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BUFFER STORAGE LOCATION UNDER ECONOMIES OF SCALE*

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Recently, storage of foodgrains has been receiving a wider attention in India, but very limited work is available in this field [2], [5] and [9]‡.[1] Even there, attention was mainly confined to the estimation of the size of the buffer and its storage requirements—either at the all-India level or at the State level—and the financial implications of operating these stocks—again at all-India level. But no work is done, specifically, concentrating on the storage cost aspect, pinpointing the locations of these stocks and the size of the storage in which they should be kept. There is a strong need to plan the locations and the capacity of storage at the district level before implementing a storage construction programme. If not, the losses—both monetary and otherwise—arising out of *mislocations*, *uneconomical sizes*, and lack of co-ordination may be unexpectedly high and at times it may even be profitable to shut down some of the existing godowns and open new ones.

An attempt is made in this paper to seek (*a*) the *optimum locations for* storage of buffer stocks of rice and wheat, (*b*) the *optimum number of storages* in each location, and (*c*) *the most economical size of storage* which together minimize (*i*) the construction cost, (*ii*) the storage cost and (*iii*) the shipment cost. A simple methodology which is particularly suitable for locating buffer storage, with the objective just mentioned, is evolved and applied to the Indian context.

COMPARISON WITH A 'SOURCES OF SUPPLY LOCATION' PROBLEM

This is mainly a location problem. Location of sources of supply—either the manufacturing plants or distributing warehouses or both—is a much discussed field in the operations research literature [1], [4], [6] and [8]. Setting up grain godowns geographically and estimating the storage requirements in each location, taking into account the supply and demand conditions, transport bottlenecks and other factors affecting storage, can also be viewed as a similar problem. In brief, the problem is to minimize simul-

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‡ Please see list of references at the end of this article.

1. See, particularly Prof. M. L. Dantwala, Summary of Discussion at the Seminar on Foodgrains Buffer Stocks, which was published earlier in *Economic and Political Weekly*, Vol. IV, No. 13 (Review of Agriculture), March 29, 1969.

taneously (*a*) the shipment cost incurred in meeting the public distribution requirements and (*b*) the storage cost incurred in storing the grain, which are affected by location and capacity of grain storage respectively.

An increase in the total storage capacity, particularly by opening godowns in new locations, reduces the number of kilometres a tonne of grain has to travel on the average and hence reduces the shipment bill, but increases the storage cost, and vice versa. The question of interest is : What is the optimum number of storages which strikes a balance between the two costs? (see Figure 1).

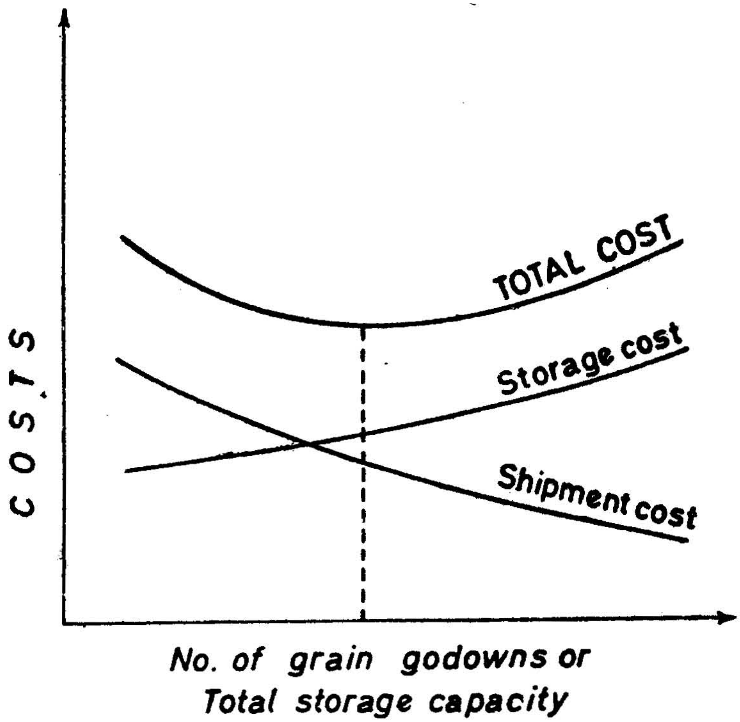


Figure 1—Unit Costs

There is another way of increasing the total storage capacity—by constructing larger storages without increasing the total number of storages. In fact, the problem facing the authorities of a storage construction programme is to decide whether to construct larger storages with higher economies of scale but possibly with lesser capacity utilization or to construct smaller storages with lower economies of scale but possibly with higher capacity utilization.

Often, in such situation, an evaluation of the relative advantages in terms of investment and annual costs, of one storage construction programme with a particular storage size over another with a different storage size, would be helpful in deciding the preference of one programme over the other. For example, confining our attention to only two storage sizes, one with a capacity of 2,500 tonnes and the other with a capacity of 5,000 tonnes, the question arises : which of the two storages should be taken as the *economical size* in which stocks in each location should be kept ?

Cost Minimization and Other Objectives

So far we have been stressing on the cost minimization objective. But, it need not be the sole criterion in determining the location and capacity of grain storage. In fact several objectives have to be kept in view. One such objective is that wherever these locations and whatever their capacities, grain should be readily available for consuming centres within a short notice. This objective is of particular interest for us since this exercise is primarily concerned with buffer stocks, *i.e.*, anti-speculative governmental stocks.[2] The objective just outlined, therefore, suggests locations in favour of deficit districts. Another important objective, for the agency operating these stocks, is that the total cost involved in the entire process of procurement, handling and shipment of grain should be minimum. On this consideration storage capacity should be located near surplus districts. Similarly, the agency constructing the storages is interested in creating enough storage facilities with minimum investment possible. Such an agency can be expected to be neutral in deciding the storage location between surplus and deficit districts provided there is no variation in storage cost from location to location. A third objective may be the optimum usage of the existing storage capacity. According to this criterion, it is not advisable to create additional storage facilities at places where the turnover of grain is more frequent but the quantum of procurement and distribution is low. This is particularly useful in suggesting the requirements for the pipeline storage.

Thus, one could arrive at a set of advisable locations and capacities of storage depending on the objective one has in mind based on some probabilistic considerations and past experience. Alternatively, some programming techniques can be used towards the same end considering the above-mentioned objectives. A more realistic approach would be to make use of both by superimposing some practical considerations on the solution obtained from the model.[3] In the present paper attention is concentrated on the third kind of approach keeping in view the second objective mentioned earlier.

2. Grain can be regarded as held with three different motives : (*a*) transactionary motive, (*b*) precautionary motive, and (*c*) speculative motive. Stocks held by the Government as an anti-speculative measure are termed as buffer and stocks held with a precautionary motive in anticipation of a bad year are termed as reserve stocks. However, due to their close substitutability buffer stocks and reserve stocks cannot be labelled separately. In the present paper buffer stocks include reserve stock also. We are concentrating only on public sector storage.

3. What we mean by 'superimposing practical considerations' can be understood as we proceed further. But as we do not wish to withhold the reader till that time, we anticipate the future discussion and explain it in brief.

The model gives a solution based only on the information which was fed into it. If some very essential extraneous information cannot be incorporated into the model either because of the computational difficulties or because of the qualitative nature, the information should not be totally ignored but at some stage or other the model should take that into consideration. This could be better understood by looking at the flow chart and footnote 11.

Before going into the actual formulation of the model, it is necessary to see that the model represents the real situation to the extent possible. It is appropriate, therefore, to identify the factors affecting buffer storage. Clearly, pipeline stocks have to be located both in deficit and surplus districts since they are required in daily transactions and their storage requirements have to be worked out taking into account particularly the distribution requirements.[4] Buffer storage, on the other hand, has to be determined, apart from climatic conditions and needs of public distribution on (*a*) the procurement potential, (*b*) the availability of transport and (*c*) the command area of the location. If one of the considerations governing the buffer stocks is to minimize the cost of procurement, locations have to be near procurement centres. In addition if it is intended to minimize the cost of shipment also locations have to be among the surplus districts in the following way : After meeting the public distribution requirements of the deficit districts in the country as a whole some of the surplus districts can still maintain some stocks. These stocks should give us an idea of both as to the location and capacity of buffer storage.

THE MODEL

We now proceed to represent our formal notions about the problem in a clear way with the help of the following notation :

		Deficit districts		Stocks	Disposable procurement
		1	2 ... n	n+1	
Surplus districts	1				S_1
	2				S_2
	.				.
	.				.
	.				.
	m				S_m
Distribution requirements		D_1	$D_2 \dots D_n$	D_{n+1}	

where m = number of surplus districts,

n = number of deficit districts,

S_i = disposable procurement in the ith surplus district (*i.e.*, procurement—public distribution requirements in the ith surplus district),

D_j = deficit in the jth deficit district (*i.e.*, public distribution requirements—procurement in the jth deficit district).

4. In the present paper we are not going into the estimation of storage requirements for pipeline storage, mainly because such capacity should be there in almost every district to keep the public distribution system going. Hence the problem of locating pipeline storage does not arise. In estimating the capacity requirements for this type of storage in each district the following identity may be made use of:

$$C = BT$$

where C is the distribution requirements for the year within a district, B the required capacity to be determined for pipeline storage and T the number of times grain rotated in a year.

Since the procurement, on the aggregate, is expected to be in excess of the public distribution requirements by the end of the planning horizon, *i.e.*, by the end of 1973-74, to convert the problem into a standard transportation problem, a (n + 1)the fictitious deficit district is imagined.[5] This fictitious demand point could be interpreted as stocks. Any surplus district sending some grain to this fictitious centre means that particular district is keeping that much stock. The shipment cost associated with this (n + 1)th district is taken as zero since no shipment is involved in that case. But there is storage cost associated with these stocks. The problem is to minimize the sum of shipment and storage costs. In order to state the objective function mathematically, we need the following four more notations :

X_{ij} = tonnes of grain to be shipped from the ith surplus district to the jth deficit district ($i = 1, 2, \ldots m$; $j = 1, 2, \ldots\ldots n+1$),

c_{ij} = cost of shipping one tonne of grains from the ith surplus district to the jth deficit district,

Q_k = storage of the kth type, $k = 1, 2, \ldots\ldots, K$

f_k = storage cost function for the kth type of storage, which we assume to be same for all locations.[6]

Now, the objective is to find those values of the decision variables X_{ij}'s (which are $m \times \overline{n+1}$) and Q_k (which is just one) which minimize the following function :

$$\sum_{i=1}^{m} \sum_{j=1}^{n+1} C_{ij} \; X_{ij} + \sum_{i=1}^{m} f_k \; (X_{i\,n+1}) \;/Q_k \qquad \ldots \quad \ldots \; (1)$$

The second term indicates the total storage cost incurred in storing stocks X_{in+1} in each location, i, in the kth type of storage Q_k.

Two important sets of constraints have to be imposed on the policy variables X_{ij} to make the exercise a meaningful one.

$$\sum_{i=1}^{m} X_{ij} = D_j \quad j = 1, 2, \ldots, n+1 \qquad \ldots \quad \ldots \; (2)$$

$$\sum_{j=1}^{n+1} X_{ij} = S_i \quad i = 1, 2, \ldots, m \qquad \ldots \quad \ldots \; (3)$$

The first constraint requires that the total volume of grain received by any deficit district from the surplus districts should match the distribution requirements of the district. The second one states that the total quantity

5. It is estimated, in consultation with State Governments, that in 1973-74 the excess of procurement over distribution will be about 3.2 million tonnes (rice and wheat).

6. As shall be seen later on, the storage cost is composed of several components of which cost of land is one. If the land rates vary from location to location so does the storage cost. This is one possible source of variation in storage cost. Another source of variation may be the labour charges which vary from region to region. However, for the sake of simplicity, we are assuming in the present paper that the storage cost function is the same for all locations.

of grain catered by any surplus district to deficit districts plus its own retentions as stocks should be equal to the disposable procurement of that surplus district.

It may be of some interest to note the basic differences in the formulation of a general location of source of supply problem (*e.g.*, see [8]) and the present one. In the former case there is no limit on the supply side at any location, *i.e.*, there are no capacity restrictions, whereas in the latter case there is a limit both on the quantity of procurement and the size of storage at each location. Secondly, in the former case, there is a proportionate manufacturing or warehousing cost, C_r, incurred in meeting the demand. In the present model there is no such analogous storage cost component since we are assuming that grain is directly shipped, after purchase, from the surplus districts to the deficit districts without storing it. Thirdly, instead of the second set of decision variables y_i^s in the former case, we have a single decision variable Q_k^* — *i.e.*, only one Q_k $(k = 1, 2, \ldots K)$ has to be determined which minimizes the total storage cost.

Non-linearities and Computational Difficulties

Clearly the objective function (1) is separable since $C_{in+1} = 0$ for every i and is sum of two components—shipment cost and storage cost. In general these two costs, owing to the economies of scale operating on them, pose computational problems. Baumol [1] concentrated on the non-linearities in the shipment cost and Manne [8] considered the economies of scale operating with the plant size.

In the present paper, there is no problem with shipment cost since all the shipment is assumed to be by rail and there is no fixed cost component. The freight rate per tonne charged by the railways is a step function of distance but not of volume of grain. Hence the shipment cost matrix can be easily computed. Also, if there is evidence to assume that there is little or no variation in storage cost from location to location and that it varies with the size of the storage, then it is sufficient to concentrate on minimizing the shipment cost only. An exercise on these lines was carried out earlier [10].

However, in practice, in most of the cases the storage cost will be either a linear function of the volume stored or a strictly concave function (see Figure 2). In the present case it is of the former type.[7] In either case, linear programming techniques cannot be directly applied to solve the objective function (1). Some algorithms [3] and [13] and heuristic methods [4] and [7] were suggested by some authors to overcome this difficulty.

7. This assumption presumes the storage cost function to be linear for each storage size considered of the form

$$f(X) \left.\begin{matrix} \\ \end{matrix}\right\} = \begin{matrix} a + bX & \text{if } X \neq 0 \\ 0 & \text{if } X = 0 \end{matrix}$$

where a is the construction cost which is different for different storage types and b is the proportionate storage cost component.

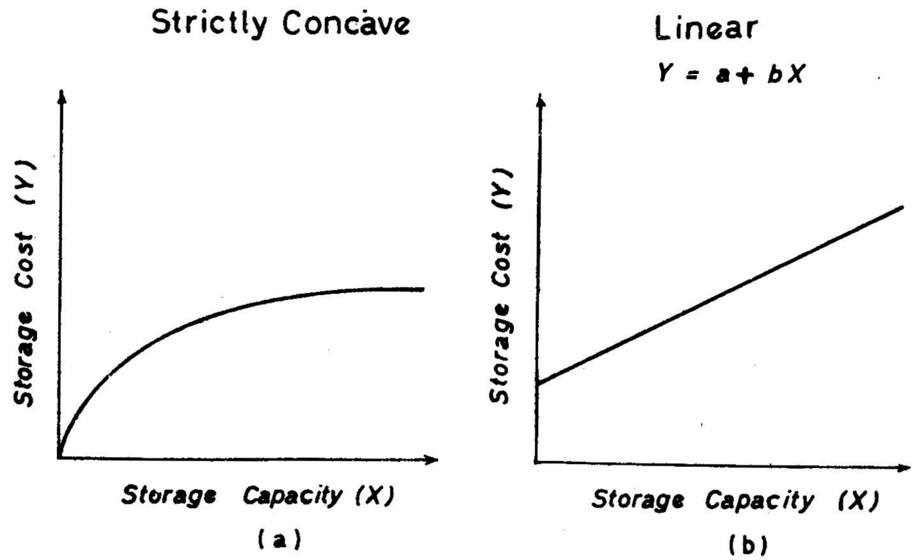


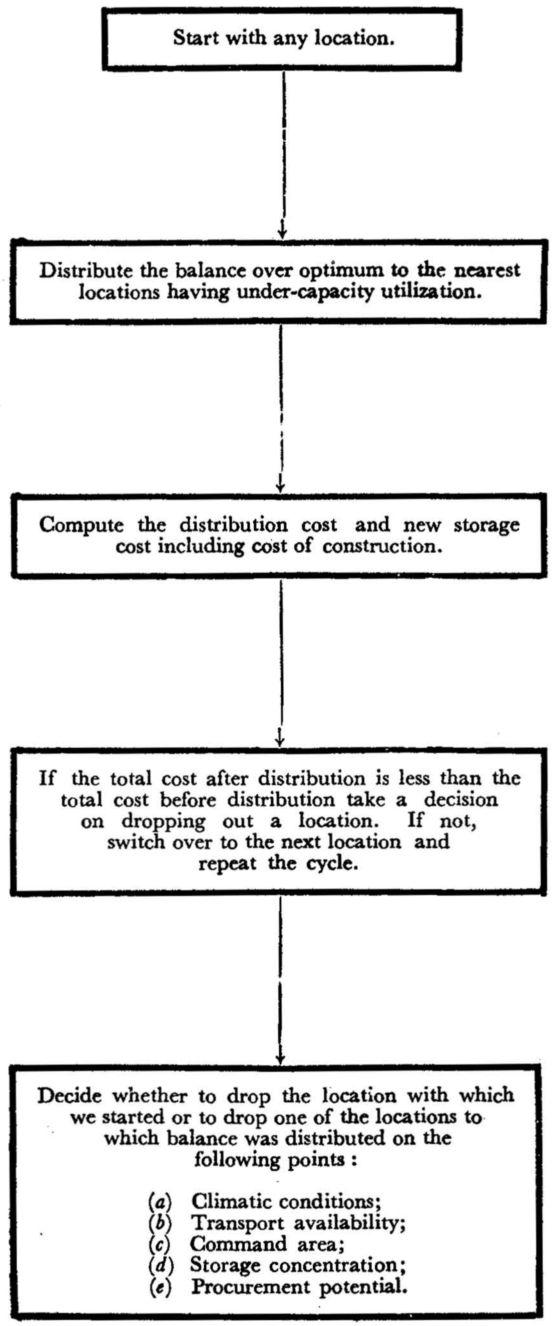
Figure 2—Storage Cost Functions

HEURISTIC APPROACH

Here, a simple heuristic method is used to solve the objective function (1). First the transportation model with surplus districts as origins and deficit districts as destinations is solved to get all the potential locations. In the second stage, for each type of storage considered, the location pattern obtained in the first stage is modified in such a way that all the storages in the new location pattern have full capacity utilization to the extent possible. This could be done by transforming the balances over optimum (which is a multiple of the capacity of the storage considered) from one location to another. The criterion which justifies the transfer of stock is that the profit by this transfer should more than off-set the loss. In this process some locations will get eliminated and the storages in the remaining locations will have full capacity utilization. This procedure is similar to the '*drop*' approach used in a warehouse location problem. The same process is repeated for each storage size. The computational procedure is indicated in the flow chart. That particular size for which the sum of (*a*) construction cost, (*b*) storage cost and (*c*) shipment cost incurred in transferring the balances over optimum from one location to another is a minimum, is regarded as the optimum size of the storage in which stocks in each location should be kept.

The advantage of this method lies in its computational simplicity. Once, the transportation model is solved on a computer and the storage cost functions are estimated for different storage types, the rest of the work could be done even with a desk calculator.

FLOW CHART


Start with any location.
Distribute the balance over optimum to the nearest locations having under-capacity utilization.
Compute the distribution cost and new storage cost including cost of construction.
If the total cost after distribution is less than the total cost before distribution take a decision on dropping out a location. If not, switch over to the next location and repeat the cycle.
Decide whether to drop the location with which we started or to drop one of the locations to which balance was distributed on the following points :
(a) Climatic conditions;
(b) Transport availability;
(c) Command area;
(d) Storage concentration;
(e) Procurement potential.

Storage Costs

A crucial task of this paper is the estimation of storage cost behaviour for different storage sizes, which is rather an engineer's concern.[8] Many technical specifications have to be observed in the construction of a grain godown—the galleries to be left between the grain stacks and the walls (in general 3′ wide), between stack and stack (in general 2′ wide), the platform to be left on each side of the godown (10′ wide in general) and the land that must be left on each side of the godown (50′ wide in general) to permit a railway siding on the one side and movement of trucks on the other.

Even though, theoretically the size and hence the capacity of a godown can be expanded, keeping the above specifications in mind, there are some reasons—economic and technical—against doing so. For example, there are serious diseconomies in increasing the height of a godown. A godown which takes 16 bags-heightwise is already becoming quite expensive; for beyond this height labour will either refuse to climb or will charge sharply rising rates per bag. Also, from the construction point of view, the valley gutter for drainage, supporting pillars and ventilators pose serious problems in expanding the size of a storage.

For the above reasons, in the present paper, the estimate of the storage cost behaviour of godowns other than those prevailing in India at present is not attempted. Mainly there are three fairly extensively used sizes : The first is a conventional bagged storage of length 427′ and width 71′ 1½″ (hereafter known as Type I). The second is another bagged conventional and vastly prevalent variety with length 405′ and breadth 45′ (hereafter known as Type II). The third is a R.C.C. flat roofed godown used in some parts of the country, *e.g.*, Andhra Pradesh, with length 454′ and width 80′ 3″ (hereafter known as Type III). We consider below in detail each component of the storage cost for each of these storage types.

Construction Cost

Construction cost is a fixed cost and in order to add all the cost components to arrive at the total cost of a storage, it is necessary to convert this fixed cost also into some kind of annuity. A logical way would be to consider the annual depreciation and interest rates on the cost of construction. The interest on cost of construction was computed at the rate of 5½ per cent per annum which was the rate of interest charged by the government from the Central Warehousing Corporation (CWC)/the Food Corporation of India (FCI) on loans. Also an usual rate of 2½ per cent per annum is taken as the depreciation on cost of construction. These two components are presented in columns 3 and 4 of Table I which gives an integrated view of storage costs.

8. In the present paper the behaviour of storage cost was examined for conventional godowns of horizontal type only. Silos are not considered here. Silos have to be constructed at places where land and labour are dear and there is quick turnover of grain. Ports are ideal location for this type of storage.

TABLE I—AN INTEGRATED VIEW OF STORAGE COSTS OF DIFFERENT STORAGE TYPES

(*Rupees per tonne*)

Storage type (1)	Volume of grain that can be stored (tonnes) (2)	Interest on cost of construction (3)	Depreciation on cost of construction (4)	Operational labour cost (5)	Aeration and fumigation cost (6)	Total storage cost (7)
Type I ..	5,750	6·03	2·74	1·30	2·80	12·87
Type II ..	2,500	9·66	4·39	0·95	2·80	17·80
Type III ..	5,000	8·80	4·00	1·30	2·80	16·90

Grain Maintenance or Aeration and Fumigation Cost

This is an important aspect of operational costs of a godown. Our conclusion on this point is that fumigation, aeration and other grain maintenance costs increase only proportionately with an increase in godown capacity and that the average grain maintenance cost per tonne remains constant for all the three types of godowns considered here. The details of grain maintenance cost for a typical horizontal type of godown with 5,000 tonnes capacity are worked out and presented in Table II.

TABLE II—ANNUAL MAINTENANCE AND FUMIGATION COST FOR A 5,000 TONNE GODOWN

				Rs.
I.	Cost of labour			
	(*i*) for fumigation—5 persons employed at the rate of Rs. 3/- a day, working for 300 days		5 × 3 × 300	=4,500
	(*ii*) for spraying and pumping — 2 persons employed at the rate of Rs. 3/- a day, working for 300 days		2 × 3 × 300	=1,800
II.	Cost of one sprayer		350	=3,700
	Cost of Malathion ..	0·64 per tonne ..	0·64 × 5,000	
	Cost of Aluminium Phosphide	0·03 per tonne ..	0·03 × 5,000	
III.	Cost of two covers		2×2,000	4,000

Annual maintenance and fumigation cost per tonne $= \text{Rs.}\ \frac{14{,}000}{5{,}000} = \text{Rs.}\ 2{\cdot}80.$

Operational Labour Cost

As the dimensions and capacity of a godown increase the mean distance over which grain has to be carried from the railway siding (or the truck unloading point) to the stacks and from the stacks back to the loading point increases. This increase in mean distance has been worked out for the three different types of storage considered here. A schedule of rates per tonne generally charged by labour over varying loads for 90 kg. bag (which is about the largest size used in practice for manual operations) has been obtained.

Applying these rates to the mean distance estimated previously and doubling the resultant figure to provide for two operations—one from unloading point to the stack and the other from the stack to the loading point—we obtain the labour bill for the total tonnage of the godown. Finally, by spreading the labour bill over the volume we obtain the labour cost per tonne. This is seen in column 5 of Table I.

Based on the above storage costs linear storage cost functions are estimated for each storage type and are presented in Table III. Each function consists of a constant term (fixed or construction cost) and a proportionate storage cost component. From Table III one can easily infer that it is very expensive to construct storages of Type III since (*a*) it has a higher construction cost and (*b*) lesser capacity. Hence, in what follows, we will be concentrating on two types of storages only—Type I and Type II.

TABLE III—STORAGE COST FUNCTIONS FOR DIFFERENT STORAGE TYPES

Storage type	Storage cost function
Type I	630† + 12·87*
Type II	439 + 17·80*
Type III	800 + 16·90*

* is the volume stored.
† the first term in every function is in thousands.

Assumptions and Sources of Data

(1) The time horizon in view in the present exercise is the Fourth Plan period. The focus is on finding out what will be the storage requirements by the end of 1973-74.

(2) It is assumed that buffer stocks are built entirely out of domestic production and no imports are assumed.[9] The expected excess of procurement over distribution is taken into account in estimating the total buffer storage requirements.

(3) There are no restrictions imposed on grain movement from one zone to another.

(4) All the shipment is assumed to be by rail.

The public distribution requirements and procurement of rice and wheat in each district by 1973-74 are estimated in consultation with the State Governments. Flour mill requirements are also taken into account in estimating the total distribution requirements in each district. The cost of shipping a tonne

9. For building buffer stocks through imports see [12].

of grain (either rice or wheat) is obtained by applying the grain-freight schedule—charged by the railways, which is telescopic in nature—on the nearest rail route. A nine per cent surcharge levied by the railways is then added to the rates thus obtained. For some routes having no convenient transport facilities a penalty cost, depending on the severity of lack of transport facilities is assumed.

Various components of the storage cost like the cost of construction, including the cost of land, cost of aeriation and fumigation, cost of labour engaged in loading and unloading operations, are estimated in consultation with the CWC and the FCI.

Even though the cost of shipping a tonne of either rice or wheat is the same, the break-up of procurement and distribution requirements into rice and wheat separately is necessary in formulating the constraints 2 and 3. Otherwise, obviously, the exercise will not have any meaning. Hence two separate linear programming exercises—one for determining the stocks of rice and the other for determining the stocks of wheat—are carried out.

SOLUTION OF THE MODEL AND CONCLUSIONS

Again it may be of some interest to note the differences in the ways in which a solution to a plant location problem (see [8]) and to the present one are obtained. In the former case, first the decision variables y_i^s are set up at the levels 0 and 1 and the locations are obtained by choosing that particular combination of y_i^s for which the total cost is a minimum and then the x_{ij}^s are determined. In the present problem first the decision variables X_{ij}^s (particularly X_{in+1}^s) are determined to find out all the potential locations and then Q_k^*, the optimum storage size is determined.

The solutions of the transportation models for rice and wheat are worked out by the author [11] but not given here for the sake of space. The main results are summarised in Table IV which gives the total cost for each storage type with all potential locations and with programmed locations. It also shows the number of storages and locations in both the cases for both the storage types. From columns 8 and 9 of the same table, it is seen that for either type of storage, the programmed locations yield a much lower cost than all the potential locations. The saving in total cost is about Rs. 25.5 million for the storage of Type I and about Rs. 16 million for the storage of Type II.

The minimum cost of Rs. 470.86 million occurs corresponding to the programmed locations and the storage of Type I.[10] The location patterns corresponding to this combination and also for Type II have been presented in Table V.

10. For construction of new storage godowns for foodgrains, Fourth Plan provides as much as Rs. 730 million besides separate outlays on warehousing facilities.

TABLE IV—COMPARISON OF COSTS, NUMBER OF STORAGES AND NUMBER OF LOCATIONS BETWEEN ALL POTENTIAL LOCATIONS AND PROGRAMMED LOCATIONS FOR EACH STORAGE TYPE

(*costs in million rupees*)

Storage type	Construction cost		Annual cost		Shipment† cost		Total cost		Number of storages		Number of locations	
	All potential locations	Programmed locations	All potential locations	Programmed locations	All potential locations	Programmed locations	All potential locations	Programmed locations	Potential	Programmed	Potential	Programmed
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Type I	363.51	339.57	45.48	39.90	87.35	91.39	496.34	470.86	577	539	76	66
Type II	558.85	543.92	58.18	55.18	87.35	89.27	704.38	688.37	1,273	1,239	76	76

† Shipment cost, for each storage type, is greater in the case of programmed locations because some locations have to be dropped and grain has to be shipped from the dropped out locations to the rest.

TABLE V—ESTIMATED OPTIMAL LOCATIONS AND NUMBER OF STORAGES OF DIFFERENT TYPES FOR STORING BUFFER STOCKS OF RICE AND WHEAT BY THE END OF THE FOURTH PLAN

Location	Number of storages*	
	Type I	Type II
(1)	(2)	(3)
Agra	—	1
Aligarh	—	1
Alwar	3	6
Ambala	11	25
Amritsar	60	137
Bahraich	8	18
Balaghat	8	17
Banda	5	12
Barabanki	12	27
Bharatpur	3	8
Bijnore	3	8
Bolangir	5	12
Bhatinda	1	2
Budaun	3	8
Bundi	1	2
Chattarpur	2	4
Chittorgarh	1	3
Cuttack	—	1
Etah	9	19
Faizabad	—	1
Farrukkbad	5	13
Ganganaagar	4	9
Ganjam	2	4
Godavari, E	13	31
Godavari, W	42	96
Gorakhpur	1	2
Guna	3	6
Gurgaon	4	8
Gonda	8	18
Hamirpur	4	8
Harodoi	6	13
Hassan	—	1
Hoshangabad	1	2
Hoshiarpur	17	40
Jalaun	6	13
Jhalwar	1	2
Jhansi	5	10
Jind	7	16
Kanara	—	1
Kanpur	2	5
Kapurthala	2	4
Koraput	6	14
Kota	4	11
Krishna	8	19
Lakhimpur	1	3
Lucknow	2	5
Ludhiana	2	6
Manipur	12	27
Mathura	4	9
Meerut	6	14
Mirzapur	—	1
Morina	4	8
Muzaffarnagar	6	14
Nainital	18	42
Nowgong	2	6

(*Contd.*)

TABLE V—(*Concld.*)

Location (1)	Number of storages*	
	Type I (2)	Type II (3)
Patiala	54	122
Pilibhit	16	35
Rae Bareily	2	5
Raipur	26	60
Raisen	4	9
Rajgarh	1	2
Rampur	9	21
Rohtak	9	21
Rupar	12	28
Sagar	—	1
Sharanpur	14	32
Sambalpur	21	47
Sawaimadhopur	2	4
Shahjahanpur	10	22
Shivpuri	1	3
Sibsagar	6	13
Sidhi	—	1
Sitapur	4	9
Tikamgarh	4	8
Udaipur	—	1
Vidisha	1	2

* The locational pattern dictated by column 2 is optimal and that indicated by column 3 is sub-optimal and hence has to be discarded. Both the locational patterns are presented with a view to comparing the optimal and sub-optimal solutions.

What is really noteworthy is the substantial difference in total costs corresponding to the two programmed locations for each storage type. About Rs. 217.5 million could be saved by storing the grain in storages of Type I with a capacity of 5,750 tonnes rather than storing it in storage of Type II with a capacity of 2,500 tonnes. This huge difference in costs can be expected to have arisen from (*a*) the higher economies of scale operating with larger storage sizes and (*b*) the comparatively much lesser number of storages of Type I to store the given volume of grain. From column 11 in Table IV, it is seen that only 539 storage of Type I are required to store the excess of procurement over distribution whereas 1,239 storages of Type II are required for the same purpose. This leads to a drastic reduction in the construction cost.

In the light of the above discussion and findings of Table IV we draw the following conclusions :

(1) Before implementing any future storage construction programme it is always advantageous to plan the locations and sizes of storage on a least-cost basis. Unexpected huge losses can be avoided by doing so.

(2) It is a serious loss to store grain in storages of capacity of 2,500 tonnes.

(3) Any storage construction programme in 1973-74 may take into account the programmed locations given in Table V with a view to reducing the total cost of the programme.[11]

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11. As with any exercise involving future projections, the reliability of the solution given in Table V depends on the actual realisations of procurement, distribution requirements and the cost structure of storage and shipment in 1973-74. However, even if it is true that there is not going to be much difference between the expectations and the realisations, the solution could not be a final one. After all, programming is an aid but not a substitute for the experience and prudential wisdom of practical men. For example, from Table V it appears that some locations, (*e.g.*, Amritsar, West Godavari and Patiala) should have huge capacities according to the solution of the model. This need not be considered as an abnormal situation. These huge capacities may be distributed within the district or State or a part of the capacity may be transferred to the neighbouring State(s) based on some other considerations which are not discussed in this paper.