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MEASUREMENT OF ATTITUDES

by

M.J. Arul & Sasi Misra

W P : 158
May 1977

The main objective of the working paper series of IIMA is to help faculty members to test out their research findings at the pre-publication stage.

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MEASUREMENT OF ATTITUDES

M.J. Arul & Sasi Misra

From the discussion in Chapter -- on the nature of attitudes, we know that attitude is a hypothetical construct to represent certain underlying response tendencies. As hypothetical constructs, attitudes cannot be measured directly. Any attempt to assess them can only be inferential in nature: study those types of behaviour which are reasonably assumed to indicate the attitudes to be measured; quantify these indications so as to get an idea of how much the given individuals or groups differ in their psychological orientations toward a particular object or issue. The behaviours to be studied for the purpose may be those which occur in a natural setting or a simulated situation. Such behaviour may be verbal or performance. For example, a person talking about, say, prohibition when he is seated in a teastall over his usual cup of tea exhibits verbal behaviour in a natural setting. If you were to formally interview him on his views about prohibition, you would again have his verbal behaviour, but in an artificial environment. Observation of his visits to bars or drink sessions at home would provide data on his natural "performance" behaviour. If, on the other hand, he served as a subject in an experiment designed to study his behaviour, we would obtain performance data in a simulated setting.

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[1] The authors gratefully acknowledge the secretarial contributions of Mr P.R. Subramanian, Indian Institute of Management, Ahmedabad.

OPERATIONS RESEARCH
IN PLANNING FOR DHARAMPUR

by
NITIN R PATEL

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ABSTRACT

This paper describes experience with application of operations research techniques in planning infrastructure for the Dharampur taluka in Gujarat. The work done covers four principal areas:

1. Design of a road network
2. Location of service centres
3. Development of an inter-active computer program using computer graphics
4. Phasing of service centres

OPERATIONS RESEARCH IN PLANNING FOR DHARAMPUR

by

Nitin R. Patel

This paper describes the application of operations research techniques to a specific instance of regional planning. In addition to discussing the models used we also highlight some of our experiences in making these applications.

The opportunity to do the work described here arose in connection with a project aimed at drawing up a development plan for Dharampur taluka in South Gujarat*. The objective of the project was to produce an integrated plan of rural development aimed at the rural poor in the region. Dharampur has a population of 1,94,000 of whom 92.5% are tribals**. It is a large taluka extending over an area of 1650 sq. kms. of Valsad district. Approximately 83% of the land is 'dungar' (hilly). About 62% of the population resides in this hilly area while the balance is in the 'talat' (flat) area. Dharampur is

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* See 'Rural Development for the Rural Poor - Dharampur Project' Vols. I & II, CMA, IIMA, 1975-76.

** 1971 census figures

a very poor taluka. A survey conducted in 1976 revealed that 85% of the population lived below the poverty line (set at Rs 60 monthly per capita income) and that, on the average, a person does not have food to eat for 21 days in the year.

After detailed studies the project team identified the following factors as the major causes of poverty:

"(a) Poor base of resources under the control of individual families, this being characterised in undulating and to an extent rocky terrain, low water table, soil erosion and in limited farm sizes.

(b) Poor and to an extent degraded forests which occupy 43% of land and wherein 62% of the population live.

(c) Inadequate and to an extent inappropriate institutional (both official and non-official) efforts for development of the taluka.

(d) Sheer physical isolation of the community, particularly in the hilly areas."

To combat poverty an action plan for development was drawn up. Programmes were specified in a number of areas such as soil conservation, irrigation, agriculture, animal husbandry, forestry, cottage and forest-based industries, etc. An important part of the development plan was the setting up of "service centres" in locations dispersed over the taluka to provide minimal infrastructure, health and education facilities. These service centres would provide agricultural extension, primary schools, ashramshalas, public health centres, co-operative service societies, fair-price shops and post offices. In each service centre official functionaries responsible for infrastructure, health and education facilities were to be provided residential accommodation. The functionaries to be so located were:

Village level workers
Talatis
School teachers
Health centre workers
Co-operative secretaries
Post office functionaries

It had been observed that under the present situation the functionaries did not live near the villages where they were to work and their work places were scattered amongst several villages. These factors resulted in poor availability of functionaries to their client groups and made it difficult for the population to avail of their services. It was felt that by having a large number of functionaries (at least eight in each service centre) staying together in their area of service, the quality and quantity of service provided would improve substantially. Presently the chief reason that functionaries preferred to stay away from their work area was that there they had no opportunity for social interaction with their own "types" and also minimal facilities for education, health and communication with towns were not available. By providing accommodation in service centres these obstacles would be overcome.

The other equally important objective of setting up service centres was to provide all villages with reasonable access to economic, educational and health services. Thus it was decided that service centres should be dispersed over the taluka so as to provide development services to clusters of villages within a five mile radius of each centre (or at worst the walking time to a centre should be about $1\frac{1}{2}$ hours). To provide infrastructure for the agricultural, animal husbandry, forestry and other programmes it was also felt that all-weather pucca roads connecting the service centres to the State highways should be constructed. At present the entire 'dungar' area was virtually cut off during almost 6 months in the year. Thus the service centre idea gave concrete expression to the plan's attack on items (c) and (d) listed in the causes of poverty above.

In line with the objectives of the service centres an analysis was made to choose suitable locations. Some of the considerations in choosing a village were whether some of the required facilities were already existent, population, growth potential, proximity to highways, nature of adjoining areas and whether the village had a 'hat' (A 'hat' is a weekly market where tribals from nearby villages - 8 to 10 miles distant - visit for selling their produce and buying consumption items such as cloth). The analysis led to selection of 44 out of the 237 villages in the taluka for location of service centres. In addition, Dharampur, the largest town and the taluka headquarters, was already a full-fledged service centre. Figure I gives a map of Dharampur showing existing highways and the service centre locations.

Once the service centres were specified the next task was assessment of the costs involved. The construction of all the forty four service centres was estimated to cost Rs 55 lakhs. In order to estimate road costs, which were expected to be sizeable, the Public Works Department was approached. The rough estimate provided was that the cost would be about Rs 9 crores covering a length of 400 miles of all-weather roads. Since the total amount available from the Tribal Sub-Plan of the Government of Gujarat for the Five-Year Plan period was expected to be no more than 13 crores, it seemed that the road programme would leave only an inadequate sum for irrigation, soil conservation, agriculture, forestry and other projects. It was at this stage that the first attempt at applying operations research was made.

Specifically the problem was to find the minimum cost road network to connect the forty four service centres to the existing main highways. For this purpose a simple modification of the minimal spanning tree algorithm of Kruskal was employed. The only modification required was to introduce an artificial 45th node to represent the existing system of highways. The distance of this node to each of the 44 service centre nodes was the shortest distance of the service centre to the highway system. It is easy to see that this device would provide the optimal solution that was required. To translate shortest (Euclidean) distances between the nodes to costs it was found that a factor of 1.5 needed to be applied to shortest length to convert it to likely actual length for the kind of terrain existent in Dharampur taluka. The PWD uses this ratio in making its estimates for this region. In addition, the cost per mile of road was also supplied by the PWD. The cost was estimated at Rs 2.25 lakhs per mile of shortest distance for the type of road specified as under:

Type	:	Black-top metalled road
Land width	:	12 metres
Formation	:	6 metres
Paymouth (actual width)	:	3 metres
Cost	:	Rs 1.5 lakhs per mile of road
		material Rs 1.05 lakhs
		labour Rs 0.45 lakhs

The shortest-tree algorithm provided the optimal solution indicated in Figure I. The total cost of Rs 1.9 crores was substantially less than the original estimate of Rs 9 crores. In fact this amount was no more than that had been spent in the previous five years for road building in this region. Identification of the optimal network thus made it possible to employ the service centre strategy since a sufficient balance of funds was left over for the programmes in irrigation, agriculture, animal husbandry, forestry, etc.

After the plan was drawn up and discussed it was found that the Rs 55 lakhs required for construction of service centres would not be available in the five year period as suggested in the plan. Whereas the other elements of the plan, including the road programme, were assured of financial support, the sources that were to be tapped for the service centre construction costs were limited. The amount that the planners would have available for the next five years was estimated at around Rs 13 to 14 lakhs. Thus, although part of the objective of the service centres - namely opening up communications to villages - could be met, there was a need for reducing the number of service centres to be constructed in the next five years to be within the available budget.

A seminar was held with local leaders, voluntary workers, government officials and planners to debate this issue. Local leaders, the most vociferous of whom came from the 'talat' region, and some officials urged that service centres in the 'talat' region be given priority. One of their arguments was that these are more likely to be successful due to the better economic and educational standards of the populace there. They argued that tackling 'easy' areas first would provide initial success which would have an important demonstration effect for future service centres. On the other hand, others, principally voluntary workers, argued that the objective of the plan was to improve the conditions in the poorest parts of the taluka and so . remotely located service centres in the 'dungar' region should be taken up in the five year period. Ultimately, the planners decided that they should use an objective criterion for choice of the service centres which would lead to a balanced level of service to the entire region. The criterion they chose was to minimize the maximum distance of any village from a service centre subject to the budget not exceeding 14 lakhs. It was decided to employ an operations research model to make this choice since an exhaustive enumeration of all combinations was infeasible (the number of combinations of service centres is $2^{44} = 1.76 \times 10^{13}$).

One can formulate the problem as specified along the following lines:

<u>Problem (P)</u>

Minimize D

Subject to $\sum_{j=1}^{m} c_j x_j \leq B$

$$\min_{j \in x_j = 1} d_{ij} \leq D \qquad i = 1,2,\ldots n$$

$$x_j = 0 \text{ or } 1 \qquad j = 1,2,\ldots n$$

where m is the number of possible service centre locations (= 44)

n is the number of villages (= 237)

$$x_j = \begin{cases} 1 & \text{if service centre } j \text{ is chosen} \\ 0 & \text{otherwise} \end{cases}$$

B is the budget (Rs 14 lakhs)

c_j is the cost of constructing service centre j

d_{ij} is the distance between village i and centre j

D is the 'service level', i.e. the maximum distance of a village from one of the chosen service centres.

However, as formulated above, the problem is a difficult non-linear integer programming problem. Hence, the problem was recast as a series of parametric problems with D, the service level as the parameter.

For a given value of D it is possible to formulate the problem of choosing the centres with minimum total cost as a (linear) integer programming problem.

<u>Problem (Q)</u>

$$\text{Min} \quad \sum_{j=1}^{m} c_j x_j$$

$$\text{Subject to} \quad \sum_{j=1}^{m} a_{ij} x_j \geq 1 \qquad i = 1,2,\ldots n$$

$$x_j = 0 \text{ or } 1 \qquad j = 1,2,\ldots n$$

$$\text{where} \qquad a_{ij} = \begin{cases} 1 & \text{if } d_{ij} \leq D \\ 0 & \text{otherwise} \end{cases}$$

In our case the size of the problem is 273 rows by 44 columns. This is a large integer programming problem. However, the problem has the special structure of the set covering problem of integer programming. Powerful algorithms are available to solve the set-covering problem efficiently. We used an algorithm of Harvey Salkin to solve the above problem for ten values of D. The values of D chosen were 5, 5.5, 6, 6.5, 7, 8, 9 and 10 miles. To facilitate processing a matrix generator program was written to automatically generate the constraint matrix for any specified value of D. Solution times averaged around 30 seconds per problem on an IBM 360/44 machine.

The idea behind parametrizing on D is to generate a curve of total cost vs. D over a wide range of costs. Once such a curve is available, we can obtain the optimal solution for Problem (P) by finding the best value of D possible for the available budget from the graph and looking up the optimal solution in Problem (Q) for that value of D.

Table I gives details of costs of the centres and Table II gives the optimal budget and optimal solutions for different values of service level. These values are graphed in Figure II. From Table II we can see that a service level of 6 miles requires a budget of

Rs 13.9 lakhs. The optimal solution to Problem (P) was therefore taken to be the optimal solution to Problem (Q) with D = 6 miles.

One interesting point about the solution is that despite slashing the budget by 75% from Rs 55 lakhs to Rs 14 lakhs, the service level changed only 20% from 5 miles to 6 miles. The number of centres also dropped by 75% from 44 to 11. Expectations in the planning group had been that service would suffer much more drastically. The optimal solution balances in an equitable manner the demands made for 'talat' and 'dungar' locations : two centres are in the 'talat' region and nine centres are in the 'dungar' region. This is approximately in proportion to the total villages in each region since 41 villages are in the 'talat' region and 196 are in the 'dungar' region.

The second point to note is that for a service level of 5 miles, the optimal solution has a budget of Rs 23.3 lakhs. Thus, the service level can be maintained at 5 miles while dropping the budget by 58%, and the number of centres drops by 64% from 44 to 16. Of course, the full benefit of all 44 centres is greater since all village functionaries will be provided residence, but from the point of view of proximity of centres to villages it is no better than a solution that costs half as much.

An interactive program with video-display was developed. The purpose of the program was to facilitate understanding and acceptance by decision-makers of the optimal nature of the solution arrived at by integer programming. The program showed an outline of Dharampur taluka and the 44 potential sites for service centres on the video screen. Using a teletype the user could enter the required service level and identify successively his choices for service centres. The video display drew circles with radius equal to the service level around each choice. It also flashed the total cost of the chosen centres. Thus interactively the user could explore the implications of various alternative choices of service centres. The program could also assist in investigation of near optimal solutions should this prove to be useful.

Once the service centre choices for the five year plan period were determined, the next problem that needed resolution was the phasing of these centres on an annual basis. Here again the problem was that each group in the taluka wanted the centres in its area of interest to be constructed first. Once more an objective criterion was sought and established. In this case the problem was balancing expenditures over time as well as balancing service levels over space. The criterion chosen was to provide the best time-average service level subject to the constraint that the expenditure in each year be within 10% of the average annual expenditure namely Rs 2.77 lakhs.

The technique used to solve the problem was dynamic programming. States were defined by an 11-dimensional Boolean vector where a 1 in the i^{th} element meant that the i^{th} service centre is already built and a 0 means that it is yet to be built. By using the budget constraints all states possible at the end of t years with t = 1,2,3,4 were enumerated. The unique states for years 0 and 5 were (0,0,0,....0) and (1,1,1,....1) respectively. At the same time the service level for each state was computed. The problem is then to find a series of transitions from t = 0 to t = 5 which minimizes total (and hence average) service level without violating the 10% expenditure constraints.

Since the number of possible states was large (788) a procedure was devised to prune the network before computing the optimal path. This was done by using judgment and heuristics to identify a 'good' feasible path. This path had a total service level of 52.8 miles or an annual average service level of 10.56 miles.

Let us define sets S_1, S_2, S_3, S_4, S_5 where S_j is the set of all possible states in year j and let m_j be the minimum possible service level for year j, i.e. m_j is the minimum of the service levels of all states belonging to S_j.

Then for any state $s_j \in S_j$ if the service level is l_j, the total service level for a path passing through s_j must be greater than $l_j + \sum_{i \neq j} m_i$. This gives a lower bound L which can be compared with the total service level of the 'good' path and if $L \geq 52.8$, the state

s_j can be deleted from S_j. This procedure enabled reduction of the number of states from 788 to 168.

After reduction, a dynamic programming routine was used to compute the optimal solution which is presented in the table below:

PHASING : OPTIMAL SOLUTION
Optimal solution for 6 miles consisted in setting up Centre Nos. - 4,5,11,15,18,24,27,30,31,34,40
(Total Service Level = 51.8 miles
Annual Average Service Level = 10.36 miles)

	Year 1	2	3	4	5
Centres to be built	11,15,27	5,31	30,40	4,18	24,34
Service Level (Miles)	17.5	12.5	8.8	7.0	6.0
Cost (Rs 000's)	275	255	285	285	285

TABLE I

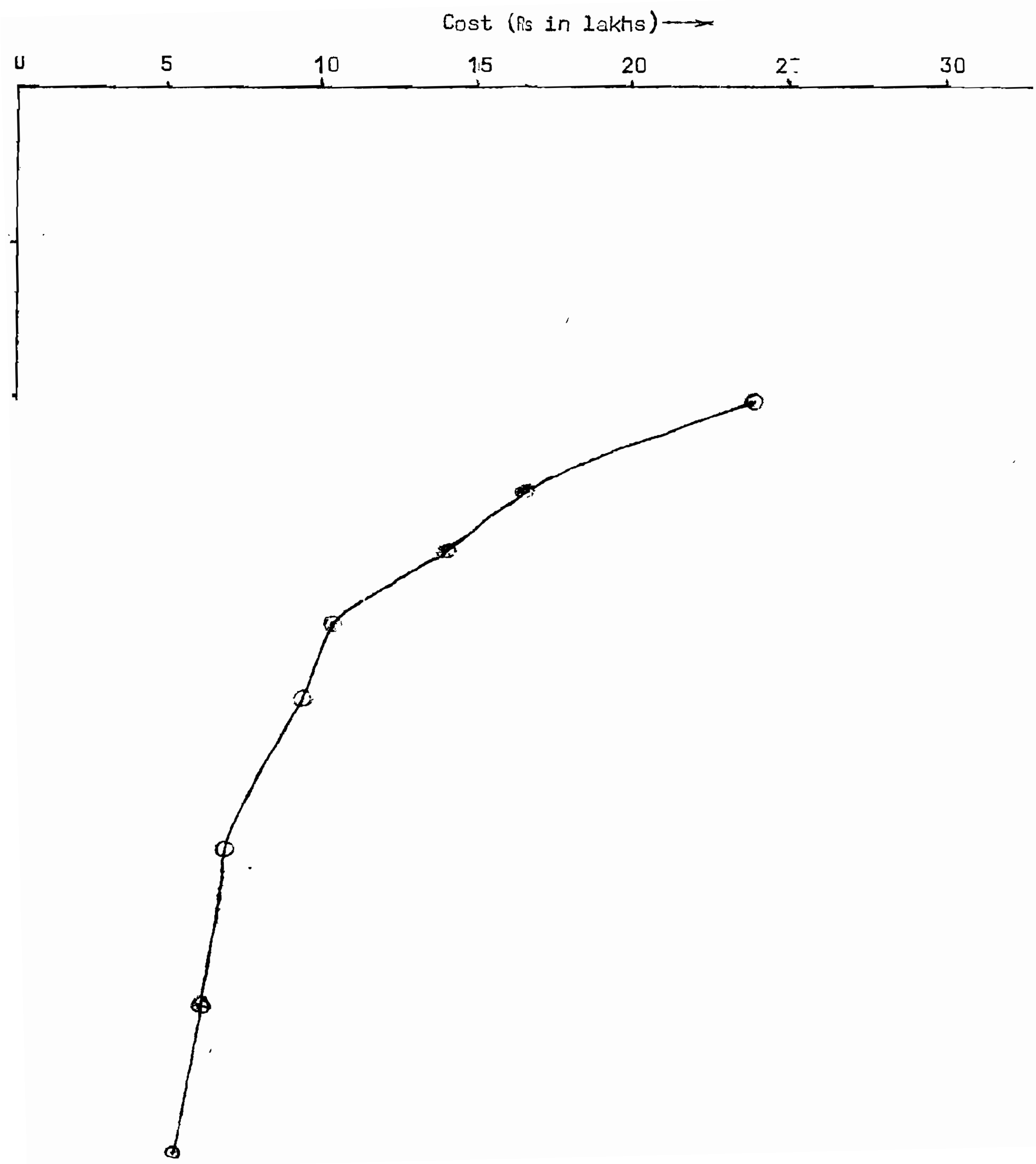
DHARAMPUR DISTRICT SERVICE CENTRES

	Centre	Cost (in lakhs)
Centres that already have 3 or more facilities	1	140
	2	115
	3	115
	4	80
	5	140
Centres that already have 2 facilities	6	95
	7	180
	8	205
	9	205
	10	105
	11	80
	12	140
	13	205
	14	205
Centres that already have one facility	15	115
	16	180
	17	105
	18	205
	19	105
	20	105
	21	205
	22	205
Centres that already have one facility	23	105
	24	180
	25	205
	26	180
	27	80
	28	180
	29	90
	30	80
	31	115
	32	205
	33	205
	34	105
Centres that do not have any facility	35	205
	36	205
	37	205
	38	205
	39	205
	40	205
	41	205
	42	205
	43	205
	44	205
Dharampur	45	(all facilities)

TABLE II

TABLE OF OPTIMAL SOLUTIONS FOR DIFFERENT SERVICE LEVELS

Service Level (Miles) (Maximum distance of a village from a service centre)	Number of service centres	Budget (in lakhs)
4.5	-	not possible
5	16	23.3
5.5	13	16.5
6	11	13.9
6.5	8	9.9
7	8	8.6
8	5	6.5
9	4	5.8
10	5	4.8



OPTIMAL COST FOR DIFFERENT SERVICE LEVELS

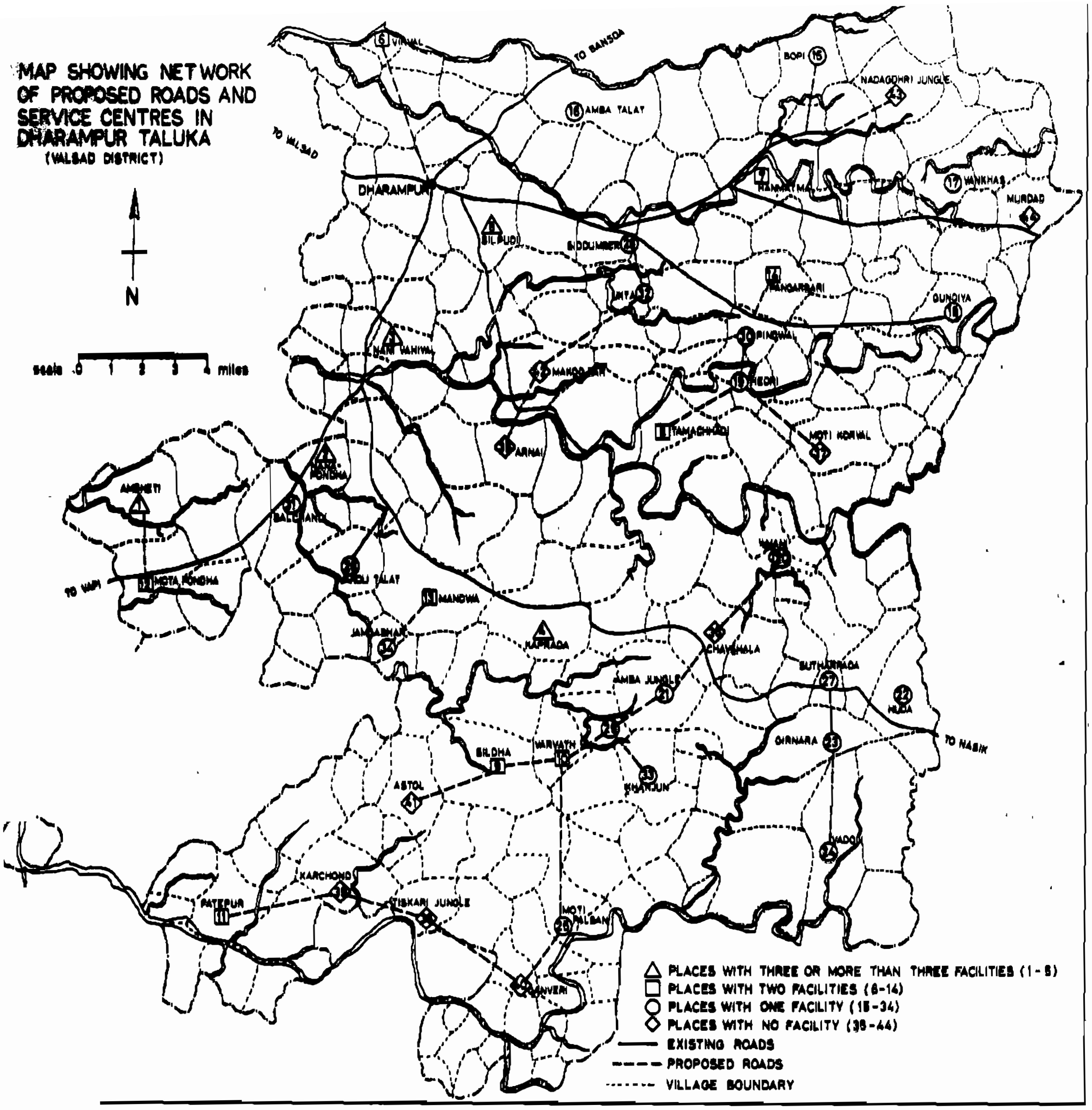

MAP SHOWING NETWORK OF PROPOSED ROADS AND SERVICE CENTRES IN DHARAMPUR TALUKA
(VALSAD DISTRICT)
N
scale 0 1 2 3 4 miles
TO BANSDA
TO VALSAD
TO VAPI
TO NASIK
DHARAMPUR
VIRVAL
BOPI
NADAGDHRI JUNGLE
AMBA TALAT
VANKHAS
MURDAD
SILPUDI
SIDDUMBER
NANGARBARI
GUNDIYA
PINDVAL
MOTI KORVAL
TAMACHHADI
ARNAI
AMBHETI
MOTA PONDHA
MANDVA
JAMBABHAR
KAPRADA
CHAVSHALA
SUTHARPADA
AMBA JUNGLE
NILIA
VARVATH
SILDHA
ASTOL
KHANJUN
GIRNARA
KARCHOND
FATEPUR
TISKARI JUNGLE
MOTI PALSAN
PANVERI
PLACES WITH THREE OR MORE THAN THREE FACILITIES (1-5)
PLACES WITH TWO FACILITIES (6-14)
PLACES WITH ONE FACILITY (15-34)
PLACES WITH NO FACILITY (35-44)
EXISTING ROADS
PROPOSED ROADS
VILLAGE BOUNDARY

Figure 2