Transportation Models

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INTRODUCTION

In order to be able to discuss the use of transportation models from a practical point of view and at the same time avoid highly mathematical aspects of the techniques, a very simple example will be used to explain the underlying methodology. This paper is oriented towards the practical applications of transportation models rather than the techniques themselves.

TRANSPORTATION MODEL

Figures 1a and 1b illustrate the underlying methodology of the solution of transportation models.

FIGURE 1a

FIRST FEASIBLE SOLUTION

DESTINATIONS SOURCES	D1	D2	D3	D4	D5	TOTAL SURPLUSES
S1	—10 3	—20 5	—5 1	—9	—10	9
S2	—2	—10	—8 3	—30 1	—6	4
S3	—1	—20	—7	—10 5	—4 3	8
TOTAL DEFICIENCIES	3	5	4	6	3	21

TOTAL COST
= (3) (-10) + (5) (-20) + (1) (-5) + (3) (-8)
+ (1) (-30) + (5) (-10) + (3) (-4)
= —R250.

Fig. la lists sources S1, S2 and S3 as well as destinations D1, D2, D3, D4 and D5. In the example discussed at a later stage, the sources would be producing cement factories and the destinations would be various railway stations and sidings. In each square of the matrix is shown the cost of moving units from each source to each destination.

Under "TOTAL SURPLUSES", the allocatable outputs of the sources are listed. Under "TOTAL DEFICIENCIES", the requirements of the various destinations are given.

For simplicity, it has been assumed that the total capacities available are equal to the total market demand. Obviously, this need not have been the case. The matrix would then have been balanced making use of dummy sources or destinations. The ringed figures in Fig. la show the result of an actual allocation decision based on what George P. Dantzig calls the "Northwest Corner Rule". Starting in the top left hand corner of the matrix, destination requirements are allocated to source capacities. The nett result of this highly arbitrary decision is, as may be seen, R251. This is the amount of money involved in distributing 21 units from the various sources to the various destinations.

FIGURE 1b:

OPTIMUM FEASIBLE SOLUTION

DESTINATIONS SOURCES	D1	D2	D3	D4	D5	TOTAL
S1	—10	—20	—5 4	—9 5	—10	9
S2	—2	—10 4	—8	—30	—6	4
S3	—1 3	—20 1	—7	—10 1	—4 3	8
TOTAL	3	5	4	6	3	21

TOTAL COST = R150

In fig. 1b, the optimum solution is shown. It may be seen that the transport costs have been reduced from R251 to R150.

As mentioned in the introduction, it is not proposed to discuss the linear programming technique used to arrive at the optimum solution.

Rather than this, the author proposed to tackle what is often a far more difficult problem, namely the use of this technique in optimising the profits of a real company.

APPLICATIONS IN THE CEMENT INDUSTRY

In an industry such as the Cement Industry, where transport is a major cost factor and huge tonnages must be moved through great distances, transportation considerations become critical. The two obvious avenues of usage are:

a. A transportation model can be used as the major technique in locating new factory sites and sizing the factories.
b. A transportation model can be used to control marketing of cement so that distribution is at its most profitable.

EXPANSION OF PRODUCTION FACILITIES

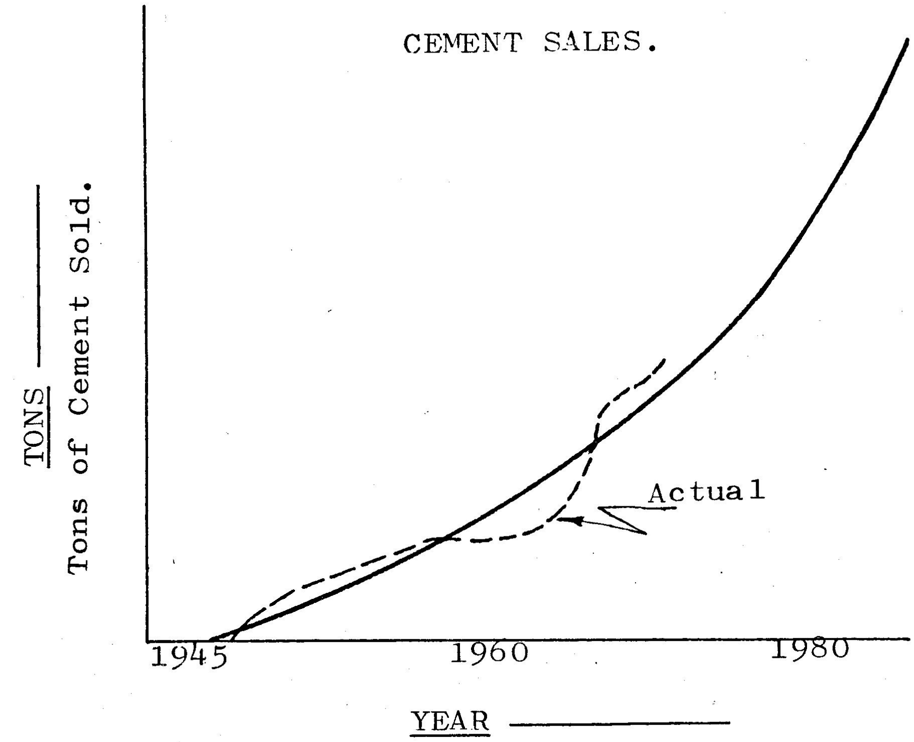
In order to illustrate the use of transportation models in the decisions involved in the expansion of production facilities, it is probably best to start by enumerating the steps used in overall expansion decisions. These are:

1. Forecast the market to a point where whatever facilities have been planned (in previous long range plans) will be fully utilised.
2. Execute transportation models on the projection without expanding the sources.
3. Increase the output of each of the sources and determine increased earnings.
4. Discount these earnings against cost of the expansion.
5. Attempt to find an optimum size for the expansion.

FORECAST

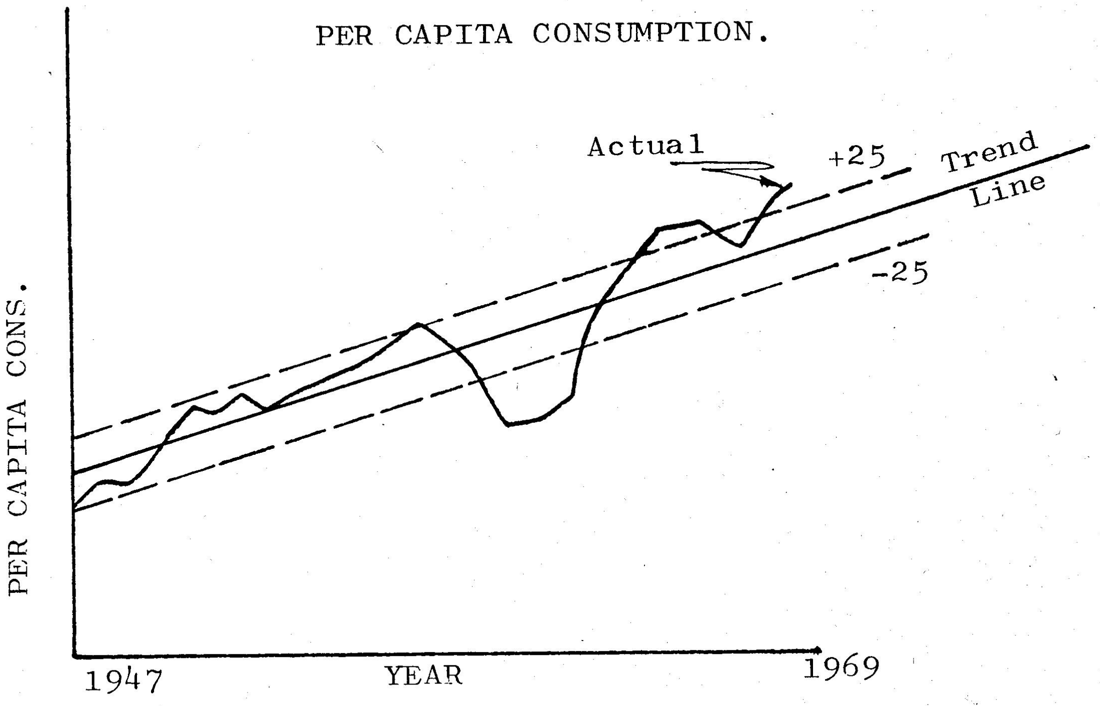
To carry out an exercise of this nature, it is necessary to attempt to look into the future and obtain, as best one can, a twenty year market projection. This will form the basis of the demands in the transportation model. Scrutiny of the history of the cement market shows an untidy exponential curve as shown in Fig. 2.

FIGURE 2:



Based on per capita cement consumption figures, a straight line fit may be obtained which can then be projected into the future, as shown in Fig. 3.

FIGURE 3:

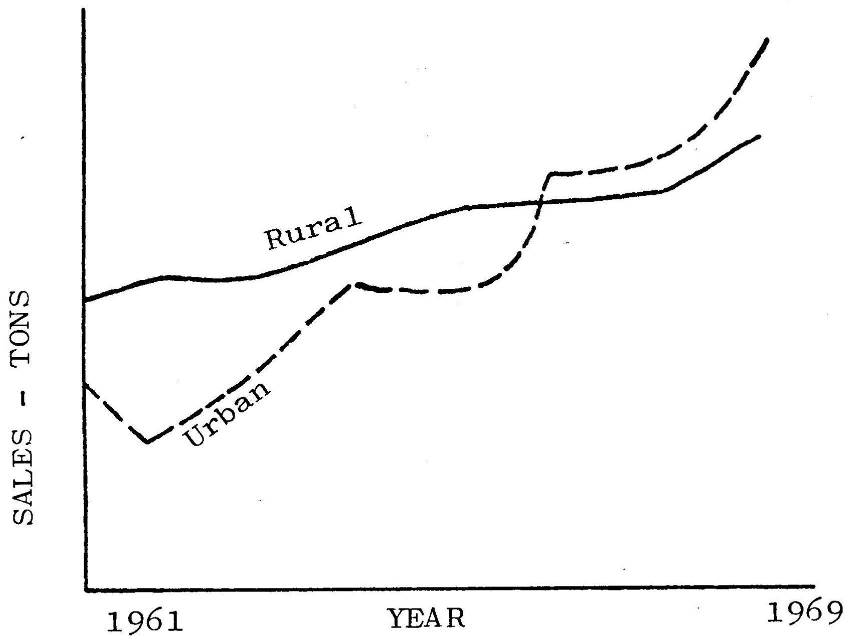


Continuous projection of this line into the future is hazardous, however, owing to the effect of saturation economics and heterogeneous growth factors. As the demand for cement is increasing very rapidly in this country at the moment, it is inevitable that the machinery of saturation will eventually operate. Saturation economics postulates that an exponentially increasing curve eventually flattens and finally declines. In order to try to take account of this in the South African economy, a study of the per capita cement consumption and gross domestic products of various other countries is made. These analyses have shown that the turning point will occur around thirty years from now in this country. It therefore appears to be fairly safe to project the straight line for a further twenty years at least. One complication which occured, is the fact that actual per capita consumption has broken through the two standard deviation probability limits based on the straight line projection. This would indicate that this method is not reliable enough for the purpose of accurate forecasting of the cement market. In order to increase the accuracy of the method, it is necessary to seek leading indicators.

The effects of various indicators such as the Gross National Product, Gross Domestic Product, the Bank Rate etc., are used to predict deviations of the per capita cement consumption from the predicted straight line. The use of multiple regressions allows any number of these factors to be taken into account.

Regarding heterogeneous growth, the history of cement consumption in an urban and a rural environment is shown on Fig. 4.

FIGURE 4:



In general, an increase in consumption in a rural area is slow and seems to be led by the Gross National Product by about two years. On the other hand, an urban pattern shows fast growth which slows down from time to time as labour, money and other constraints are reached. If these constraints are not taken into account in forecasting, however, the resultant transportation models may give indifferent results.

TRANSPORTATION MODEL

The demands from a large number of stations and sidings are fed into the transportation model. These demands obviously reflect a projection of the future which may either be based on a projection for each station at a constant, country-wide percentage growth or on districts, using an heterogeneous growth. In practice, it is found that the use of both alternatives is advisable.

Of course, any necessary constraints must be introduced. One of these is the fact that certain customers may require deliveries from specific factories.

The output from the transportation model is voluminous and may contain mistakes. The end results are almost meaningless unless one pauses and leavens the computation with a little skepticism and cross checking.

Having established that the basic input data is correct, it can be used for expansion calculations. Capital expenditure estimates for various capacity increases are now required and on successive runs, the constraints of each source or factory are increased, and by subtracting the earnings from the first or unexpanded run, a set of year by year earnings is obtained for the various expansions considered.

Once again, when it is ascertained that one set of earnings is higher than another, it is necessary to pause and attempt to ascertain why this is so. Blind acceptance of computer output has been the downfall of many a planner. A further point that should be borne in mind is that it is wise to use more than one forecasting method when determining demands. Expressed in relatively simple terms, the method suggested above appears as follows:-

$$[\sum Pv(M_2 - F) - \sum PvM_1)(1 - d) - (M_c - PvT)$$

M_1 are the Marginal Incomes on the unexpanded factories obtained by a succession of transportation models.

M_2 are as above but with one of the sources expanded.

F are the additional fixed costs incurred.
M_c is the Capital cost of the Expansion.

T are tax allowances.

Pv is Present value.

d= tax on profits.

The optimum expansion decision will be given when the above expression is at maximum.

The method briefly described above is equally applicable to the building of a new factory at a new location or to expanding an existing factory.

A difficult factor which arises is the determination of the size of the expansion. When the location, (or factory for expansion) has been decided upon, the effects of variations in size should be optimised. A moment's consideration will show that there are great weaknesses involved — mainly because of the enormous size of the calculation. A calculation of this size could easily lead to incorrect decisions if each step is not subjected to careful analysis. It should also be borne in mind that expansions previously regarded as uneconimical would improve if varied in size — once again a certain amount of logical analysis of the results obtained is necessary.

Finally, it is vitally necessary, however distasteful it may be, to audit the results once a decision has been taken to go ahead. The estimates which have been made in the process of planning are disproved to a greater or lesser extent by auditing the actual results obtained after the execution of the plan. Obviously, a corporate planner can only increase his efficiency if he measures his plans against reality and attempts to explain the variances. The information so obtained will be invaluable in increasing the reliability of planning techniques.

TRANSPORTATION MODELS IN MARKETING

Obviously, a transportation model may be executed using present capacities (sources) and markets (demands).

Let us assume that the results of such a transportation model, when compared with actual sales distribution costs, show a large variance and therefore indicate inefficient distribution. It would be naive to imagine that producing these results and simply showing them to those people concerned with distribution is all that will be required. Once results are obtained, the first requirement would be to see whether there are reasons for distributing cement in a particular manner. Obviously, customer preferences will play a part here. It is inherent in the results obtained from using a transportation model that, in certain areas, customers will be supplied from one factory in June and another in July. Where that customer is erecting a large structure, a change in cement colour could be disastrous. As the colour of cement definitely varies from factory to factory, it will be necessary to supply this customer from a single source.

A further constraint is the fact that a customer may prefer to be supplied from an area with the shortest delivery distance in order to ensure a continuous supply of trucks, rather than risk delays due to the effect of truck bunching which takes place over longer distances. The shortest delivery distance may not necessarily be the most economical traffic distance.

In cases like those described above, these factors should be built into the model as constraints.

Normally a formidable list of misdirected traffic is obtained by comparing the transportation model results against actual distribution figures. Often these may be reduced to a relatively small number of destinations. This fact obviously reduces the work considerably as each case can be examined on its merits.

It is desirable to introduce a "distribution variance" into the budgetting system so that constructive plans may be made to reduce it.

GENERAL REMARKS REGARDING OPERATIONS RESEARCH

It will have been noticed that the authors, in discussing transportation models have refrained from comparing techniques or suggesting any modifications to existing techniques. This whole paper has been confined to a use of a known technique. It is the authors' belief that the recognition of fields of application, the creation of realistic models and the integration of results into a corporate picture is far more important than the investigation of the nature of the technique.

An analogy with the medical profession may not be out of place. Imagine a doctor in general practice who comes across a patient suffering from a new disease. Should the doctor immediately commence research on this disease at the expense of the other patients or should he hand this case over to a specialist? Many exponents of operations research insist that once a technique has been discovered and put into practice, its further development, and investigation of its applications, fall outside of the scope of operations research. On the other hand, if it is required to secure acceptance of the field, the author feels that a great deal more attention should be given to the application of the techniques as against their invention or discovery.

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