A GEOGRAPHIC APPLICATION PROJECT UTILIZING LOCATION-ALLOCATION COMPUTER PROGRAMS TO DETERMINE CANNING FACILITY LOCATIONS IN THE WILLAMETTE VALLEY

BY

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A GEOGRAPHIC APPLICATION PROJECT UTILIZING LOCATION-ALLOCATION COMPUTER PROGRAMS TO DETERMINE CANNING FACILITY LOCATIONS IN THE WILLAMETTE VALLEY

ABSTRACT: A Willamette Valley farm cooperative was interested in evaluating locations for their canning facilities based on the criterion of minimizing aggregate distance to their contract farms. This location problem presented an excellent opportunity for a geographic application project as it was characterized by one, a spatial distribution of farms and two, the need to minimize one variable, distance. The project's aim was to provide a methodology utilizing location-allocation analysis performed by a geographic tool, the computer, to solve the specific facility location problems of the cooperative. Since the growers were constrained to existing roads in transporting their produce to the canning facilities, the problem became one of minimizing distance over a route network. Two location-allocation computer programs, designed to solve location problems on a network were called upon to generate locations for the canning facilities. The cooperative was presented with detailed information about one very important variable, distance minimization, to be considered along with the many complex variables weighing in their ultimate locational decision.

INTRODUCTION

The application of geographic theory to solve spatial problems related to decision making in government and private enterprise has been important in advancing the professional competencies of the discipline. Location theory in particular has found widespread application to geographic problems involving land use planning, transportation, and industrial location.

Though a location problem may seem simple when first examined, a more penetrating analysis leads one to discover how complex it really is.[1] The geographer, trained in solving spatial problems, is well prepared to consider the range of economic, environmental, and social factors upon which a locational decision is predicated. Since some factors weigh more heavily than others, methodologies exist allowing certain quantifiable variables to be thoroughly investigated.

One such variable, distance, has been a critical concept in the evolution of geographic thought. Its importance as a geographic variable was recognized in the location theories of Johann Heinrich Von Thünen and Walter Christaller, both equating distance with cost.

Today, with attentions focused on the energy situation, distance remains an important geographical variable because it can also be equated with transportation energy consumption. When the distance variable in a locational decision is minimized, so too is the amount of transportation energy consumed.

A location problem reflecting on this variable of distance minimization can be approached as a geographic application project. An application project promotes a more thorough understanding of a problem by incorporating components of geographic theory with geographic problem solving tools. This paper will describe the methodology for a project using one such tool, the computer, and applying elements of location theory, economic geography, land use planning, and location-allocation analysis.

Statement of Purpose

An agricultural cooperative wanted to consider the effects of one important locational variable, distance minimization, in the evaluation of locations for their canning facilities.

The cooperative, Agripac, comprises 156 contract farms distributed throughout the Willamette Valley. The farms vary in size and produce different amounts of four commodities: beans, corn, beets, and carrots. The actual number of tons produced by each farm constitutes its weighting value, a measure of the locational demand exerted by the farms. At harvest, the cooperative's growers incur costs of transportation in trucking their produce via existing roads to the nearest canning facility for processing. Agripac wishes to minimize the growers transport costs and thus energy consumption by locating their canning facilities in such a way that the "aggregate weighted distance" to all farms is minimized. The term "weighted distance" represents a combination of each farm's production and its distance to the nearest cannery. "Aggregate weighted distance" represents the sum of the weighted distances for all 156 farms. Since the growers are constrained to existing roads in transporting their produce to the canning facilities, the problem becomes one of minimizing distance over a route network. Solutions to the problem, that is, canning facility locations that minimize aggregate traveling distance from the farms, present Agripac with detailed information of the variable, distance minimization. Lacking the proper facilities to thoroughly investigate the location problem, Agripac enlisted assistance from the Oregon State University Geography Department.

Methodology

Due to the large amount of information requiring assimilation, Oregon State University's CYBER-70 computer provided the most efficient means for solving the problem. It was able to utilize a recently implemented package containing fourteen computer programs for location-allocation problems.[2] Capable of generating exact solutions to a wide range of location problems, the various computer programs were compiled and made available by the Geography Department at the University of Iowa. Two of those programs, designed to solve location problems on a route structure, were called upon to solve the specific location problems of the application project.

The cooperative provided the raw data for the project consisting of a map denoting farm locations and a table describing individual farm production in terms of acreage devoted to each commodity. First the input was formulated. It consisted of farm labels, farm weighting values, and shortest travel distances between adjacent farms. The computer algorithm calculated distances between all farms and determined locations for the canning facilities based on minimizing the weighted distance to all the farms. Separate solutions were generated locating one, two, and three canneries to serve the contract farms. Additional solutions were generated based on the isolated distribution of each of the four commodities.

These computer generated solutions allowed Agripac to thoroughly investigate one geographic variable - distance minimization. From the set of solutions, Agripac was able to consider the number and locations of their canneries that would best minimize the growers' transport costs. Further, they were able to scrutinize the distribution of the four commodities determining the proximity of each to the canning facilities.

This paper first presents a background which examines the underlying geographic concepts of the application project. Next, the solution procedure for the canning facility location problem is outlined in three parts: preparation of input data, computer program usage and presentation of results. Then, a conclusion summarizes the objectives and methodology of the application project and discusses the importance of location-allocation analysis as a geographic problem solving technique.

BACKGROUND

The Location-Allocation Problem

Truly a geographical problem, a location-allocation problem has three things that can vary: one, the number of facilities to be assigned; two, the size or capacity of the facilities; and three, the locations to which the facilities must be allocated.[3] One way to approach a complex locational problem of this nature is by holding constant some of the variables. If the number and size of the facilities are held constant, their locations may be solved for by evaluating the given criterion, distance minimization. Isolating certain variables in this manner allows a location problem to be solved by a systematic procedure.

The systematic solution procedure to a location-allocation problem asks the question: how can certain objects be located in order that a certain variable or variables attain a maximum or minimum value? Under these circumstances the maximum or minimum value attained is said to be that variable's "optimal" value. Definable in many ways, the term optimal in this case refers to canning facility locations that minimize the aggregate weighted distance from the farms. Minimizing that particular variable is the sole criterion for solving the problem at hand. Inasmuch as the cooperative's ultimate locational decision will be based on a wide range of criteria, and, only one variable is under consideration, the minimum or maximum values found for that variable do not necessarily yield the best solution to the problem. They do provide, however, a solution reflecting the given criterion. When a location-allocation problem is solved by finding a minimum or maximum value for a single variable or set of variables, the solution to that problem can be called the optimal solution. Hence, locations for canning facilities that minimize the variable of aggregate weighted distance are termed optimal locations.

This geographic application project was approached by considering discrete location-allocation problems. The location-allocation problem formulated for this project asked the question: how shall one set of facilities be allocated to serve a second set of locations (Fig. 1)? The cooperative provided the locations (farms) and asked for a set of facilities (canneries) to be allocated.

Location Theory

In each geographical problem, there is some spatial distribution under consideration. Location theory offers different approaches for analyzing the given criteria and explaining the areal distribution which are created. In short it uses the "where" to explain the "why".

The first attempt at explaining the location of economic activities was provided by the German economist, Johann Heinrich Von Thünen.[4] His concentric ring model, accounting for the types of agriculture that prospered around an urban market, made three assumptions. First, Von Thünen assumed that farmers wishing to maximize a variable (profits) were able to make adjustments. Next, he assumed there was only one means of overland transportation. Third, he stated transportation costs were directly proportional to distance.

Comparisons may be drawn to Von Thünen's assumptions in order to simplify the canning facility location problem. First, the cooperative's objective of minimizing a variable, distance, could be reached by adjusting cannery locations. Second, growers are correspondingly constrained

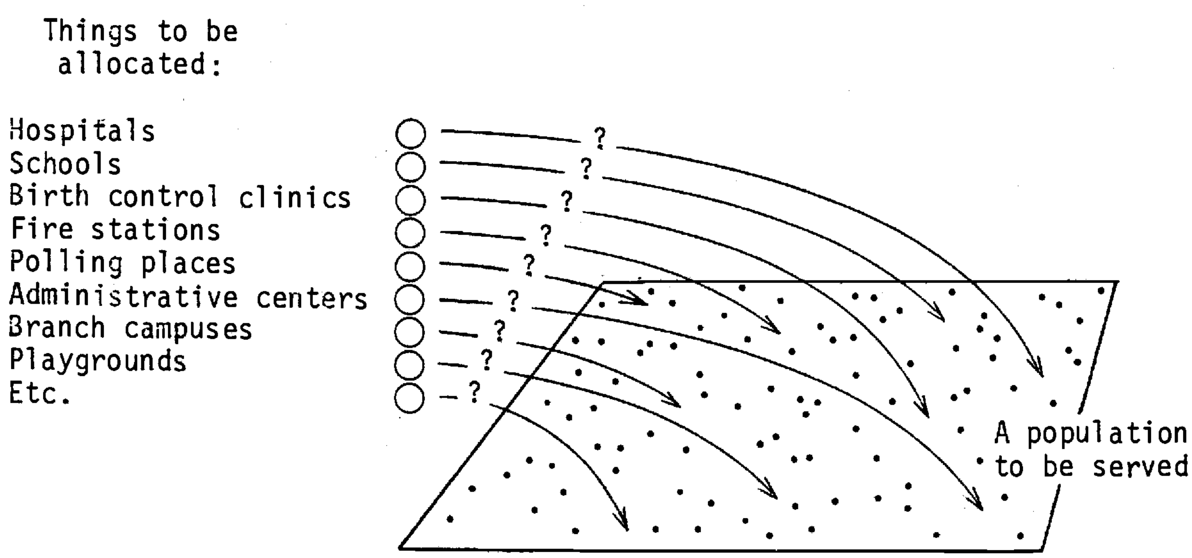


Figure 1. The Location-Allocation Problem.*

*Taken from: Abler, Adams, and Gould, Spatial Organization, p. 532.

to a single means of overland transportation. Third, cost is directly proportional to distance as growers traveling greater distances incur higher transportation costs. These characteristics correspond to ways in which the problem may be simplified so that the computer can generate a locational solution based on a single variable.

Comparisons may also be drawn to Walter Christaller's Central Place Theory. Based on hypothetically uniform terrain, movement, and distribution, Central Place Theory was the first to offer explanations for the location pattern of market centers.[5] It postulated a uniform hierarchical arrangement of central places in response to varying need and availability of goods and services. Evaluating a given distribution pattern of people and goods, the theory accounted for the number and location of service centers to best serve that distribution. During the early 1900's when the theory was developed, the major locational constraint was ease of traveling, or, in other words, accessibility. If easily accessible to many people, a location prospered.

The canning facility locations for the application project may be correlated with Christaller's central places and are also concerned with accessibility - to the contract farms. In this case, based on the distribution pattern of farms, locations for the canneries were not explained, they were deduced. Again, as in Central Place Theory, the most important criterion in deducing locations for the canneries was minimizing distance, thus maximizing accessibility.

Definitions of Most Accessible

A more thorough understanding of location-allocation problems and their applications can be gained through examination of different types of optimal values corresponding to various locational decisions. One approach to solving problems is to ask the following questions: if one wanted a certain variable or variables to attain a maximum or minimum value, could certain values be relocated to achieve this? If so, where should those locations be? Because people are distributed unevenly in earth space, they must obtain many kinds of goods and services located at widely separated places.[6] Their interest is in the locations of facilities being "most accessible". By defining the term "most accessible", the different types of location-allocation problems can be better understood.[7]

In his book Optimal Location of Facilities, Gerard Rushton offers a number of definitions for the term "most accessible". Those definitions correspond to different types of optimal solutions.

The first defines a location as being "most accessible" when the total of the distances of all the people from their closest facility is minimum. This is equivalent to minimizing the "average distance". The application project falls into this category. Another example of this type would be in locating a warehouse to serve the supermarkets of a region. If the aggregate distance from the supermarkets to the warehouse is minimized, so too are transportation costs. The next definition of "most accessible" is when the farthest distance of people from their closest facility is minimum. This criterion is used when locating emergency facilities such as fire and health care services. The third defines a location as "most accessible" when the number of people in the proximal area surrounding each facility is approximately equal. This is known as the "equal assignment" criterion. Locations of facilities such as schools, hospitals, and polling places are evaluated in this manner. The fourth definition of "most accessible" is when the number of people in the proximal area surrounding each facility is always greater than a specified number i.e., must exceed some "threshold" value. The location of a swimming pool maintenance business falls into this category as its viability depends upon a sufficient amount of swimming pools in the area. The fifth definition of "most accessible" is when the number of people in the proximal area surrounding each facility is never greater than a specified number. This "capacity constraint" is often considered when locating public services. Health care devices, institutions, and jails are some examples of public services that cannot accommodate more than a specified number of people.

Each definition can be interpreted in a number of ways corresponding to different locational problem situations. For example, in the second definition, a location is defined as most accessible when the farthest distance of people from their closest facility is minimum. Instead of requiring that the farthest distance be minimized, a problem may state that the farthest distance from the people to their closest facility cannot exceed a specified number. This constraint might govern the location of a fire station where the maximum response time could not exceed a specified number of minutes.

These examples provide a brief overview of the different types of location decisions that must be made. More thoroughly understood, they can provide insight into the wide range of capabilities of location-allocation analysis.

Computer Treatment of Location-Allocation Problems

The approach to this geographic application project utilizes location-allocation analysis performed by computer. Although complex in nature, the computer methodology for solving location-allocation problems can be explained in rudimentary terms.

The computer deals with numerical values. Before it can solve the location-allocation problem, the input data must be transformed into some symbology (i.e. numerical values) that the computer can understand.[8] The computer then manipulates the input data with an "algorithm". An algorithm is a prescribed set of instructions (or logical procedure) for solving a given recurrent mathematical problem. The algorithm searches for the optimal location by generating solutions corresponding to different locations and comparing them to one another. First, a solution is generated for one location, that is, the aggregate weighted distance from that location to all farms is calculated. The solution for the first location is stored and will be compared to subsequent solutions. After generating a solution for the next location, the computer compares that solution to the previous one and from the pair selects the "best" solution. The subsequent solutions for each location is compared to the current "best" value in the same manner. In each case the better of the two is retained as the "best" value. After all feasible locations have been evaluated, the location corresponding to the current "best" value becomes the optimal location.

Locations on a Route Structure

Constrained to a route network the location problem is altered slightly: given distances defined between each node, or point on a route network, find that point from which the sum of the distances to all other points is least. Weights may be associated with the nodes. There is a theorum, developed by Hakimi (1964), stating that the node for which this is true is itself a node on the network.[9] Hakimi's theorum states:

> There is a point of the graph which minimizes the sum of the weighted shortest distances from all nodes to that point which is itself a node on the graph.

The theorum can be restated as: there never will lie a point on an arc between two nodes that will have a smaller total distance to the remaining nodes than either of the nodes themselves. This is important as it has encouraged solution methods that evaluate alternative nodes on the route network to find the optimum node. Time need not be spent unnecessarily examining points along the arcs connecting nodes.[10]

Location-Allocation Computer Programs

The preceeding discussions have outlined how the solution to a location-allocation problem can be determined through a series of mathematical manipulations. Performed systematically by computer, the manipulations become a program. Of the location-allocation package's fourteen programs, two are designed to solve problems on a route network and are called upon to solve the canning facilities location problem.

The first program called SPA, an acronym for shortest path algorithm, computes the shortest distances and paths between all pairs of nodes on a route network. Input for SPA consists of integer labels for all nodes on a route network and distances between adjacent nodes. Output from SPA is in the form of a distance matrix denoting the distances from each node to all other nodes on the network. The distance matrix that is part of the output from SPA comprises a portion of the input for the next program, ALLOC.

Short for location-allocation, the program ALLOC offers solutions to a wide range of location problems along a route network. The various types of solutions are categorized three ways. The first locates one or more facilities to minimize total distance (or time) traveled to the closest facility. The Agripac problem requires this type of solution. Optimally locating the canning facilities will minimize the aggregate distance traveled by the growers to their nearest cannery. The second group of solutions determine locations that again minimize aggregate distance (or time). In this case, the problem is subject to the constraint that no person be further than a specified distance (or time) from their closest facility. The third group solves the problem of optimally locating one or more facilities such that the maximum distance to a demand point's closest supply center is a minimum. Corresponding to definition three of "most accessible", this type of solution is often generated when locating emergency services. SPA and ALLOC's input, output, and capabilities are discussed in greater detail in the following section.

APPLICATION PROJECT

The problem's solutions of where to locate the canning facilities were based on the demand exerted by the cooperative's 156 farms.

More than distance alone, each farm's demand is the product of its distance to the nearest cannery (in miles) and its output (in tons). Output naturally varies because of unequal farm size and differing acreages devoted to each of the four commodities. Each commodity is associated with a certain average tonnage per acre e.g., an acre's yield of carrots weighs more than acre's yield of beans. The various average yields are: beans - 5.6 tons/acre, corn - 9 tons/acre, beets - 20 tons/acre, and carrots - 24 tons/acre. As a result, some growers must transport heavier loads than others - they must overcome a greater amount of ton-miles. Although referred to as distance, the amount of ton-miles constitutes each farm's "weighted distance".

In each case, problem solutions locating the canning facilities minimized the criterion of aggregate weighted distance. First, locations for the canning facilities were generated with weighting values describing each farm's total tonnage of all four commodities. Then the problem was broken down and locations were found based on the distribution of each of the four commodities. The latter problem determined, for example, the location for a bean cannery based on the cooperative's distribution of bean growers.

The Agripac problem is characterized in four ways. One, a spatial distribution of farms is under consideration. Two, each farm is associated with a weighting value corresponding to the tonnage it must haul to the canning facilities. Three, the produce is transported by truck over existing roads (route network). Four, the desired solutions are based on the sole criterion of minimizing weighted distance in moving the commodities to the canning facilities.

These four characteristics not only constituted a classic geographic problem, they provided an excellent educational opportunity for a geographic application project.

Preparing Input Data

By far, the most time consuming task in using SPA and ALLOC to solve this location problem was formulating the input data. Agripac provided a map of the Willamette Valley denoting the 156 farm locations. To begin with, the farm locations were transferred to an identical second map. Nodes (farm locations), their integer labels, and the shortest routes between nodes were designated on the second map. Nodes were indentified simply by integer labels; no georeferencing was necessary as the algorithms function is to interpret internodal distances. Since the computer programs were dimensioned for a maximum of 150 nodes, the data had to be simplified. Pairs of nearly adjacent farms were incorporated into single nodes with combined tonnages serving as the weighting value for each node. This was done for eight pairs of farms reducing the node total to 148. Next, the distances between adjacent nodes were calculated with the Geography Department's digitizing planimeter and graphic display computer terminal. An interactive computer program on the graphic terminal facilitied data transfer from map to computer memory tape. The interactive program asked for the map scale and node labels, then converted the digitized distances between nodes into miles. Labels and internodal distances for pairs of adjacent nodes were stored on the graphic terminal's memory tape - ready for transfer to the CYBER. It is important that only distances between pairs of adjacent nodes on the route network were input - SPA calculated distances and shortest paths for all pairs of nodes on the route network.

Using SPA and ALLOC

The primary function of the program SPA is to formulate and output a matrix comprised of distances between all nodes. Additional output from SPA is in the form of two options. Option 1 provides the shortest paths between all pairs of nodes on the network. In other words, each grower is told the shortest routes from his farm to all others. Option 2 provides the shortest paths between a specified sub-set of nodes and all other nodes on the network. If distances and routes are needed to and from farms growing only carrots for example, then option 2 would be selected. Output from SPA can also include an "echo check" of the input data allowing it to be validated.

The inter-nodal distance matrix supplied the bulk of the input for the program ALLOC. Additional input for ALLOC consisted of the following:

1. The total number of places (nodes) along the route network (148).
2. Integer identification numbers of the nodes (1-148) and their corresponding weights (tonnages).
3. The number of service sites required. Three solutions respectively locating one, two, and three canneries were generated.
4. Source locations for the canneries. The program utilizes a heuristic algorithm and must therefore be provided with a logical starting point. A heuristic algorithm is a solution procedure that relies on a starting point provided by the user. It first calculated the aggregate weighted distance to the source locations, then compared alternative locations.
5. Locational constraints. Three types of locational constraints are considered by ALLOC. One, a "constrained location" is always forced into the final solution. Two, a "feasible location" may be chosen in the final solution. Three, an "infeasible location" cannot be

present in the final solution but its demand influences the solution. If the cooperative had one existing cannery and desired a location for a second, the existing cannery would be forced into the final solution thereby influencing the optimal location of the second.

6. Distance constraints. These are applicable when a problem has maximum distance constraints.

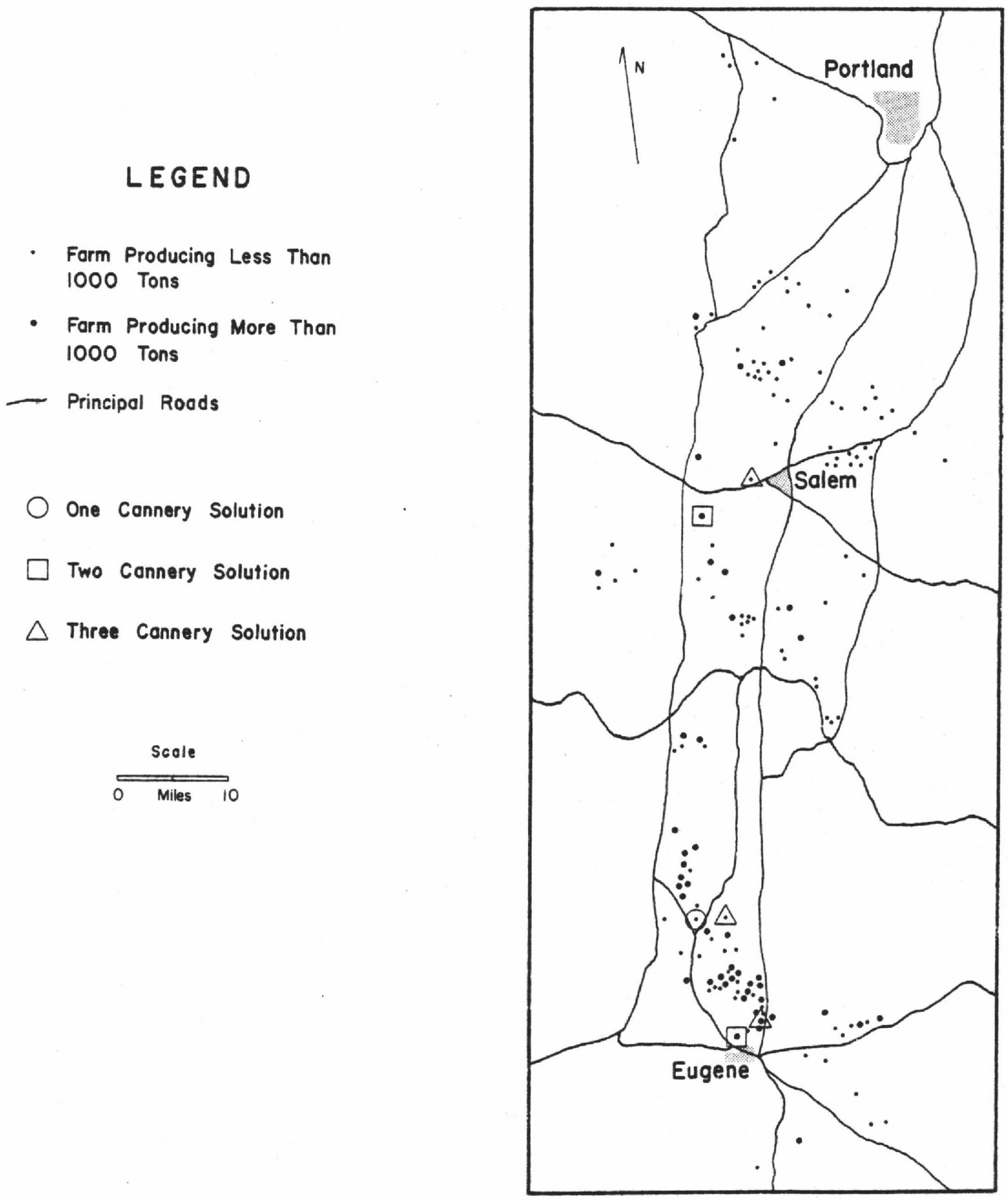
In addition to solving the optimal locations, program ALLOC assigned each node to its nearest supply center i.e., directed each grower to the nearest cannery. Output also contained the aggregate weighted distances (ton-mileage) for each node evaluated during the search for the optimal node.

Results

It will be recalled that the application project had two principal objectives. The first was to determine locations for canning facilities based on the criterion of minimizing aggregate weighted distance to the contract farms. Weighting values were assigned to each farm describing its total production. Three separate solutions were generated respectively locating one, two, and three canneries (Fig. 2). The second objective relied on farm weighting values reassigned to describe individual commodity production. For each of the four commodities, solutions were generated locating two canneries to reflect individual commodity distribution. (Fig. 3). In all cases, as per Hakimi's theorum, locations for canning facilitites occurred at nodes on the route network.

The first solution found the optimal location for one cannery. That location was found to be at node 102. A single cannery located there resulted in an aggregate weighted distance of 4.5 million ton-miles.

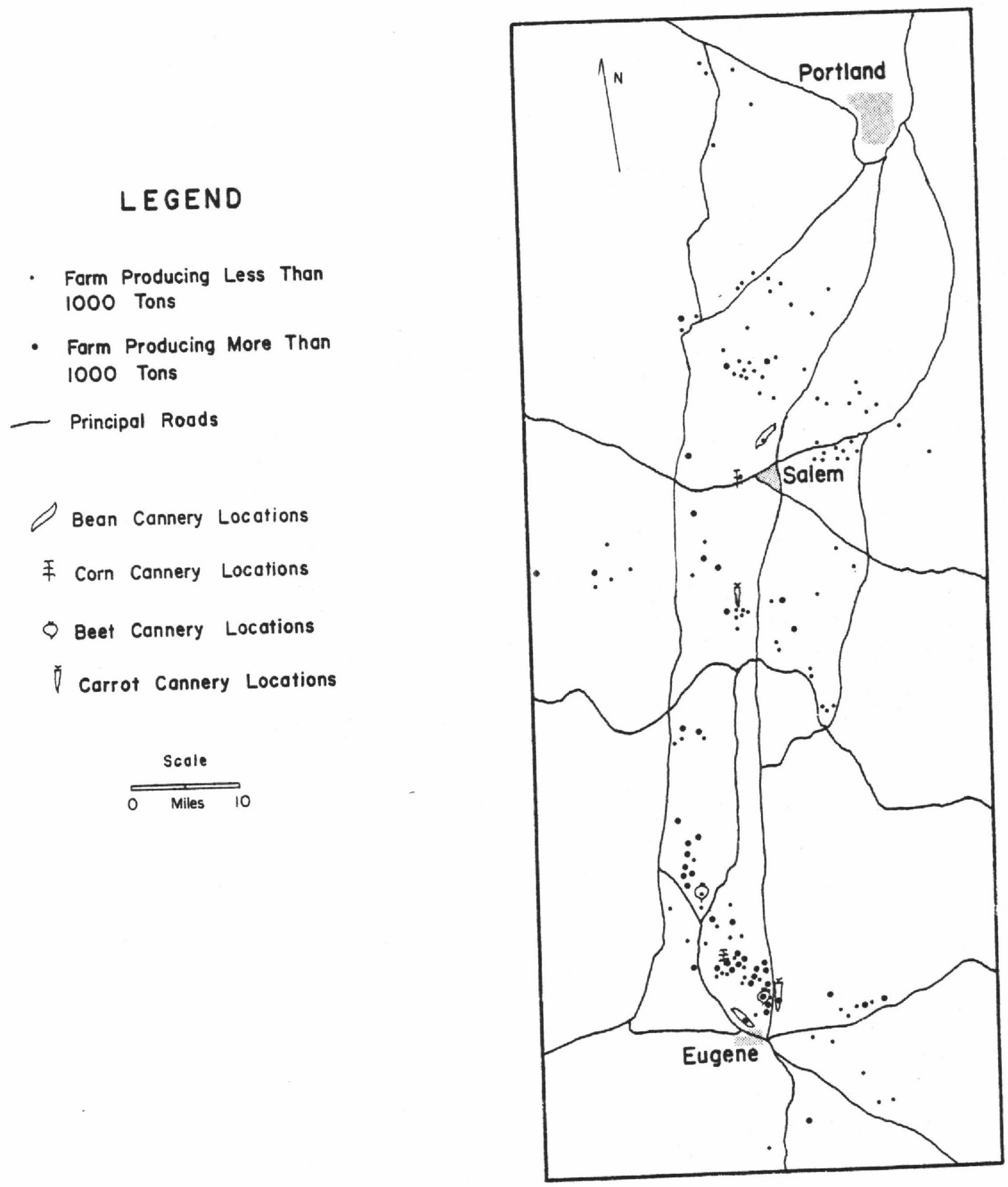
OPTIMAL LOCATIONS OF CANNING FACILITIES FOR WILLAMETTE VALLEY CONTRACT FARM DISTRIBUTION*



*Based on the minimization of aggregate distance

Figure 2. Optimal Locations of Canning Facilities for Willamette Valley Contract Farm Distribution - Based on Total Production.

OPTIMAL LOCATIONS OF CANNING FACILITIES FOR WILLAMETTE VALLEY CONTRACT FARM DISTRIBUTION*



*Based on the minimization of aggregate distance

Figure 3. Optimal Locations of Canning Facilities for Willamette Valley Contract Farm Distribution - Based on Individual Commodity Production.

Node 102 is located in Junction City, 112 miles from the northernmost farm and 44 miles from the southernmost. This indicated the block of farms in the South Willamette Valley are generally larger in size thereby exerting greater demand on the cannery location. The next solution located two canning facilities. Those locations were found to be at nodes 64 and 140. Essentially one cannery would be centrally located in the block of South Willamette Valley farms with the other serving the farms in the northern two/thirds of the valley. Two canneries would result in an aggregate weighted distance of 2.5 million ton-miles. This is considerably less than the 4.5 million ton-miles for one cannery. Finding the optimal locations for three canneries led to some unexpected and encouraging results. The three optimal locations were found to be at nodes 62, 105 and 135 corresponding to respective locations on the outskirts of Salem, Junction City, and Eugene. Those cities house Agripac's three existing canneries; hence, the three canneries are already in the optimal locations with respect to the given criterion. The aggregate weighted distance for the three canneries is 1.9 million ton-miles, slightly less than that for two canneries. Comparing 1.9 million ton-miles with the two cannery aggregate weighted distance of 2.5 million ton-miles illustrates how three canneries only slightly reduce the aggregate weighted distance for all the farms. The difference between one and two canneries on the other hand, is large (4.5 as compared to 2.5 million ton-miles). Agripac is thus provided with one basis for evaluating the number and location of their canning facilities.

Additional solutions were generated for each of the four commodities. In the first of four cases, green bean tonnage alone constituted the weighting value for each particular farm. Problem solutions solely dependent on the distribution of beans located two canneries in roughly the same places as those considering total output indicating uniform bean production throughout the Willamette Valley. The next solution, corresponding to corn, indicated a distribution skewed slightly to the north, that is, contract farms in the northern part of the valley devote more acreage to corn. The solution evaluating beet production placed two canneries in the southern part of the valley, indicating farms there produce large amounts of beets. In the fourth case, carrot distribution was shown to be skewed just slightly to the south, contrary to the distribution of corn. The solutions generated assisted the cooperative in evaluating locations for their canneries based on total production of the farms and production of each of the four commodities.

CONCLUSION

A number of complex variables may weigh in a locational decision. This paper has described an application project focusing on the effects of one important variable, distance minimization. By holding other variables constant, the agricultural cooperative was able to evaluate the effects of distance in locating their canning facilities to best serve the distribution of contract farms. The distance variable served as the criterion for determining optimal canning facility locations. To aid in comprehending the application project's problem solving technique, the criterion, originally stated as "distance minimiztion", was transformed to "aggregate distance minimization" then to "aggregate weighted distance minimization". Since the growers were constrained to existing roads, the criterion became one of minimizing aggregate weighted distance along a route network. Two location-allocation computer programs designed to solve such a locational problem were called upon to generate locations for the canning facilities based on the specific needs of the cooperative. The results indicated that given constant factory size, the difference in ton-mileage for three as opposed to two canneries was small. Two canneries as opposed to one however, substantially reduced the number of ton-miles.

The results, i.e., optimal canning facility locations and their corresponding ton-mileages, provided Agripac with information about the effects of one locational variable, distance. Other locational variables such as cannery size, land availability, and marketing costs may also be considered by Agripac in the evaluation of their canning facility locations.

The terms "aggregate weighted distance", "transportation costs", and "transportation energy consumption" were presented to the facilitate a more thorough understanding of the application project. While expressing three distinct concepts, those terms can be equated in the following way: when a location is found that minimizes aggregate weighted distance, that location also minimizes transportation costs and transportation energy consumption.

The locational pattern of any activity influences the quantity and quality of services received. Methodologies exist as this paper has pointed out, "to evaluate the <u>locational effectiveness</u> of any location pattern, to determine improvements that can be made, and to compute location patterns that are optimum with respect to defined criteria."[11] In adopting the question of finding the best location pattern to meet specified requirements, "the prime concern is no longer to explain things how they are but to make rational assertions about how they should be."[12] With this in mind, location-allocation analysis departs from traditional descriptive science and enters the realm of prescriptive science.[13] This approach to geographical problem solving is timely "for pressures of expanding populations in relation to finite land resources are demanding new approaches to locational decisions."[14]

FOOTNOTES

1 Ronald Abler, John S. Adams, and Peter Gould, Spatial Organization (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1971), p. 531.

2 A detailed description of the locational problems, algorithms, and input requirements of the fourteen location-allocation programs is given in Gerard Rushton, Michael F. Goodchild, and Lawrence M. Ostresh, Jr., Computer Programs for Location-Allocation Problems, University of Iowa Department of Geography Monograph Series, 6 (Iowa City: University of Iowa, 1973).

3 Abler, Adams, and Gould, Spatial Organization, p. 533.

4 John W. Alexander and Lay James Gibson, Economic Geography, 2nd ed. (Englewood Cliffs, New Jersey: Prentice-Hall, Inc., 1979), p. 440.

5 Edgar C. Conkling and Maurice Yeates, Man's Economic Environment (New York: McGraw-Hill, 1976), p. 157.

6 Gerard Rushton, Optimal Location of Facilities (Wentworth, New Hampshire: COMpress, Inc., 1979), p. 31.

7 Rushton, Optimal Location of Facilities, the term "most accessible" is defined seven different ways followed by separate instructional explanations, p. 32-33.

8 Waldo R. Tobler, "Automation and Cartography," Geographical Review 49 (October 1959): 526.

9 Rushton, Optimal Location of Facilities, p. 64.

10 Ibid.

11 Ibid., p. 2

12 Ibid., p. 8

13 Ibid.

14 Ibid.

APPENDIX

USING SPA AND ALLOC ON OREGON STATE UNIVERSITY'S CYBER-70 COMPUTER

The following instructions refer to the general procedure for accessing and running the programs SPA and ALLOC on Oregon State University's CDC CYBER-70 computer. If optional capabilities of the programs are desired, the user is directed to the more detailed explanation offered in the mongraph <u>Computer Programs for Location-Allocation Problems</u>, edited by Gerard Rushton et. al.

For clarity, file names "INDATA", "OUTDATA", "MATRIX", and "ALOUT" are used in the following explanation. They are arbitrary; any 1-6 character file name is suitable.

This appendix is to be used in conjunction with <u>NOS User Guide, Vol. 1</u> and <u>Text Editor Reference Manual</u>.

I. Formulate Input for SPA.

SPA's primary function is to calculate a "distance matrix" describing shortest distances between all node pairs to serve as the bulk of the input for ALLOC.

1. Control Card.

Place "1" in column 7 if actual shortest paths are to be printed; otherwise leave blank.

Column 10 designates "print/punch" option for distance matrix.

Leave column 10 blank - matrix is printed.

"1" in column 10 - matrix is printed; matrix is stored in a local file entitled "PUNCH".

"2" in column 10 creates local file "PUNCH".

Place "TRUE" in columns 16-20 if an echo check of data cards is desired; if not place "FALSE".

2. Data Cards.

Computer algorithm recognizes nodes by their labels.

Each node label must be a 1-6 digit integer i.e. the range is 1-999999.

Internodal distances must be in the form of 1-5 digit integers.

Columns 1-10: label for node A.

Columns 11-20: label for node B.

Columns 21-25: distance between node A and node B.

In each of the above cases the integer is to be "right justified" i.e. if node A is labeled "52" a 5 is placed in column 9, the 2 in column 10; if the internodal distance is 12 miles, a 1 is placed in column 24, the 2 in column 25, etc.

If an input file is created using the interactive program on the Geography Department's graphic display terminal, that file must be sent to the CYBER.

The PACK command must be exercised to prepare the file for proper formating.

A FORTRAN program entitled "REFORM" reformats the input data placing node lables and distances in their respective columns.

3. End Card.

Place "END" in columns 1-3.

II. Run program SPA.

Once the input file is prepared, SPA must be accessed by typing:

GET, SPA/UN=ARCHIVE.

If the input file is named "INDATA" and the output file is to be named "OUTDATA" the following command is typed:

SPA, INDATA, OUTDATA.

This runs program SPA using the information contained in "INDATA" as input. Output from SPA is placed in a file named "OUTDATA". "INDATA", "OUTDATA", and "PUNCH" are all local files that are destroyed when the user logs off. If they are needed for future reference, they must be copied onto a permanent file. This is done with the SAVE or DEFINE commands.

III. Formulate input for ALLOC.

The local file "PUNCH" constitutes the bulk of the input for ALLOC. The filename "PUNCH" must be changed as it is a filename reserved by the CYBER. This is done using the COPY command:

COPY, PUNCH, MATRIX

which copies the information contained in "PUNCH" to a newly created local file named "MATRIX".

The file "MATRIX" will serve as input for program ALLOC and must be augmented with additional data. This is done using the Text Editor (refer to: Text Editor Reference Manual).

Input for ALLOC is as follows:

1. Node Total Card.

   Place in columns 1-5, right justified, the total number of nodes in the internodal distance matrix.

2. Fortran Format Statement Card.

   This tells the algorithm how to read the information contained in the distance matrix. The format statement is in the following form:

   (X(14I5/),YI5).

   The variables X and Y represent integers and are dependent on the total number of nodes.

   For node totals >13, add 1 to the node total. Divide that number by 14. The quotient becomes X with the remainder as Y. For example, if the node total is 33 then the following steps are taken: 33+1=34. 34÷14=2 with a remainder of 6. Thus, the format statement takes the form

   (2(14I5/),6I5).

   For a node total of 148: 148+1=149. 149÷14=10 has a remainder of 9. Thus, the format statement would be

   (10(14I5/),9I5).

   For node totals of 13 or less the statement simply reads

   (ƵI5/)

   where Ƶ equals the total number of nodes plus one. For example, a node total of 9 yields: 9+1=10. The format statement takes the form

   (10I5/).

3. Distance Matrix.

   The input file for ALLOC is built around this.

4. Format Statement Card for Place Labels and Weights.

   Format statement takes the form:

   (I5,I5).

5. Node Label and Weight Cards.

   Node label is placed, right justified, in columns 1-5 with corresponding weight, right justified, in columns 6-10.

   There will be one card for each node.

6. Control Cards.

   These instruct ALLOC which duties to perform. In all cases numbers placed in the designated columns are to be right justified.

   CARD 1. Columns 1-5: number of service sites desired.

   Column 10: select algorithm desired; 1 = Maranzana, 2 = Tietz and Bart, 3 = Minimax Solution. Tietz and Bart yields the most reliable solution.

   CARD 2. Initial source node labels: User provides the algorithm with logical nodes to start with. If three service sites are desired for example, three source locations must be provided by the user.

   Columns 1-5: node label for first source location.

   Columns 6-10: node label for second source location, etc.

7. Blank Card.

   Necessarily placed at end of input file.

IV. Run Program ALLOC.

Once input file for ALLOC is complete, the following commands are typed:

```
GET,ALLOC/UN=ARCHIVE
REWIND, MATRIX
ALLOC, MATRIX, ALOUT
```

This runs program ALLOC using MATRIX as input and placing output on a newly created local file named ALOUT. If any of the files contain information that may be desired at a later date, they must be saved as permanent files. For example, if the input "MATRIX" and output "ALOUT" of ALLOC must be saved, the following commands are typed:

REWIND, MATRIX, ALOUT

SAVE, MATRIX, ALOUT

If hard copies of the two files are desired than the following commands are typed:

ROUTE, MATRIX/DC=LP

ROUTE, ALOUT/DC=LP

The files' contents are printed on the line printer.

The preceeding information corresponds to the most basic form of output generated from SPA and ALLOC. To facilitate programs' use, the user should become familiar with the following commands in addition to those previously noted:

CHANGE	CLEAR	ENQUIRE
PURGE	RENAME	REPLACE