ARMA (p, d).
- The second step is to estimate the ARIMA model using a nonlinear method (nonlinear least squares or maximum likelihood).
- The third step is to check whether the estimated model reproduces the model that generated the data.

5.2. The models of Lot-sizing

Using different mathematical modeling techniques based mainly on models of Lot-sizing, we analyze several new decision variables and the mathematical formulation of the model, we will use the case study as follows [10]:

- The objectives of the supply chain:

$$Min \left[\sum_{i \in N} \sum_{t \in T} \left[\begin{array}{l} \alpha(i) h_i I_{i,t} + \sum_{k \in K} \beta(i) p_{i,t} X_{i,k,t} \\ + \gamma(i) DAp_{j,t} \times CAp_j + \theta(i) D_{i,t} \\ \times CD_i \end{array} \right] \right] \tag{1}$$

$$Max \left[\sum_{i \in N} \sum_{t \in T} a_{i,t} D_{i,t} \right] \tag{2}$$

Given that the objective (1) is the minimization of costs of the supply chain management (procurement, storage, production and distribution). The objective (2) is to maximize the profit during the planning period.

With:

T: all periods of the planning horizon;

N: set of products (finished products, components, raw materials);

K: set of resources;

h_i : Storage cost of product i (which may be a raw material, components or finished products);

$p_{i,t}$: Cost of producing one unit of product i in period (t);

CAp_j : Supply cost of one unit of j;

CD_i : Distribution cost of one unit of i;

$a_{i,t}$: Profit of the distribution one unit of product i in period (t);

The decision variables of the model are related to:

Production: $X_{i,k,t}$ represents the quantity of product i produced on the resource k in period t;

Supplies: $DAP_{i,t}$ represents the amount of raw material i that must supply during the period t;

Distribution: $D_{i,t}$, represents the quantity of finished product i distributed in t;

And finally, the state variable $I_{i,t}$ is the stock level of product i at the beginning of t.

Constraints: The constraints of the planning model for supply chain management are:

- The evolution of the stock:

$$I_{i,t+1} = I_{i,t} + \sum X_{i,t,k} - \sum g_{i,j} X_{i,t,k} + DAp_{i,t} - D_{i,t} \text{..(1)}$$

- Limited capacity:

a) Production:

$$\sum_{i \in N} b_{i,k} X_{i,k,t} \le C_{k,t} \; / \; k \in K, t \in T \text{.......(2)}$$

b) Storage:

$$\sum_{i \in N} I_{i,t} \le S_t \; / \; t \in T \text{.......... ....(3)}$$

c) Transportation:

$$\sum_{i \in N} D_{i,t} \le T_t \; / \; t \in T \text{.......... ....(4)}$$

$$X_{i,k,t}, DAp_{i,t}, D_{i,t}, I_{i,t} \ge 0 \text{.......... ....(5)}$$

The constraint (1) calculates the stock level change between two consecutive periods. This equation, called state equation, involves the production achieved according to the nomenclature of the product over the period, the quantities that should be expected supplies and deliveries. Constraints (2, 3, 4) can limit the production, transport and storage according to the available capacity. Finally, constraint (5) indicates that all decision variables are nonnegative.

With:

$g_{i,j}$: Quantity of product j required to produce one unit of product i;

$b_{i,k}$: Amount of resources required to manufacture one unit of product i on resource k (Range of manufacture);

$C_{k,t}$: Production capacity of resource k in period t.

5.3. The compromise programming

This model aims to solve the economic problems which have conflict objectives whose optimal solutions are not known. The analytical form of this model is as follows [Ignizio P.J. (1982)]:

$$g_i = \begin{cases} g_i^* = Max \quad f_i(x), x \in F \\ g_i^* = Min \quad f_i(x), x \in F \end{cases}$$

$$C_l(x) \le 0, \quad l = 1, 2, \ldots, L$$

With:

gi: functions of goals.

fi(x): linear functions.

In this model we have two goals $f_1(x)$ and $f_2(x)$ where we want to maximize the first and minimize the second under the constraints $C_l(x)$.

Solving this kind of model involves two important steps:

- Seek the maximum or minimum value of each objective separately constrained by the use of linear programming.
- Solve the model by the use of weighted goal programming where we give a weight (w_i) to each objective as follows:

$$Min \quad Z = \sum_{i=1}^{m} w_i(\delta_i^+ + \delta_i^-)$$

$$sujet \quad à$$

$$\begin{cases} f_i(x_j) + \delta_i^- - \delta_i^+ = g_i^* \\ f_i(x_j) + \delta_i^- - \delta_i^+ = g_i^* \\ C_l(x) \le 0, \quad l = 1, 2, \ldots, L \\ x_i \le 0 \quad avec \quad i = \{1, 2, 3, \ldots, n\} \end{cases}$$

With:

i: the number of the objective function.

j: the number of decision variable.

l: the number of constraints.

And δ_i^+ and δ_i^- the positive and negative deviations for the gap between the level of achievement of the goal and aspiration level (of the decision maker).

6. Case study of the Atlas Chimie company (mathematical modeling of supply chains for products)

The case study involves an Algerian company.

6.1. Presentation of the company

ATLAS Chimie is a corporation since November 2009 and its capital is estimated at 200 million dinars. It was created in 1976 by the company SOGEDIA UTR which is located in Boufarik (Blida). This company specializes in the production of fats and employs 199 workers (03 executives, 24 managers, 99 employees and 73 employees of mastery of execution). It is headquartered in the city of Meghnia (Tlemcen), city where it deploys its production.

6.2. The current situation of the Atlas Chimie company

The company specializes in the production of three types of fat:

– Soap, glycerin, oil (Abbad Echems).

It becomes difficult to determine the appropriate method for forecasting if we do not know the nature of the product and the forecast period. In addition, the modeling process cannot be achieved without knowing the different objectives and constraints imposed by determinants of products such as the time required for procurement, production and distribution and the capacity available to the company.

After a detailed study of the characteristics of this company's products, we have compiled the following table:

Table 1. Characteristics of products

Products	Soap	Glycerin	Abbad Echems oil
Selling price of a unit	80 DA/kg	103 DA/litre	104 DA/litre
Storage cost per unit	2.10 DA/kg	1.12 DA/litre	1.90 DA/litre
Distribution cost per unit	3.19 DA/kg	4.05 DA/litre	1.80 DA/litre
Cost of production	15.16 DA/kg	14.77 DA/litre	23.42 DA/litre
Procurement cost of raw materials	44.56 DA/kg	47.00 DA/litre	71.40 DA/litre
Unit profit	14.98 DA/kg	36.06 DA/litre	5.48 DA/litre
Unit Cost of Quality	0.1462 DA/kg	0.087 DA/litre	0.0121 DA/litre

Source: Table prepared by the researchers based on the accounting records of the company.

6.3. The problem in supply chain management of the company

We know that the objectives of the supply chain management are set in order to meet the customer needs in terms of quantity required in due course, at the ideal place and following a quality standard. All this must be done by the company that will minimize costs and maximize profit.

Through the study of the characteristics of the company's products ATLAS Chemie we are led to study the monthly sales of products of this company during the years 2007, 2008, 2009 and 2010 to carry out their modeling and forecasting.

After studying the supply chain of products of this company it was found, on the one hand, that it suffers from several problems such as high costs of raw materials of high quality, random management of the supply chain, especially the problem of transfer of finished products to customers of the company which creates increased distribution costs due to the absence of a clear marketing plan for products, and costs resulting from poor quality of finished products.

On the other hand, there was strong competition in the market launched by a few companies which were also subsidiaries of the industrial complex of fat (ENCG), among them the fats complex of Bejaia and Algiers.

As for the objectives in this practical case, they can be summarized as follows: maximizing the quality of all sales, minimize costs of the supply chain, maximizing the profit of the company, meeting forecast demand of customers . The process of achieving these goals requires the use of a multi-criteria method called "compromise programming".

6.4. Forecast sales for the first three months of 2011 of the three products

We used the method of Box and Jenkins to forecast the monthly sales of products by developing predictive models and using the Eviews 5.1 software:

- Soap:

  $$savoncvs_t = 1.0083 savoncvs_{t-1} + \varepsilon_t$$

  $savoncvs_t$: Soap sales seasonally adjusted at time *t*.

  ε_t : white noise at time *t*

- glycerin:

  $$\Delta glycécvs_t = -0.24 \Delta glycécvs_{t-1} + 0.131\varepsilon_{t-1} + 0.94\varepsilon_{t-2} + \varepsilon_t$$

  $$\Delta glycécvs_t = glycécvs_t - glycécvs_{t-1}$$

  $glycécvs_t$: Glycerin sales seasonally adjusted at time t.

- Abbad Echems oil:

  $$huilecvs_t = 1.77 huilecvs_{t-1} - 0.77 huilecvs_{t-2} - 0.97\varepsilon_{t-1} + \varepsilon_t$$

  $huilecvs_t$: Sales of Abbad Echems oil seasonally adjusted at time *t*.

Note that the time series of monthly sales of three products are affected by seasonal variations, knowing that the series of soap sales is affected by its previous value. As for the series of glycerin sales, it is affected by its previous value and the random error of the two previous periods which may be produced during a period and act on the following values, while the series of sales of the oil is affected by its two preceding values and the random error of the previous period.

The results of sales projections of the first three months of 2011 are:

Table 2. Predictable sales of the first three months of 2011

Products	Soap	Glycerin	Abbad Echems oil
Sales projections of the first month	214651	24368	148424
Sales projections of the second month	215988	22901	150085
Sales projections of the third month	217559	23156	151938

Source: Calculated by the researchers on the basis of previous models

6.5. Mathematical modeling of the supply chain

The problem facing the management of the supply chain of products of the company ATLAS Chimie is represented by the manner of determining the quantity produced and when it must occur to achieve the objectives of supply chain management company. These objectives are:

- Minimization of the total cost of the supply chain.
- Maximization of total profit.
- Optimization of the sales quality.

Quality was evaluated as follows:

Soap: 1/0.1462 = 6.84

Glycerin: 1/0.087 = 11.49

Abbad Echems oil: 1/0.0121 = 82.64

The company seeks to determine the production quantity of each product that minimizes the costs of the supply chain, maximizes profit while achieving better quality at lower cost.

$$Z_1 Min = \begin{bmatrix} 2.10\sum_{t=1}^{3} I_{1t} + 1.12\sum_{t=1}^{3} I_{2t} + 1.90\sum_{t=1}^{3} I_{3t} + 15.16\sum_{t=1}^{3} X_{1t} + \\ 14.77\sum_{t=1}^{3} X_{2t} + 23.42\sum_{t=1}^{3} X_{3t} + 40\sum_{t=1}^{3} DAp_{1t} + \\ 70\sum_{t=1}^{3} DAp_{2t} + 15\sum_{t=1}^{3} DAp_{3t} + 35\sum_{t=1}^{3} DAp_{4t} + \\ 50\sum_{t=1}^{3} DAp_{5t} + 80\sum_{t=1}^{3} DAp_{6t} + 3.19\sum_{t=1}^{3} D_{1t} + 4.05\sum_{t=1}^{3} D_{2t} \\ + 1.80\sum_{t=1}^{3} D_{3t} \end{bmatrix}$$

$$Z_2 Max = \left[14.98\sum_{t=1}^{4} D_{1t} + 36.06\sum_{t=1}^{4} D_{2t} + 5.48\sum_{t=1}^{4} D_{3t} \right]$$

$$Z_3 Max = \left[6.84\sum_{t=1}^{4} X_{1t} + 11.49\sum_{t=1}^{4} X_{2t} + 82.64\sum_{t=1}^{4} X_{3t} \right]$$

x_{1t}: the quantity produced of soap during the month t.

x_{2t}: the quantity produced of glycerin during the month t.

x_{3t}: the quantity produced of oil during the month t.

But there are several constraints or objective conditions that limit the achievement of the optimum level of these objectives and which are represented by:

- The volume of production must not exceed the volume of sales projections for the first three months of 2011.
- The constraints of production capacity and product characteristics.
- The volume of soap production must exceed 170000 kg, that of glycerin 4400 liters while the volume of oil production must exceed 95000 liters because the monthly demand of products during the last months of the year 2010 did not drop below these amounts.
- The constraint of the limited amount of raw material (soda), which is estimated at 170000 kg / month.

$$I_{i,t+1} = I_{i,t} + X_{it} - D_{it} / i = \{1,2,3\}, t = \{1,2,3\}$$
$$D_{1t} \geq 170000 / t = \{1,2,3\}$$
$$D_{2t} \geq 4400 / t = \{1,2,3\}$$
$$D_{3t} \geq 95000 / t = \{1,2,3\}$$
$$DAp_{1t} = 0.75 X_{1t} / t = \{1,2,3\}$$
$$DAp_{2t} = 0.15 X_{1t} / t = \{1,2,3\}$$
$$DAp_{3t} = 0.1 X_{1t} / t = \{1,2,3\}$$
$$DAp_{4t} = 0.0875 X_{1t} + 0.0018 X_{2t} + 0.0051 X_{3t} / t = \{1,2,3\}$$
$$DAp_{5t} = 0.94 X_{2t} / t = \{1,2,3\}$$
$$DAp_{6t} = 0.89 X_{3t} / t = \{1,2,3\}$$
$$0.0875 \sum_{t=1}^{3} X_{1t} + 0.0018 \sum_{t=1}^{3} X_{2t} + 0.0051 \sum_{t=1}^{3} X_{3t} \leq 510000$$
$$170000 \leq I_{11} + X_{11} \leq 214651$$
$$170000 \leq I_{12} + X_{12} \leq 215988$$
$$170000 \leq I_{13} + X_{13} \leq 217559$$
$$4400 \leq I_{21} + X_{21} \leq 24368$$
$$4400 \leq I_{22} + X_{22} \leq 22901$$
$$4400 \leq I_{23} + X_{23} \leq 23156$$
$$95000 \leq I_{3t} + X_{3t} \leq 148424$$
$$95000 \leq I_{3t} + X_{3t} \leq 150085$$
$$95000 \leq I_{3t} + X_{3t} \leq 151938$$
$$X_{i,k,t}, DAp_{i,t}, D_{i,t}, I_{i,t} \geq 0$$

6.6. Resolution of the model using the method of compromise programming

The final mathematical form of the model takes the following form:

$$Min \quad Z = 0.20\delta_1^{+} + 0.50\delta_2^{-} + 0.30\delta_3^{-}$$

Under the constraints:

$$\left[\begin{array}{l} 2.10\sum_{t=1}^{3} I_{1t} + 1.12\sum_{t=1}^{3} I_{2t} + 1.90\sum_{t=1}^{3} I_{3t} + 15.16\sum_{t=1}^{3} X_{1t} \\ + 14.77\sum_{t=1}^{3} X_{2t} + 23.42\sum_{t=1}^{3} X_{3t} + 40\sum_{t=1}^{3} DAp_{1t} + \\ 70\sum_{t=1}^{3} DAp_{2t} + 15\sum_{t=1}^{3} DAp_{3t} + 35\sum_{t=1}^{3} DAp_{4t} + \\ 50\sum_{t=1}^{3} DAp_{5t} + 80\sum_{t=1}^{3} DAp_{6t} + 3.19\sum_{t=1}^{3} D_{1t} + \\ 4.05\sum_{t=1}^{3} D_{2t} + 1.80\sum_{t=1}^{3} D_{3t} \end{array}\right]. = 60740600$$

$$\left[14.98\sum_{t=1}^{4} D_{1t} + 36.06\sum_{t=1}^{4} D_{2t} + 5.48\sum_{t=1}^{4} D_{3t}\right] = 14740600$$

$$\left[6.84\sum_{t=1}^{4} X_{1t} + 11.49\sum_{t=1}^{4} X_{2t} + 82.64\sum_{t=1}^{4} X_{3t}\right] = 42467720$$

$$I_{i,t+1} = I_{i,t} + X_{it} - D_{it} \,/\, i = \{1,2,3\}, t = \{1,2,3\}$$

$$D_{1t} \geq 170000 \,/\, t = \{1,2,3\}$$

$$D_{2t} \geq 4400 \,/\, t = \{1,2,3\}$$

$$D_{3t} \geq 95000 \,/\, t = \{1,2,3\}$$

$$DAp_{1t} = 0.75 X_{1t} \,/\, t = \{1,2,3\}$$

$$DAp_{2t} = 0.15 X_{1t} \,/\, t = \{1,2,3\}$$

$$DAp_{3t} = 0.1 X_{1t} \,/\, t = \{1,2,3\}$$

$$DAp_{4t} = 0.0875 X_{1t} + 0.0018 X_{2t} + 0.0051 X_{3t} \,/\, t = \{1,2,3\}$$

$$DAp_{5t} = 0.94 X_{2t} \,/\, t = \{1,2,3\}$$

$$DAp_{6t} = 0.89 X_{3t} \,/\, t = \{1,2,3\}$$

$$0.0875\sum_{t=1}^{3} X_{1t} + 0.0018\sum_{t=1}^{3} X_{2t} + 0.0051\sum_{t=1}^{3} X_{3t} \leq 510000$$

$$170000 \leq I_{11} + X_{11} \leq 214651$$

$$170000 \leq I_{12} + X_{12} \leq 215988$$

$$170000 \leq I_{13} + X_{13} \leq 217559$$

$$4400 \leq I_{21} + X_{21} \leq 24368$$

$$4400 \leq I_{22} + X_{22} \leq 22901$$

$$4400 \leq I_{23} + X_{23} \leq 23156$$

$$95000 \leq I_{3t} + X_{3t} \leq 148424$$

$$95000 \leq I_{3t} + X_{3t} \leq 150085$$

$$95000 \leq I_{3t} + X_{3t} \leq 151938$$

$$X_{i,k,t}, DAp_{i,t}, D_{i,t}, I_{i,t} \geq 0$$

δ_1^- et δ_1^+ : negative and positive deviations of costs achieved in relation to its minimum level.

δ_2^- et δ_2^+ : negative and positive deviations of the profit achieved in relation to its maximum level.

δ_3^- et δ_3^+ : negative and positive deviations of the quality achieved in relation to its maximum level.

By using the software Lindo61, we obtained the following optimal solution:

$Z_1 Min = 80492594$

$Z_2 Max = 12647770$

$Z_3 Max = 41522441$

$X_{11} = X_{12} = X_{13} = 170000$

$X_{21} = 24368$

$X_{22} = 22901$

$X_{23} = 23156$

$X_{31} = 148124$

$X_{32} = 150085$

$X_{33} = 151938$

The results can be interpreted as follows:

The Atlas Chimie company must produce 170000 kg of soap each month of the scheduled period, 24368, 22901 and 23156 liters of glycerin in the first, second and third month in succession and 148124, 150085 and 151938 liters of Abbad Echems oil in the first, second and the third month in succession. The initial stock of each month shall be zero. This production requires an amount of 80492594 DA representing the cost of the supply chain management and realizes the maximum profit estimated at 12647770 DA and better quality sales.

7. Conclusion

In this research we tried to show how to use methods of sales forecasting and modeling as a strategic tool for supply chain management; which is considered as a useful technology in channeling the flow of raw materials, semi-finished and finished products, from the first suppliers to final customers at reduced costs, depending on the requested quantities, where and when appropriate. At each step of the planning process, the manager must make the best decision among a broad set of available alternatives. However, this is done in order to ensure proper management of logistics including all kinds of materials, either inside or outside the company, in ways to minimize costs and time as well as to raise the service standard.

The Case Study carried out on The Atlas Chimie has shown that this company is experiencing difficulties in recent years because of the increase in competition which is getting fiercer every year. Analysis of its sales occurred over four years (2007, 2008, 2009 and 2010), in order to know the historical and explanatory factors. Three important goals were to achieve: maximizing the profit, minimizing costs and maximizing the quality of products. This modeling allowed us to release the amount to be produced by the company in order to achieve the objectives of the supply chain management.

However, these techniques and methods are tools to facilitate decision making and must be supplemented by the experience and expertise of the decision makers themselves.

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