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Product Mix Planning: A case in point to enhance realization

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ABOUT THE AUTHOR

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ABSTRACT

The Indian Cement Industry, the second largest in the world, is in the grip of a wide-sweeping environmental change. Over capacity, slackening of demand growth, see-sawing prices, shrinking realizations, industry consolidation, the charge of the Global Giants, the threat of cheaper imports - it's all happening! Success, and even survival, depends on how nimbly organizations prepare themselves to cope.

Manufacturers, ostensibly, have limited individual control on variables dominated by the external environment. Thus, an enhanced, continuing focus on internally controllable variables becomes an absolute imperative to even maintain a black bottom-line.

Realizing this need for continuous improvement, most companies have initiated focused programs covering various aspects of cement operations. With markets displaying clear signs of product differentiation, and different products consuming different resources to manufacture, the potential of appropriate product mix planning in enhancing the bottom-line is being increasingly recognized.

Mathematical modelling, suitably populated with hard-core field data, provides a good tool to address the complex issues governing product planning. This paper, defining Holtec's approach to product planning, takes an integrated view of marketing, production, inventory control and related functions in order to maximize the competitive advantage that could be derived by cement manufacturers.

The theoretical dimensions of this paper is embellished through an actual Case Study in the Indian Cement Industry that highlights the performance outcomes achieved through the application of the different features of the proposed approach.

1.0 INTRODUCTION

The Indian Cement Industry is passing through an intensely competitive phase, as growth in production potential continues to outstrip growth in demand. As a natural corollary, returns in the cement industry, despite intermittent upsurges, are, on an overall basis, getting severely constrained. While large segments of the industry view this environment to be threatening their very sustenance, progressive companies are increasingly using this as an opportunity to adopt innovative approaches targeted at differentiating the winners from the losers.

Apart from price, brand image and quality, which have so far played a key role in influencing the push-pull characteristics of cement demand, there appears to be a growing market awareness of the use of different types of cements for different applications. Currently, the options available include:

- 33, 43 and 53 grades of Ordinary Portland Cement (OPC),
- Blended cements such as Portland Pozzolana Cement (PPC) & Portland Slag Cement (PSC), grades for which are currently under consideration
- A host of special cements such as white Cement, Sulphate Resistant Cement (SRC), Oil Well Cement (OWC), Masonry Cement (MC), Rapid Hardening Cement (RHC), Low Heat Cement (LHC), etc. meant for very specific applications.

With technology specifications, market demands, prices, input requirements, equipment utilisation and costs being different for different products, the immense potential of a product planning exercise, in influencing the bottom-line, is clearly evident.

2.0 PRODUCT PLANNING

Integrated product planning is an exercise targeted at answering the following questions:

- What product(s) should the company be manufacturing?
- Where should these be marketed?
- What facilities and resources should be used in the process of manufacture?

The result of the product planning exercise is termed as the **product mix**.

Traditionally, product mix decisions in the cement industry have largely been based on the ability to sell a particular product. It cannot be denied that in the buyers' market of today, **what the consumer requires has to be produced** and not the contrary. However, the success of a company in deriving a competitive advantage, lies in making the optimum choice. A choice between the various products that it can sell, after taking into consideration the revenues (read as price x volume) it can expect on the demand side and the costs & material/ resource constraints imposed by the supply side.

Each item in a product mix contributes differentially to total sales, profits and resource utilization. Thus, it becomes essential to know the proportion of total sales, profits and resource utilization, contributed/ consumed by each product. The analysis of the current mix is essential to determine the extent of reliance on each product and the possible impact caused by volume changes consequent to external factors.

An appropriate product mix assures the following advantages:

- Superior profit performance
- Optimum utilisation of available resources, be it money, materials or machines
- Strategic presence in different market segments
- Protection against vulnerability due to changes in market characteristics.

Product mix decisions are not as simple as they may appear. This is because the overall profitability of the company is governed by several factors, including the direct & indirect costs incurred in production, distribution and promotion. Moreover, as new cement types are added, several new costs arise, which may include design and engineering costs, inventory costs, manufacturing changeover costs and costs for promoting the entire product range.

A judicious approach, therefore, has to be taken to determine the product mix. Though cement is not a very technologically intensive product, the production planning exercise is nevertheless, governed by a multitude of constraints - both marketing and technical, which are difficult to analyze in isolation. Mathematical modelling provides an efficient method to optimally integrate these.
Holtec Consulting has carried out several exercises in product planning for both, domestic and international, cement companies. This paper describes the methodology adopted and the outcomes achieved in one such case.

3.0 CASE STUDY

For reasons of confidentiality, the identity of the producer, the location of the plant and the markets in which its outputs are sold, have not been revealed.

3.1 Assignment Objective

The client wanted Holtec to recommend the optimum product mix for the subsequent period. In addition, it also wished to determine the financial benefit it would have derived in the year just transpired, had it adopted, albeit with assumptions relevant to that year, the prescribed optimization model.

3.2 Assignment Backdrop

The geographical setting of this case is in India. It concerns a 2.8 million tpa cement plant, employing three kilns, 3 cement mills and 7 cement silos. The plant's location enables it to service markets in 8 states. In the past, the plant had been manufacturing and selling 5 products viz. OPC 33, OPC 43, OPC 53, PPC and SRC in different proportions.

3.3 Determinants

Determinants, that governed the development of the optimization model were:

- The respective **demand volumes** for each product were different in different markets. Since it was not possible to differentially estimate product demands for each grade of product, banding was done with respect to product types. Thus, while it was possible to forecast the demands for OPC and PPC separately, demands for OPC 33, OPC 43 and OPC 53 were considered to be in the same proportion to overall OPC, as manifested in previous consumption.

- Due to reasons of relative competitive advantage, the **ceiling market shares** that this plant could capture were different for different markets. These were determined using Holtec's proprietary Competitive Advantage - Market Attractiveness (CAMA) Model.
- To be able to maintain a limited market presence, at the very least, product sales below certain floor limits, as specified for each market, was not permissible. This resulted in the specification of **floor market shares** for each market.
- The average price realized at the factory gate, for each product, was different. These were back calculated from the respective **market prices** for each product, by removing all elements of the price waterfall, subsequent to the factory gate.
- For each product, **mill output rates**, as well as **unit energy consumption**, were different. In addition, on account of respective motor capacities as well as running hours, the **energy availability** during a period was different, for different mills.
- Due to a variety of **technical considerations** including plant layout, equipment connectivity, storage capacities, etc., it was not possible to grind each cement type in each mill.
- **Material costs**, while being different for each cement type, were independent of the mill in which grinding is effected. However, **material availibilities** governed their maximum degree of usage.

3.4 Model Selection

The models that are available for product mix decisions belong to the class of mathematical modelling, and include linear programming, non-linear programming and integer programming models. On account of the variables being continuous (i.e. not assuming integer values only) & non-negative, and the objective function & constraints being represented by linear equations, the **linear programming model** was found to be appropriate in this particular case.

In this specific case, the **software package, LINDO** was employed for mathematical computations. This package conveniently runs on a reasonably configured, Pentium class PC.

3.5 Decision Variables

The decision variables selected were the **production volumes, in tons, of various cement types that needed to be ground in various mills**. It was assumed that separate runs would be carried out for different periods. Consequently, the time period does not appear as a component variable.

These variables are represented by "X_{ij}", which represents the tons of cement type "i", required to be ground in mill "j".

"i" would vary from 1-5, with i=1 being OPC 33, i=2 being OPC 43, i=3 being OPC 53, i=4 being PPC and i=5 being SRC, and "j" varying from 1-3, with j=1 being Mill No. 1, j=2 being Mill No. 2 and j=3 being Mill No. 3

3.6 Objective Function

Maximization of total contribution was considered to be the overall objective.

The unit contribution was computed by subtracting the unit cost "C_{ij}" of producing cement type "i" from mill "j", from the factory gate price "R_i" of product type "i". "C_{ij}" itself was computed by adding the unit material cost "M_i" of product type "i" to the unit energy cost "P_{ij}" of grinding cement type "i" in mill "j". Given the existing energy tariff and the unit energy consumption in each mill for each product type, "P_{ij}", was easily computable. All costs, common to the production of all cement type in any mill, could be ignored, since these negated each other, in making a choice, and thus had no effect on the final solution.

The objective function can thus be written as:

$$\textbf{Maximise} \sum_{i=1}^{5} \sum_{j=1}^{3} X_{ij} (R_i - C_{ij})$$

3.7 Constraints

The objective function stated here, needed to be maximised subject to simultaneously satisfying several sets of constraints. These were:

3.7.1 Market Constraints

The tonnages of each cement type were constrained by the limits imposed by the summing the volumes across each market computed from the desired values of maximum and minimum market shares. The volumes thus arrived at appeared as Right Hand Side (RHS) constants "V_{iUL}" and "V_{iLL}", denoting the Upper Limit (UL) and the Lower Limit (LL) respectively for cement type "i".

Thus for cement type "1", the relevant constraints were:

$$\sum_{j=1}^{3} X_{1j} <= V_{1UL} \text{ and,}$$

$$\sum_{j=1}^{3} X_{1j} >= V_{1LL} \text{ respectively}$$

Likewise, Upper and Lower Limit Market Constraints were developed for all 5 product types.

3.7.2 Production Capacity Constraint

An upper limit on the total cement Production Capacity was defined for the plant. In this particular case the relevant Production Capacity for a period (PC) was computed from the annual capacity of 2.8 mio tpa. Consequently, there was an upper bound on the total production. The relevant constraint was thus defined by the equation:

$$\sum_{i=1}^{5} \sum_{j=1}^{3} X_{ij} <= PC$$

3.7.3 Energy Availability Constraints

The specific energy requirements for producing one ton of each cement type from each mill were already available as coefficients with the nomenclature "En_{ij}". Given the motor ratings, an energy transmission efficiency of 95% and the running hours per period for each mill, the upper limits of total energy availability for each mill were computed as RHS constants, "M_j".

Thus, for Mill No.1, the relevant constraint was written as:

$$\sum_{i=1}^{5} En_{i1}\, X_{i1} <= M_1$$

Likewise, equations were developed for the other two mills as well.

3.7.4 Operating Hours Constraints

The mill capacities in terms of tons produced per hour for each cement type from each mill were already available as inverse coefficients "MC_{ij}".

Given the operating hours available for each mill to be the RHS constants, “R_j”, the relevant constraints were written for each mill.

Thus, for Mill No.1, the operating hours constraint was written as

$$\sum_{i=1}^{5} \mathbf{X_{i1} / MC_{i1}} \quad <= \quad \mathbf{R_1}$$

Likewise, equations were developed for the other two mills as well.

3.7.5 Material Availability Constraints

For the types of cement considered, the materials required for their manufacture were clinker, pozzolana (fly ash) and gypsum. It was assumed that there were no limits on the materials (basically limestone, correctives and fuel) required to produce clinker equivalent to the actual kiln capacity. While there were definite limits on the availability per period of clinker (Cl) and pozzolana (P), the availability of gypsum (G), in this particular case, was unrestricted. Knowing that one ton of cement of type ”i” required “Cl_i”, “P_i” and “G_i” tons of the three materials, respectively, irrespective of the mill in which it is produced, the relevant constraints for material availability were formulated.

Thus, for clinker, the material availability constraint was written as:

$$\sum_{i=1}^{5} \mathbf{Cl_i} \sum_{j=1}^{3} \mathbf{X_{ij}} \quad <= \quad \mathbf{Cl}$$

In the same way, the constraint for pozzolana was also developed.

3.7.6 Technical Constraints

As already explained under 3.3, viz. Determinants, restrictions placed by the layout, equipment connectivity, storage capacities (cement silos in this case) and other technical considerations, it was not physically possible to grind each cement type in each mill. This resulted in the following set of constraints:

$$\mathbf{X_{13}, X_{32}, X_{43}, X_{51}, X_{52} \quad = \quad 0}$$

3.7.7 Non-negativity Constraints

As is apparent from physical considerations as well as the variable bounds applicable for Linear programming problems, no variable can assume a negative value. Thus:

$$\mathbf{X_{ij}} \quad >= \quad \mathbf{0}$$

for all i = 1 – 5, and all j = 1 – 3

3.8 Cases Considered

Based on a discussion with the client, a total of 9 cases were taken up for analysis. The conditions considered under each, the results as well as certain comments are discussed below.

3.8.1 Case 1

- The maximum demand restrictions placed on OPC 33, 43, 53 and PPC were based on market estimations (using the CAMA Model) and that on SRC at 20% greater than the level achieved in 2002; Minimum demand restrictions were placed only on PPC and SRC, at the levels attained in 2002.
- The restriction on total cement production was assumed to be equal to the levels attained in 2002.
- Restrictions on energy availability and mill operating hours were taken to be the same as available during 2002.
- Availability of clinker was taken to be equal to that achieved in 2002 whereas that for pozzolana was assumed to be equal to the maximum volume contracted with the source.
- Technical constraints and non-negativity constraints were taken to be the same as mentioned under 3.7.6 and 3.7.7, respectively.
- Other than these constraints, factory gate prices for different products, material ratios in different products, material prices, energy tariffs, specific energy consumption, etc. were assumed at values prevalent during 2002.

3.8.2 Case 2

- All conditions in Case 1 except that stated below.
- A minimum demand restriction on OPC 33, at the production level attained in 2002, was also assumed.

3.8.3 Case 3

- All conditions in Case 2 except that stated below.
- Maximum and minimum demand restrictions on PPC and SRC changed to the sales levels achieved in 2002.

3.8.4 Case 4

- All conditions in Case 3 except that stated below.
- Maximum and minimum demand restrictions on OPC 33 and maximum demand restrictions on OPC 43 and OPC 53 removed and replaced by the actual sales made during 2002.

3.8.5 Case 5

- All conditions in Case 4 except those stated below.
- Maximum demand restriction on each product changed from market driven values to 10% more than the levels attained in 2002.
- Minimum demand restrictions on OPC 33, PPC and SRC same as mentioned in Cases 1 and 2.

3.8.6 Case 6

- All conditions in Case 5 except that stated below.
- Maximum demand restrictions for all products changed to 5% more than the levels attained in 2002.

3.8.7 Case 7

- All conditions in Case 1 except those stated below.
- No production of OPC 33 and SRC.
- Factory gate prices for different products, material ratios in different products, material prices, energy tariffs, specific energy consumption, etc. were assumed at values existing during 2002.
- Maximum and minimum demand restrictions on OPC 43, OPC 53 and PPC assumed to be the same as in Case 1.

3.8.8 Case 8

- All conditions in Case 7 except that stated below.
- Minimum demand restriction on OPC 53 changed to the level attained in 2002.

3.8.9 Case 9

- All conditions in Case 7 except that stated below.
- It was assumed that there was no demand for PPC.

3.9 Outcomes & Comments

These are shown in the table below:

Case	Contribution over 2002 (US $ mio) and Comments	
1	0.35	• Contributions can be increased by US $ 14.60 and 27.32 for every additional running hour available in Mill 2 and Mill 3, respectively.
2	0.27	• Contributions can be increased by US $ 14.60 and 27.32 for every additional hour available in Mill 2 and Mill 3, respectively. • Contribution can be increased by US $ 2.42 for every 1 ton of relaxation in the minimum demand for OPC 33.
3	0.03	• Contributions can be increased by US $ 11.19 and 27.32 for every additional hour available in Mill 2 and Mill 3, respectively. • Contribution can be increased by US $ 1.83 for every 1 ton of relaxation in the minimum demand for OPC 33.
4	0.02	• Contributions can be increased by US $ 11.19 and 27.32 for every additional hour available in Mill 2 and Mill 3, respectively.

Case	Contribution over 2002 (US $ mio) and Comments	
5	0.15	• Contributions can be increased by US $ 11.19 and 27.32 for every additional hour available in Mill 2 and Mill 3, respectively. • Contribution can be increased by US $ 1.83 for every 1 ton of relaxation in the minimum demand for OPC 33.
6	0.08	• Contributions can be increased by US $ 11.19 and 27.32 for every additional hour available in Mill 2 and Mill 3, respectively. • Contribution can be increased by US $ 1.83 for every 1 ton of relaxation in the minimum demand for OPC 33.
7	0.20	• Contributions can be increased by US $ 10.96 and 30.89 for every additional hour available in Mill 2 and Mill 3, respectively. • Contribution can be increased by US $ 0.04 for every 1 ton of increase in the maximum demand for OPC 43.
8	0.09	• Contributions can be increased by US $ 10.96 and 30.89 for every additional hour available in Mill 2 and Mill 3, respectively. • Contribution can be increased by US $ 0.04 for every 1 ton of increase in the maximum demand for OPC 43. • Contribution can be increased by US $ 0.53 for every 1 ton of decrease in the minimum demand for OPC 43.
9	~ 0	• Contributions can be increased by US $ 10.96 and 30.89 for every additional hour available in Mill 2 and Mill 3, respectively. • Contribution can be increased by US $ 0.57 for every 1 ton of increase in the maximum demand for OPC 43.

4.0 CONCLUSIONS

As demonstrated in the case, the advantage of such product planning exercises is that these provide a sensitive tool to analyze the implications of various scenarios on the company's contribution. In addition, through an analysis of, what in linear programming terminology are termed as "shadow prices", these also provide information on key items, modifications in which, result in an increase in contribution Thus, possible outputs could include:

- The ideal product mix that can maximise contribution
- Effects on clinker utilisation for different product mixes
- Decisions on what products need to be produced from which resources and for which markets
- Effects on the contribution of adding or reducing a product, its volumes or the resources it utilizes
- Effects of varying prices for different products
- Bottlenecks in production facilities that have an implication on contribution.

It is therefore strongly recommended that cement companies employ this method to re-assess the appropriateness, or otherwise, of their current product mix and use the conclusions, thus derived, for future planning. **A significant contribution to the bottom line is almost certainly assured**!