An Evaluation of the Management of Stocks in a Chemical Company

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ABSTRACT

The present article describes an example of the application of the MDS approach (Modelli Dinamici per Strategie - Dynamic Models for Strategies) to the study of criteria for a supply policy and for a consequent economic evaluation of the different supply policies which may be adopted. The aim of the study is limited to an evaluation of the direct economic effects of the different hypothetical policies, excluding those associated with the market and with different production steps.
The results of a series of simulations using the model are presented along with an outline of the economic benefits deriving from the adoption of a "tight-rein" stocks policy carrying a reasonable level of risk.

INTRODUCTION

This paper refers to the use of the MDS system (Gervasio, 1984, pp.231-237) for evaluating the overall effects of alternative policies of purchasing and managing raw material stocks on the economic results of a company.

The company considered runs chemical and petrochemical plant and produces a wide range of products including both fine and heavy chemicals.

The production is located at several sites having a number of plants, with a large variety of processes and raw materials.

The rigid schedules and the continuity required for production, typical of process industries render raw material supplies one of the most delicate stages in the whole production cycle.

The supply policy thus takes on great importance and plays an important role within the general company strategy.

In the past, with the emphasis focussed upon production, raw material reserves policies were based upon the following criteria:

a) devolution of decision-making to the single factory level;

b) absolute priority given to the safeguarding of production.

This policy, in reality, tends to favour an overdimensioning of reserves which leads to a freezing of liquidity and other related financial disadvantages, which can not be ignored, given the high cost of money.

In the light of the growing importance of financial problems, with respect to previous periods, the company felt the need for a close examination of this policy with the following aims in mind:

1. To quantify the costs of running out of stocks and/or keeping an excess of raw materials, as well as the relative financial costs for the different supply policies, in order to find an "optimum" policy, or at least a "satisfactory" one.

2. To succeed in formulating a set of uniform criteria as the basis of supply policies, which could then be applied to each plant.

Point 1 has, as its central aspect, the evaluation of the main risks connected with a policy of "tightening" reserves of raw materials with respect to the current practice of the "abundance" of reserves, comparing possible damage of the former with the known financial disadvantages of the latter.

In this way it is possible to make certain choices which, while respecting local plant autonomy, are based upon certain general criteria (point 2).

The problem is a complex one due to a series of structural aspects.

a) The largely random nature of the system of supplies. The most important raw materials generally come from faraway countries and are usually transported by sea. Even with a careful programming of supplies, the arrival dates of the lots purchased as well as their quantities are often subject to great uncertainty due to exogenous factors which are completely beyond company control. These include, above all, "disturbances" which lead to changes in transport plans and schedules (such as, for example, weather conditions) and unpredictable commercial policies of untrustworthy suppliers.

b) The difficulties in evaluating the economic damage resulting from running out of raw material supplies. Often there may be incidents which interrupt production, but not the regular flow of sales of the finished product, or even incidents which cause long down times leading to exhaustion of finished product reserves thus, leading to direct effects on sales. The negative effects of these two situations are serious, due to both the high costs associated with interrupting the production cycle (this requires a series of interventions and operations on the plant) and also to possible consequent reductions in market share and deterioration of company image.

c) Finally, a part of these products may be used as raw materials for other productive processes of the company and this makes an evaluation of the economic implications of running out of stocks even more difficult.

The application described here has, for the sake of simplicity, been limited to the direct economic effects of the hypothesised policies, thus excluding those associated with the market and other production processes which depend upon the particular product.

THE MDS SYSTEM

The structural characteristics of the problem require the use of a simulation system, such as the MDS one, for the following reasons.

1. The MDS methodology (Bartezzaghi et al., 1982) allows one to model the set of interrelations existing between the different company subsystems involved (especially the supplies and production circuits and the economic/financial subsystem), in order to be able to measure correctly the costs relating to the different supply and stock policies.

2. The behaviour of the real system, where the uncertainty in the exogenous variables is added to that of the operating conditions of production, can only be represented by computer simulation. Only by using this instrument is it, in fact, possible to study the economic effects produced by completely random processes, which are, however, limited by the framework of hypotheses which fix the maximum range of random variations of the significant variables of the system.

3. The MDS system, in the present example, allows one to evaluate the long term behaviour of suitable indicators of company performance, given the adoption of a certain supply policy. The need for representing the evolutionary dynamics of company

activity and for evaluating the long term performance are related to two fundamental aspects:

- the necessity for ignoring transitory conditions and thus describing the normal situation which effectively represents the economic trends determined, "coeteris paribus", by the simulated supply policy;

- the need for "filtering" anomalous results due to short term random effects: the low frequency of annual purchases, which characterises the supplies of strategic raw materials for production, requires the extension of the simulation over a long period.

The MDS system was used, first of all, for a single plant and for supplies of a single raw material, sulphur.

This particular case is illustrated below, the concluding paragraph showing the effects produced by the results on the overall policies of the company along with some possible developments in the application of the MDS system.

THE MODEL

The plant produces caprolactam (feedstock for synthetic fibre production) and, as a by-product, ammonium sulphate. The entire production of the plant is absorbed by group members and thus the relationships with the market are limited to the economic transactions existing between the plant and the group to which it belongs.

The raw material examined is sulphur which, while not being the main one on the basis of the quantity used, it is the simplest to deal with as it involves fewer interactions with other plants. The main sources of primary supply are Canada and Poland. There are also other secondary sources of supply (that is, sellers and not producers). A group of the latter are called, for simplicity, the "Mediterranean area", while another source is an Italian company which can provide small quantities of sulphur for immediate delivery.

The availability of sulphur in Italy allows the possibility of interventions whenever the reserves fall below the desired minimum quantity. But these possibilities are diminished by the total amount available, which imposes a maximum limit on the quantity of sulphur available annually in Italy.

Since the "market" in which the company operates ensures the sale of all of its product, the supply plan may be defined annually on the basis of the production plan (optimised for an efficient use of plant) and of the predicted availability of the different sources of supply.

Once the production (and thus the production rates) and the initial warehouse level of sulphur are known, it is possible to formulate a purchasing plan. Such a plan defines: the desired arrival dates of the lots purchased from the three commercial sources, the ordering dates (having fixed the delivery terms for each supplier) and the quantities for each order.

Having fixed certain exogenous conditions regarding the quantities which may be periodically ordered (availability of the different suppliers), the most significant decisional variable in the formulation of the purchasing plan is the minimum stock level (MSL). The latter, given a certain production plan, requires a certain scheduling of the purchasing of lots, within the margins allowed by the Italian purchasing situation, to resolve urgent problems of low reserves of the raw material.

The MSL value corresponds to the acceptance, by the company, of a policy involving a certain risk, given the aleatory conditions of supplies and production. These conditions can cause changes, even significant ones, in previously formulated plans and thus breaks in stock.

The value of the minimum stock level used before the application of the model was 5000 tons of sulphur.

Given this method of operation, the aim of the MDS model was to simulate the dynamic behaviour of the supply and production functions and evaluate the economic/financial effects in order to:

1. determine the minimum stock level for sulphur which statisfies the criteria of economic efficiency;

2. determine, on this basis, the supply policy for sulphur.

Given the simplicity, in this specific case, of the market subsystem, the subsystems represented using the MDS methodology are the technology/resources and the economic/financial subsystems.

The overall model produced consisted of 23 levels, 40 flows and 30 parameters.

RESULTS OF THE SIMULATION

It can be seen that the decisional variable, which determines the different purchasing policies for sulphur, is the minimum stock level.

In order to determine its "optimum" value it will thus be necessary to carry out, for each alternative minimum stock level, a number of simulations covering all the possible configurations of the external environment. For each possible range of uncertainty there will then be different values of the accumulated result, which summarise the 10-year evolution of the company, as described using the MDS model.

The results of the simulations are given in Figure 1, which shows the plots of the accumulated result E as a function of the chosen Minimum Stock Level (MLS) and of the variations in the parameter r, relating to the delivery dates. In the figure the continuous lines interpolate the set of discrete points corresponding to the same value of r.

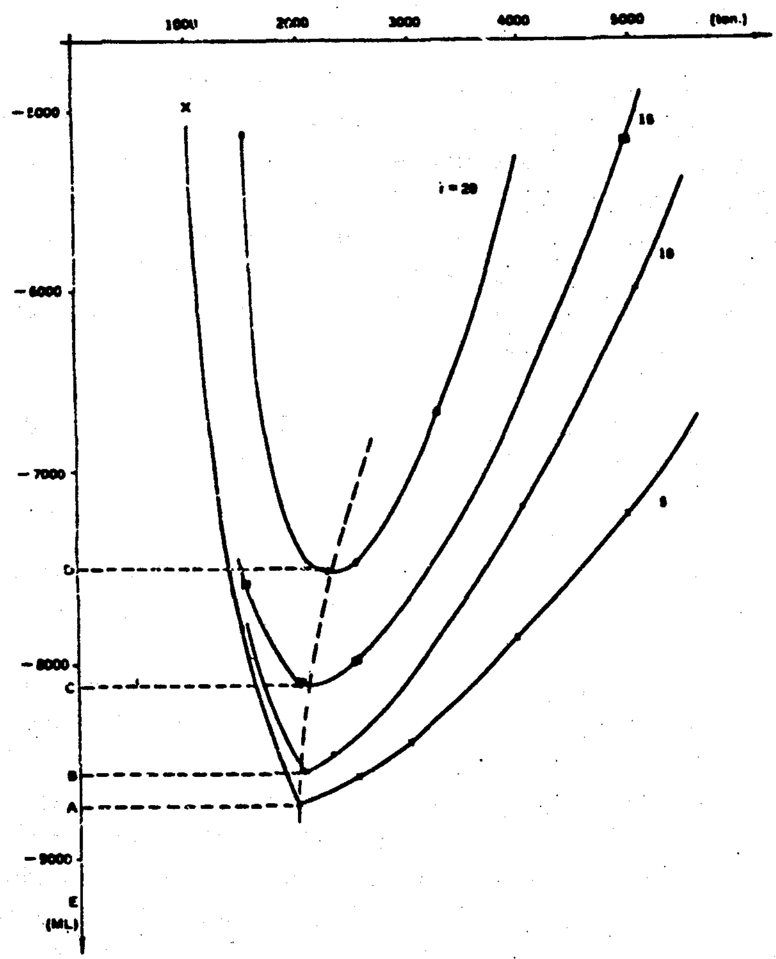

Figure 1. The Accumulated Result

The amount by which the minimum stock level can vary is between a minimum of 1,000 and a maximum of 5,000 tons of sulphur (the latter is the level used so far by the company).

Within this interval, the plots of the accumulated results show a clear minimum (it should be remembered that the MDS model shows a positive result with a level of negative sign).

The position of the minimum, on varying r, is to be found within an interval of between 2,000 - 2,500 tons of minimum stock.

One fundamental result of the simulation is thus an indication that the "abundant" stocks policy (MSL = 5,000 tons) does not satisfy the economic criteria of the accumulated result, and does, in fact, worsen the situation.

Entering into the merits of the overall behaviour of the accumulated result, the following points can be made.

That part of the curve corresponding to low minimum stock levels is the zone in which breaks in stock occur. The gradient of the curve is very steep due to the very high fixed costs of breaks in stock. On going from MSL values of 2,000 tons (breaks in stock are then practically absent) to values of 1,000 tons (with 5-6 breaks in stock over 10 years, corresponding to 15 days of uncertainty in the arrival of the sulphur) there is a worsening of the accumulated result of the order of 2.5 - 3 billion lire (US$ 1.3 - 1.5 million).

The part of the curve corresponding to high MSL values is a region where breaks in stock are absent, but where there are often excess quantities of stock.

The gradient of this part is less steep and is determined on the basis of the costs of excess raw material and the increased financial costs.

Figure 1 shows that the minima of the set of accumulated result curves are concentrated in the region of 2,000 - 2,500 tons of minimum stock.

In particular, when the behaviour of the minima is compared with the range of uncertainty, r, it can be seen that the shift Δmin. between the "absolute" minimum of the accumulated result (for r = 5 days) and the "relative" minima ($r > 5$ days) is fairly small when the delays/early arrivals are within $\pm$ 15 days (see Figure 2).

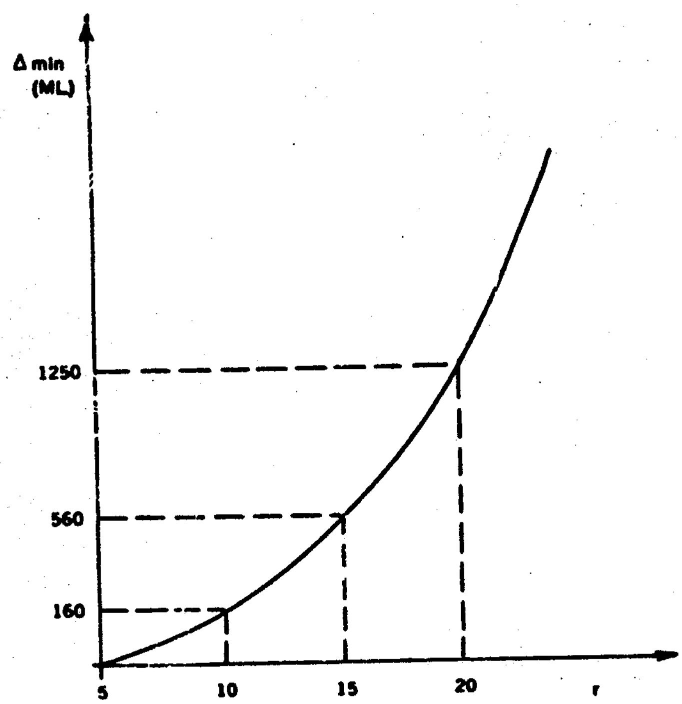

Figure 2. Shifts in the minimum values of the accumulated result

Given the hypothesis that this time interval will not be exceeded, this means that operating with a MSL of between 2,000 and 2,500 tons will not lead to breaks in stock, or penalties for excess of stock, and will produce a relative "stability" of the accumulated result.

Comparing such a policy with an "abundant" stock policy (MSL = 5,000 tons) it can be seen, for example, that for an uncertainty of 10 days in the arrival of the sulphur, there will be, other things being equal, an improvement in stock management of about 250 million lire p.a.(US$125,000), of which 60 million are due to reduced financial costs and the remaining 190 to the reduction in costs of excess stock.

REFINING THE METHOD FOR MSL DETERMINATION

If greater precision is required in the determination of the minimum stock level a more detailed analysis is required regarding the uncertainty of the arrivals. It should be noted that the parameter, r, utilised (which was given the values of 5, 10, 15, 20, ..., days) is the estimate of the maximum delay/early arrival considered plausible for a given supply situation (an automatic mechanism included in the model gives a "random" arrival date within the interval $t_o \pm r$, where t_o is the programmed arrival date).

It should be possible for a purchasing expert, using his own estimates and/or using past data, to construct a graph of the type shown in Figure 3, where p is the probability that Q, the arrival date, does not lie within the interval $t_o \pm r$ at least once a year).

In the graph it is assumed that the probability of a delay/early arrival of more than 20 days with respect to the planned arrival date, t_o, is very low (almost insignificant) and, vice versa, the probability of delays/early arrivals of more than 5 days is very high.

Given this, the graph of the accumulated result can be re-examined (see Figure 1), where the line (a) represents the locus of the minima for the stock levels.

It is assumed that working points along that line are chosen. Remaining at the intersection with the curve r = 20 days it is practically certain that values outside of the range will not occur and, consequently, every extra penalty for breaks in stock due to the arrival of sulphur outside of the predicted range may be excluded. In this case, however, there is a loss of "margin' equal to the segment DA (estimated over 10 years) with respect to the improbable case corresponding to r = 5, with no values of arrival dates outside of the range $t_o \pm 5$ days.

By taking progressive intersections between the line (a) and the curves with the parameter r = 15, 10 days, working points with progressively lower theoretical losses of margin are obtained (segments CA, BA) which include, however, growing probabilities of values falling outside of the range and thus of extra costs.

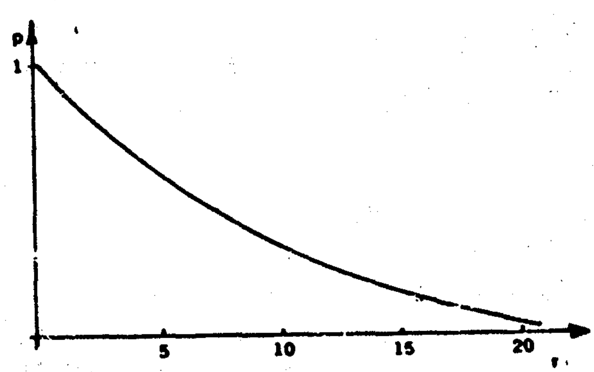

Figure 3. Probability associated with the "range of uncertainty"

For a quantitative evaluation of these extra costs the following assumptions can be made:

- for low values of the probability p one may ignore the event of a value falling outside of the range more than once a year;

- given operation along the line (a), locus of the minima, it is assumed that every value falling outside of the range causes a break in stock (this assumption is a very cautious one because of the serious effects of breaks in stock).

Given these assumptions, the extra penalty p.a. can be taken, for low values of p, to be equal to the product p(r) for the fixed costs of breaks in stock (500 million lire, US$250,000).

This is shown in Figure 4, where an unbroken line has been used for the meaningful portion of the graph.

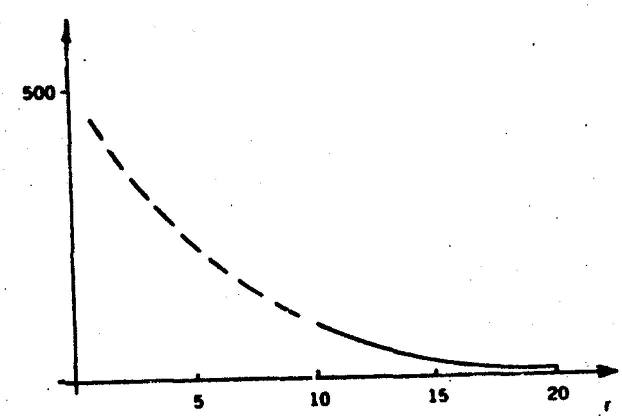

Figure 4. Extra costs due to breaks in stock

The loss of theoretical margins p.a. must be added to these costs, and these are evaluated as a function of decreasing values of r and can be quantified using the intervals EA, DA, CA, BA (reduced by a factor of 10, equal to the number of years' simulation). On adding the two trends, the trend shown in Figure 5 is obtained.

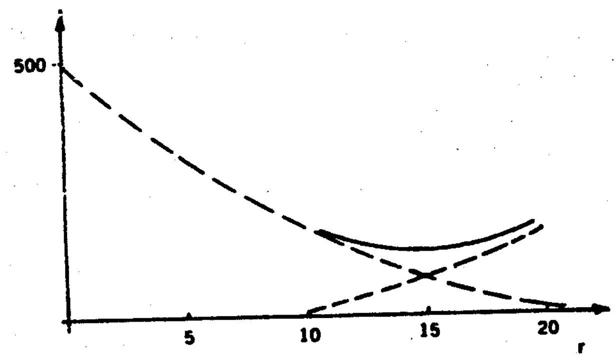

Figure 5. Extra costs due to breaks in stock and loss of margins

CONCLUSIONS

The methodology and the method developed allow the extension of simulations to situations involving a higher level of complexity, with a simultaneous consideration of the ranges of uncertainty relating to several variables. The model thus allows one to define efficient policies for the management of stocks over wideranging conditions of variability of the environment and of the economic criteria relating to the long term performance of the company.

It is thus possible to objectively and quantitatively measure the economic benefits deriving from the adoption of a stock policy which pays more attention to the global effects which it has in the company, rather than a policy having a strictly "functional" orientation (especially towards production, as in past company experience).

The MDS application has thus led to the beginning of a general process of revision of the supply policies, following the lines and the criteria developed in this example.

There is the prospect of applying the MDS methodology to more complex situations. One can develop a simulation model, extended to include several plants of the same company, which takes into account the interactions existing between the different operational units and their production. For example, the already mentioned utilisation in series of products from some plants which are used as raw materials or partly prepared products for others.

Also, systems with a high structural flexibility can be developed in response to the different requirements of the management. Regarding the latter, it is possible, in particular, to introduce procedures capable of modifying in a simple and rapid way the interactions which link the different "operational states", each of which is characterised by a suitable description. In this way it is possible to carry out simulations given the hypothesis that the operational context which is being analysed changes, i.e. that the macrostructure of the model changes. This allows the study, for example, of supply policies for single plants and for integrated groups of them.

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