Sales and operations planning optimisation. Contribution and limits of linear programming

André Thomas, Patrick Genin, Samir Lamouri

Chapter 14

SALES AND OPERATIONS PLANNING OPTIMISATION

Contribution and limits of linear programming

Patrick Genin, Samir Lamouri and André Thomas
Ecole des Mines de Paris, Ecole des Mines de Paris, CRAN Faculté des Sciences Vandoeuvre-les-Nancy

Abstract: Operations' planning requires making strategic decisions on inventories levels, on demands and operations constraints. The importance of these decisions leads to elaborate and optimise Sales and Operations Plans on a planning time fence at least as long as the budget. Models using linear programming give the "optimal" strategy but it does not resist frequent changes in parameters. Other mathematical tools as well as Taguchi methods are interesting in realising a simple but robust compromise.

Key words: Sales and Operations Planning, Optimisation, Linear Programming, Robustness, Planning

1. INTRODUCTION

Today, Supply chain Management becomes the function that chooses the global level of production and the performance of the other activities in order to satisfy the actual sales forecasts. Planning production allows to make arrangements on time to satisfy sales with needed quantities and promised delays at the smallest cost. These three objectives cannot be simultaneously achieved. The planning decisions are always the result of a balance between on-time deliveries, risks on inventories and operations costs.

The Sales and Operations Plan process (S&OP) builds the sales and operations strategy that realises the best balance, on a time fence at least as long as the budget, for product groups [13]. The expected performance for other activities is deduced on a mid/long term.

The traditional S&OP calculation is based on graphical techniques or on Linear Programming models [3]. This chapter sets out how an approach of S&OP by linear programming, can balance inventories, on-time deliveries and operations costs but also points out the limits in robustness of the strategy.

2. THE S&OP FUNCTION

S&OP puts into practice strategic objectives established by management when dealing with the strategic plan. It is the link between the sales planning and operations. S&OP is entirely integrated in information and demand management systems. It drives the execution of the different Master Planning Schedules (MPS). S&OP is a useful tool for prospective analysis over the medium to long term.

As the operations system is not flexible enough to follow sales changes day by day, adjustments are needed at that planning level. Sales are uncertain data with quick and unpredictable variations. If the demand could be exactly forecasted, the workload on resources should react the same way. However this is not always possible. The number of machines is fixed, training new staff takes time and the negotiations with suppliers have an impact on lead-time and quantities produced. The firm has to answer the following question: How can the production system capacity keep up with fluctuations in the sales volumes? It is the key role of S&OP to answer that question [8].

The S&OP anticipates the evolution in products families' sales in order to adapt the operations and supply chain system to its market. At that level, budgetary capacities are going to be taken into account. The S&OP will check cash, inventories, workforces, rough-cut capacities availability to turn the sales and strategic objectives (market shares…) into activities to complete on the mid term. The different sub-system are linked together (Figure 14-1).

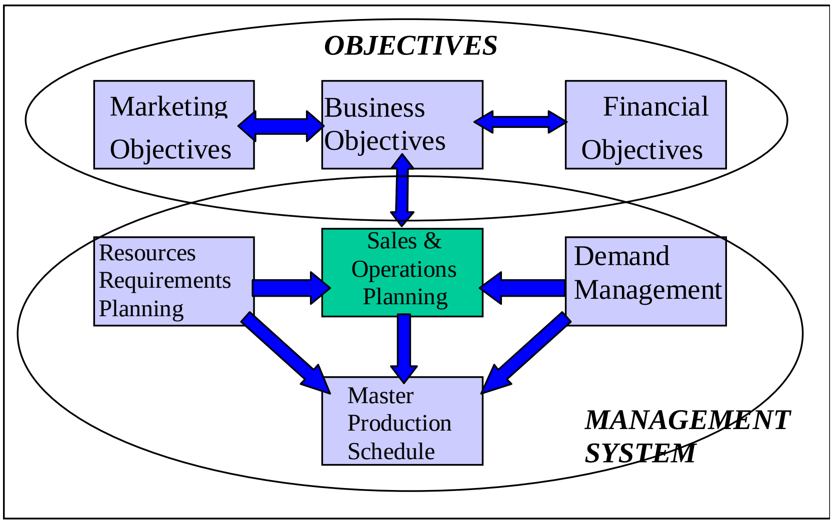

Figure 14-1. S&OP and industrial management functions

The planning horizon will often be 18 months long with a monthly planning frequency. These parameters are set to take account special events such as promotions, special agreements, …

Several simulations could be performed in order to determine the optimal strategy that will minimise the total cost while maximising the sales.

3. S&OP OPTIMISATION TECHNIQUES

Two approaches are frequently used: graphical methods and optimisation by Linear Programming [4, 5, 6].

The spreadsheets and graphical methods are widespread because of the easiness of use and understanding. The plans are obtained with few variables settled at a time to let the manager compare the forecasted demand to the existing capacity. These graphical methods work by iterations; they identify different integrated and realisable plans but costs are not necessarily the lowest. The manager must consequently use his feelings to determine the appropriate plan.

Graphical methods generally proceed in 5 steps as follow:

1. Determination of the demand per month;
2. Capacity determination in normal work hours, in overtime and in subtracting per month;
3. Identification of manpower costs, carrying cost, etc.;
4. Strategy evaluation changing workforce or inventory level;

5. Setting of alternatives and balancing of total costs.

These management tools help to evaluate different strategies but do not generate them. Whereas decision makers expect a systematic approach that considers the whole costs and gives an efficient answer to that problem. Mathematical models, using linear programming propose such an approach [1]. In the following, an application in an industrial context is described.

4. VALLOUREC PRECISION ETIRAGE (VPE) PROBLEMATIC

VPE produces steal tubes in parts or full length for automotive markets (layer 1, 2 and 3 supplier) and for mechanical markets (heaters, boilers, circuits). The Supply Chain initiative reengineers business process (industrial and administrative) in order to reach 98 % of on-time delivery.

Settled in 4 production entities, The 10 flow-shops ensure the production of the 70 commercial families by working 5 days out of 7 in 3x8. The demand by products family "the load” is different each month. On the contrary the capacity is relatively stable.

The S&OP is the monthly process for updating the tactical planning by consolidating production and demand on a 12 months time-fence. The steps are (Figure 14-2) [2]:

1. Demand Forecast calculation in the sales department in families and production lines;
2. Load calculation and load and capacity balancing on each line by its manager and parallel calculation by the supply chain manager at the firm level;
3. Scenario construction and actions plan by line and for the whole company;
4. Consolidation of resources requirements and availabilities and action plans validation by the supply chain manager;
5. Monthly meeting to present the scenarios and choice of the strategy by the steering comity.

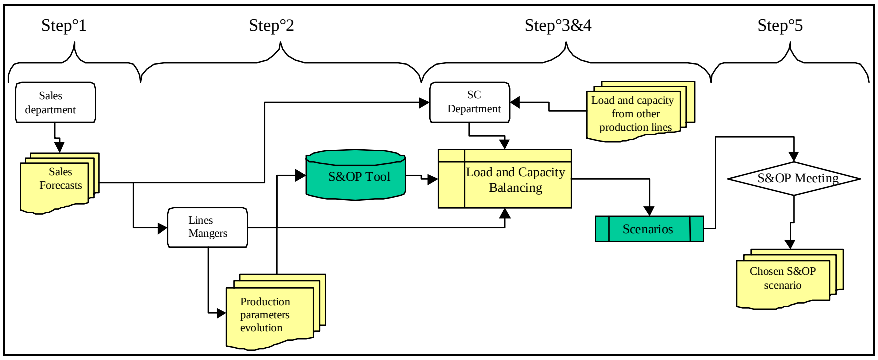

Figure 14-2. S&OP Process of VPE

The firm adjusts a set of logistic variables to spread the workload during its S&OP process:

– Seasonal inventories;
– Capacity adjustments (working during weekends and public holidays);
– Subcontracting (limited for strategic reasons);
– Backorders or inventories;
– Priorities by products family on production resources.

The determination of scenarios and associated total costs is difficult to make by hands. Linear Programming makes it possible to find the optimum for a whole set of given conditions.

5. THE LINEAR PROGRAMMING MODEL PROPOSED FOR VPE

The model presented is simplified: we do only consider one production line and only one products family. Moreover, data are truncated for confidentiality reasons.

The S&OP determines for the considered products family:

– production level;
– inventory level;
– subcontracting level;
– number of additional working days or non-working days;
– S&OP over-cost engaged by the scenario.

The main over-cost is due to production. It is composed of the over-costs caused by additional or non-working days and of subcontracting. In addition to this production over-cost, VPE considers the carrying costs. The Business Plan aims at a service rate of 100 %, that is to say any delay, and a level of stock lower than 3 days, 195 T Consequently, algebraic stock cannot be negative. It thus lies between 0 and 195 T. That last constraint does not consider the seasonal inventory.

Table 14-1. S&OP data

Item	Value
Unit inventory cost by period, c^I	190 €
Unit backlog Cost by period, c^B	2 300 €
Unit cost incurred per additional day, c^{OV}	800 €
Unit cost incurred by non-production day, c^{NP}	1 300 €
Unit cost for subcontracting, c^{SC}	600 €
Beginning Inventory, *I(0)*	100 T
Available capacity expressed in unit per day, *e*	65 T/d

5.1 The variables definition

t is the period index. T is the number of periods (it is the horizon lenght : 12 in our case). *D(t)* represents the forecasted demand for period t. *N(t)* corresponds to the standard working days in period t, $N^*(t)$ is the maximum of working days per period t. *u(t)* is the standard capacity in period t. It is determined by the formula (1). $O^*(t)$ is the maximum overtime capacity in period t. Relation (2) gives it. The values used are presented in Table 14-1.

$$\forall t,\ u(t) = e \times N(t) \tag{1}$$

$$\forall t,\ O^x(t) = e \times [N^x(t) - N(t)] \tag{2}$$

5.1.1 The decision variables

O(t) is the number of tons manufactured in additional days within period t. *S(t)* is the number of tons manufactured in subcontracting during period t. $S^*(t)$ is the upper limit to subcontracting. *N(t)* is the number of tons which have not been produced during the non-working days in period t. *I(t)* is the inventory level at the end of period t. *B(t)* is the backlog level at the end of period t. *P(t)* is the total production carried out.

5.1.2 The objective function

The objective of the problem is represented by the minimization of the sum of the different cost factors, i.e. the costs for production in overtime and for non-production, subcontracting, inventory, backlogs. It determines the over-cost of the determined scenario (3).

$$\sum_{t=1}^{T} c^{OV} \times O(t) + c^{NP} \times N(t) + c^{SC} \times S(t) + c^{I} \times I(t) + c^{B} \times B(t) \quad (3)$$

5.1.3 The constraints

The following describe the constraints in the model.

$$\forall t,\ P(t) = u(t) + O(t) - N(t) + S(t) \quad (4)$$
$$\forall t,\ P(t) = D(t) + I(t) - I(t-1) + B(t) - B(t-1) \quad (5)$$
$$\forall t,\ I(t) \le I^*(t) \quad (6)$$
$$\forall t,\ S(t) \le S^*(t) \quad (7)$$
$$\forall t,\ O(t) \le O^*(t) \quad (8)$$
$$\forall t,\ N(t) \le u(t) \quad (9)$$
$$\forall t,\ 0 \le O(t), N(t), S(t), I(t), B(t) \quad (10)$$

Constraints (4) state that in each period the whole production is obtained with the standard capacity plus or minus what is produced in overtime or not produced, and subcontracting. The balance equations among the whole production and inventories, total demand and backlogs are established through constraints (5). Clearly, constraints (5) may easily be modified to accommodate alternative assumptions concerning lost demand. Constraints (7) are constraint conditions, stating that the amount stored must be less than the storage capacity, for each time period. Similarly, constraints (8) stipulate an analogous condition for subcontracted units limited by management. Upper limits on overtime workforce capacity are given by inequalities (9).

Table 14-2. S&OP parameters

Period t	1	2	3	4	5	6	7	8	9	10	11	12
N(t)	19	9	21	22	21	16	22	20	22	20	20	20
$N^*(t)$	24	17	30	31	30	24	30	28	31	30	20	30
D(t)	1475	510	1655	1320	1757	1210	1603	1475	1320	1685	1199	1782
$S^*(t)$	300	300	300	300	300	300	300	300	300	300	300	300
$I^*(t)$	195	195	195	195	195	195	195	195	195	195	195	195

5.2 S&OP optimisation

Working out the problem and using of EXCEL solver determine the optimal solution according to the given conditions. The results are shown below (Figure 14-3 and Figure 14-4).

Sales & Operations Planning

Parameters					
Beginning inventory	100	T	Carrying costs	190	€/T
Capacity	65	T/d	Production over-costs in overtime	700	€/T
			Production over-costs in non-working hours	1300	€/T
			Backlog over-costs	2300	€/T
			Subcontracting over-costs	600	€/T

Results														
Period t		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
Demand *D(t)*		1 475	510	1 655	1 320	1 757	1 210	1 603	1 475	1 320	1 685	1 199	1 782	**16 991 T**
Production		1 235	585	1 365	1 430	1 365	1 040	1 430	1 300	1 430	1 300	1 300	1 381	**15 161 T**
Subcontracting *ST(t)*		140	0	215	0	282	170	173	175	0	275	0	300	**1 730 T**
Total prod		1 375	585	1 580	1 430	1 647	1 210	1 603	1 475	1 430	1 575	1 300	1 681	**16 891 T**
Inventory *S(t)*	100	0	75	0	110	0	0	0	0	110	0	101	0	**T**
Production in overtime *HS(t)*		0	0	0	0	0	0	0	0	0	0	0	81	**81 T**
Over-costs		84	14	129	21	169	102	104	105	21	165	19	237	**1 170 K€**

Figure 14-3. Optimised S&OP results

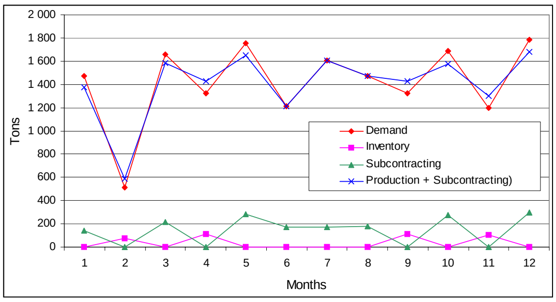

Figure 14-4. Optimised S&OP graph

The recommended strategy is inventory building during the under-load periods and the use of subcontracting in overloaded periods. The demand being strong during period 12, 81 tons are produced in overtime, less expensive than subcontracting and storage during period 11. The over-cost of this scenario is 1 170 K€. If the global approach is logical, the specific choices for each month cannot be obvious [1].

Let us suppose now that various events occur in production few hours, few days after the implementation of this S&OP scenario:

5.2.1 An exceptional order

It consumes 50% of the beginning inventory! How does the optimum evolve?

Sales & Operations Planning

Parameters					
Beginning inventory	50	T	Carrying costs	190	€/T
Capacity	65	T/d	Production over-costs in overtime	700	€/T
			Production over-costs in non-working hours	1300	€/T
Change			Backlog over-costs	2300	€/T
			Subcontracting over-costs	600	€/T

Results														
Period t		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
Demand *D(t)*		1 475	510	1 655	1 320	1 757	1 210	1 603	1 475	1 320	1 685	1 199	1 782	**16 991 T**
Production		1 235	585	1 365	1 430	1 365	1 040	1 430	1 300	1 430	1 300	1 300	1 381	**15 161 T**
Subcontracting *ST(t)*		190	0	215	0	282	170	173	175	0	275	0	300	**1 780 T**
Total prod		1 425	585	1 580	1 430	1 647	1 210	1 603	1 475	1 430	1 575	1 300	1 681	**16 941 T**
Inventory *S(t)*	50	0	75	0	110	0	0	0	0	110	0	101	0	**T**
Production in overtime *HS(t)*		0	0	0	0	0	0	0	0	0	0	0	81	**81 T**
Over-costs		114	14	129	21	169	102	104	105	21	165	19	237	**1 200 K€**

Figure 14-5. Optimised S&OP results after the order integration

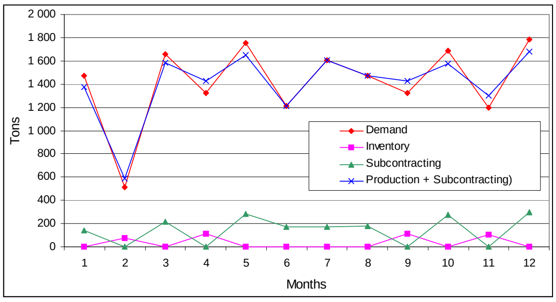

Figure 14-6. Optimised S&OP graph after order integration

Volume in subcontracting will be more significant involving an additional over-cost of 30 K€. The other part of the scenario remains identical (Figure 14-5 and Figure 14-6). This exceptional order is profitable only if its margin is higher than these 30 K€. In addition, if this event is anticipated, that makes it possible to warn the subcontractor to take the 50 additional tons. If this order is not anticipated, the 50 tons are made in overtime instead of sub-contracted. 5 additional K€ (50 X (700-600)) have to be added.

5.2.2 Capacity restriction of our supplier

Because of a contract for a new strategic market, our subcontractor can treat only 80 % of our needs! What becomes of the optimum?

Sales & Operations Planning

Parameters					
Beginning inventory	100	T	Carrying costs	190	€/T
Capacity	65	T/d	Production over-costs in overtime	700	€/T
			Production over-costs in non-working hours	1300	€/T
			Backlog over-costs	2300	€/T
			Subcontracting over-costs	600	€/T

Results														
Period t		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
Demand *D(t)*		1 475	510	1 655	1 320	1 757	1 210	1 603	1 475	1 320	1 685	1 199	1 782	**16 991 T**
Production		1 235	585	1 365	1 430	1 407	1 040	1 430	1 300	1 430	1 335	1 300	1 441	**15 298 T**
Subcontracting *ST(t)*		140	0	215	0	240	170	173	175	0	240	0	240	**1 593 T**
Total prod		1 375	585	1 580	1 430	1 647	1 210	1 603	1 475	1 430	1 575	1 300	1 681	**16 891 T**
Inventory *S(t)*	100	0	75	0	110	0	0	0	0	110	0	101	0	**T**
Production in overtime *HS(t)*		0	0	0	0	42	0	0	0	0	35	0	141	**218 T**
Over-costs		84	14	129	21	173	102	104	105	21	169	19	243	**1 184 K€**

Figure 14-7. Optimised S&OP results after restriction

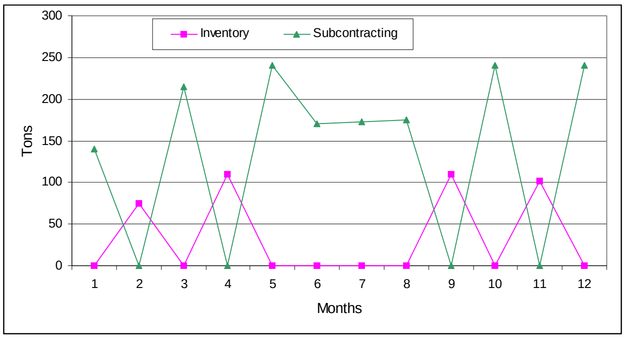

Figure 14-8. Optimised S&OP graph after restriction

Subcontracting is now limited to 240 tons per month (Figure 14-7 and Figure 14-8). Additional days are to be envisaged for the overload periods. The resulting over-cost is of 14 K€.

5.2.3 Reduced capacity

An event in production constraints VPE to produce during the first two months with a reduced capacity of 20 %! Where is the new optimum?

Sales & Operations Planning

Parameters					
Beginning inventory	100	T	Carrying costs	190	€/T
Capacity	65	T/d	Production over-costs in overtime	700	€/T
			Production over-costs in non-working hours	1300	€/T
			Backlog over-costs	2300	€/T
			Subcontracting over-costs	600	€/T

Results														
Period t		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
Demand *D(t)*		1 475	510	1 655	1 320	1 757	1 210	1 603	1 475	1 320	1 685	1 199	1 782	**16 991 T**
Production		988	468	1 365	1 430	1 365	1 040	1 430	1 300	1 430	1 300	1 300	1 381	**14 797 T**
Subcontracting *ST(t)*		300	42	290	0	282	170	173	175	0	275	0	300	**2 007 T**
Total prod		1 288	510	1 655	1 430	1 647	1 210	1 603	1 475	1 430	1 575	1 300	1 681	**16 804 T**
Inventory *S(t)*	100	0	0	0	110	0	0	0	0	110	0	101	0	**T**
Production in overtime *HS(t)*		87	0	0	0	0	0	0	0	0	0	0	81	**168 T**
Over-costs		241	25	174	21	169	102	104	105	21	165	19	237	**1 383 K€**

Figure 14-9. Optimised S&OP results after event

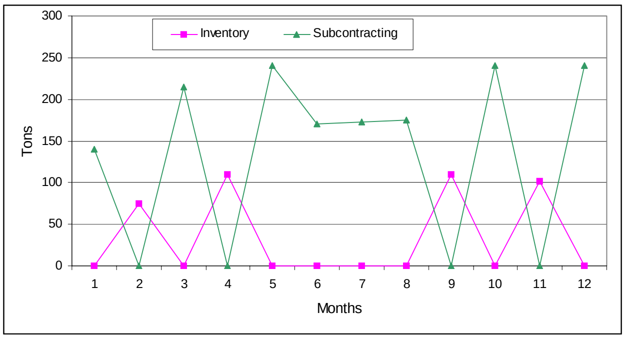

Figure 14-10. Optimised S&OP graph after event

Overtime are carried out in period 1. Subcontracting makes it possible to fulfil demand during months 2 and 3. Then the scenario remains identical (Figure 14-9 and Figure 14-10).

5.2.4 Forbidden Storage

Storage becomes impossible – Imax(t) = 0. What becomes the optimum?

Sales & Operations Planning

Parameters					
Beginning inventory	100	T	Carrying costs	190	€/T
Capacity	65	T/d	Production over-costs in overtime	700	€/T
			Production over-costs in non-working hours	1300	€/T
			Backlog over-costs	2300	€/T
			Subcontracting over-costs	600	€/T

Results														
Period t		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	
Demand *D(t)*		1 475	510	1 655	1 320	1 757	1 210	1 603	1 475	1 320	1 685	1 199	1 782	**16 991 T**
Production		1 235	510	1 365	1 320	1 457	1 040	1 430	1 300	1 320	1 385	1 199	1 482	**15 043 T**
Subcontracting *ST(t)*		140	0	290	0	300	170	173	175	0	300	0	300	**1 848 T**
Total prod		1 375	510	1 655	1 320	1 757	1 210	1 603	1 475	1 320	1 685	1 199	1 782	**16 891 T**
Inventory *S(t)*	100	0	0	0	0	0	0	0	0	0	0	0	0	**T**
Production in overtime *HS(t)*		0	-75	0	-110	92	0	0	0	-110	85	-101	182	**-37 T**
Over-costs		84	97	174	143	244	102	104	105	143	240	131	307	**1 875 K€**

Figure 14-11. Optimised S&OP results with 0 storage capacity

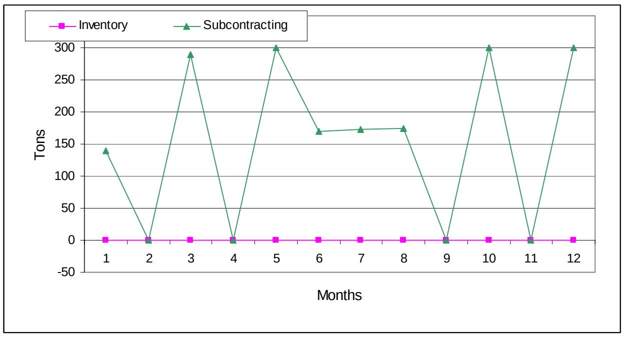

Figure 14-12. Optimised S&OP graph with 0 storage capacity

The under-load periods cause unemployed hours and the overload periods imply the subcontracting and overtime saturation. The over-cost of the strategy is then 1 875 K€, that is to say a variation compared to the optimum of 60 % (Figure 14-11 and Figure 14-12)!

6. LIMITS OF LINEAR PROGRAMMING

What do we have to conclude from preceding simulations? That the level of beginning inventory is not very significant? Certainly, but it is more interesting to note than the optimum is not stable!

Linear Programming makes it possible the Supply Chain Manager to generate the optimal scenario for a given set of parameters. It is more adapted than the graphic techniques to exploit problems with multiple constraints by providing a technique that leads to an optimal mathematical solution, for a given set of conditions.

However, the scenarios developed previously show that an event in production can make strongly diverge the optimum and thus to change the optimal scenario. In a dynamic mode, nothing prevents the model to give highly different solutions at only two days intervals. On a given date, the firm directs its strategy towards the optimum, implements heavy actions (an investment for example), the following day, the conditions are different and the actions differ widely! The dispersion of the mathematical optimum given by the linear programming model is caused by the parameters variability in time whereas they are regarded as static in the model. This assumption is not always exactly satisfied in practice on the whole time-fence of the S&OP: for example, subcontracting capacity can be punctually limited.

Use of such tools is inseparable from attentive check of the significance and validity of these assumptions, which in practice are unfortunately called into question. Indeed, the coefficients of resources consumption or the costs generally depend on the quantities: a subcontractor reduces his unit price if the quantities are more significant. Linear programming cannot treat these cases. “Linear Programming allows convex structures of production and storage costs (non-decreasing marginal costs). What is awkward in this type of constraint is the impossibility of introducing a launching cost, because in general, at on a few months term, the production is realised at non-decreasing marginal cost, once production of the first unit released” [3]. A problem formulation in linear programming language requires lots of assumptions (linearity and independences of the variables).

7. FUTURE PROSPECTS OF S&OP

How can the models that use Linear Programming be extended? The answer will be to seek models using the non-linear and dynamic programming. Certain authors suggested, in particular cases, other approaches (stochastic optimisation models, Monte Carlo) [7, 10]. How can the S&OP be approached in the industrial case of multiple production lines? A deep research in the scheduling techniques must provide a suitable answer. How can the scenario suggested by the linear program be reinforced? The answer is by using the S&OP …

The S&OP is the process that drives the capacity level and actions to be implemented so that Master Production Schedules can be completed. It must thus be relatively stable, because of the weight of the taken decisions. For example, the inventory level is limited by the storage capacity. In case of events, the scenario of replacement can become then extremely expensive for the firm whereas a simple contract with a storage partner could be signed to provide a more robust scenario.

The S&OP becomes the decision tool to make robust the scenario suggested by the model according to the given set of conditions (parameters). The Decision Support System must give an average answer that will be the best possible response for several sets of conditions. The S&OP will not be then mathematically optimised but will vary little when a change in parameters will occur.

Design plans are the traditional tool used to establish the robustness of the system answer (i.e. reduce the variability of the answers) by influencing the control parameters (of adjustment) [9].

In the case of our S&OP models, the input parameters represent the Sales forecasts. The control parameters are those that make possible to control the system: costs of overtime, subcontracting, maximum inventory … They are the action levers for the planner. The parameters of disturbance are all those which intervene on the system independently of the will of the planner. It is the case for example for the beginning inventory, the capacity of the line …

Taguchi calls the not-controllable parameters “noises” [11]. The more “robust” a system will be, the lower the variability in scenario. A scenario will be robust if it is not called in question by non-controlled external factors (noises).

Use of Design plans allows to test, with a restricted number of trials, the average scenarios that optimise the S&OP while limiting their variability. The planner must fix, during the process, the nominal values of the control parameters according to a double optimisation:

– the optimum operation of the system,
– the resulting robustness.

We neglect too often the second optimisation. We then work out strategies on paper that cannot to be implemented or lead to the sub-optima in a “disturbed” environment.

8. CONCLUSION

Within the framework of recent work, we have initiated this way of research on the robustness of the S&OP thanks to simulations carried out by taking into account controllable and not-controllable variables for the industrial system and the manager [12]. Our survey of the literature made clear to us that others mathematical tools can be interesting to test these scenarios. We want to show that an optimum research in this field must be obtained by various levels of simulations: a first step to define an optimal target, a second to define a tolerable range of variation without degradation of cost and finally a law defining the marginal loss according to the difference to the optimum.

REFERENCES

1. Crandall, R.E., 1998, Production Planning in a variable Demand Environment, *Production and Inventory Management Journal*, 4th Quarter, APICS, p. 41-48.
2. Genin P., 2000, *Le Plan Industriel et Commercial : Recherche des pratiques optimales du processus d'élaboration*, Mémoire de DEA, LATTS, Ecole Nationale des Ponts & Chaussées, Paris, France.
3. Giard V., 1988, *Gestion de la Production*, Economica, Coll. Gestion, 2ème édition.
4. Giard V., 1998, *Processus productifs et Programmation linéaire*, Economica.
5. Heizer and Render, 1995, *Production and Operations management*, Prentice hall.
6. Lamouri S and Thomas A., 1999, Optimization of the process of development of the SOP, In: *Proceedings of the International Conference on Integrated Design and Production* (CPI' 99), Tanger, Maroc, p. 328-338.
7. Moutaz K., 1998, An aggregate production planning framework for the evaluation of volume flexibility, *Production Planning and Control*, Vol: 9 Nbr 2, p. 127-137.
8. Nollet, Kelada and Dioro, 1992, *La gestion des opérations et de la production*, Editions Morin Gaetan.
9. Pillet M., 1992, *Introduction aux plans d'expériences par la méthode Taguchi*, Editions d'organisation Université, Paris.
10. Silva Filho O. S., 1999, An aggregate production planning model with demand under uncertainty, *Production Planning and Control*, Vol 10 Nbr 8, p. 745-756.
11. Taguchi G., 1987, *Orthogonal arrays and linear graph*, American Supplier Institute press.
12. Thomas A. and Lamouri S., 2000, The new problem with Sales, Inventories and Operations planning in a Supply Chain environment, In: *Proceedings of the International Society for Optical Engineering on Intelligent Systems in Design and Manufacturing*, Boston, USA, p 321-329.
13. Vollmann, Berry and Whybark, 1992, *Manufacturing, Planning and Systems Control*, The Business One Irwin.