Multifacility Location Decisions for Meeting Customer Service Commitments

by

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In the competitive global economy location decisions have strategic and operational implications. The two conflicting aspects of location decisions for the companies are as follows: on one hand, the attempt is to reduce the associated capital and operational costs. On the other hand, the struggle is to improve customer service quality by making the product/service available to the customer at the right place and the right time.

This conflict is examined for a major manufacturer and distributor of medical diagnostic equipment. To address the current and future service needs within the North American market, a set of optimization models for location selection is developed. These models assist the organization in deciding how many locations are required and where to position them.

Location decisions can significantly impact operating costs, revenues, customer service, market shares, and sales. Whether the facility(ies) being located is for manufacturing, distribution, service, or sales, the decision can be of strategic importance. In this study, we present a facility location technique to identify multiple geographically dispersed facility sites such that service “coverage” is provided for current and projected future customers. The critical issue regarding the customer service quality is the limited time window, promised by the company, for offering the service “coverage.” The primary objectives of this decision are to minimize the associated capital and operational costs while meeting a demanding customer service requirement.

Although this study presents location decisions of service personnel for medical diagnostic equipment where the organization has a customer service commitment of an eight-hour time window, the critical issues are similar across industries where multiple facility location decisions are the focus. This is particularly true where there is a need to provide coverage to customer regions. Effective geographic regional coverage involves a limited travel time, distance, and/or volume of customers to be served. Examples of other such applications include locating retail outlets, distribution centers, restaurant franchises, sales offices, medical facilities, branch banks, etc.

In today’s marketplace where companies are strategically competing on the basis of quality and time, organizations cannot afford to lower customer service quality nor can they bear the cost of having an excessive number of locations. To balance these two issues it is essential for an organization to set a service goal and strategically plan their sites to achieve this goal at minimum cost.

Background

Roche Diagnostics is a major international manufacturer of medical diagnostic systems. Their customers include medical laboratories of all kinds such as those in hospitals, research centers, medical clinics, etc. Over 12,000 laboratories around the world utilize their diagnostic systems. A recent
acquisition has put sales in excess of three billion dollars annually.

Recently, Roche has developed the Integra, an innovative medical diagnostic apparatus that consolidates the operations of many different pieces of lab equipment. The Integra is expected to reduce the cycle time of medical tests and increase the efficiency of the lab. The Integra is an integrated system of hardware, software, and reagents, which offers economic viability through task consolidation. The majority of laboratory work load can be streamlined on this single multi-tasking system.

As a result, operation of the Integra is critical to operation of the lab. Regular preventive maintenance is used to minimize unscheduled down time, and remote diagnostic capabilities allow many service requests to be handled without an on-site visit. For service requests that require a site visit, Roche offers customers within the continental U.S. a service commitment to respond within a time window of eight hours or less. There are exceptions in installations located in remote areas.

Response time refers to the time from when a customer service request is received until the needed part(s) and the technician arrive at the customer location. Thus, supporting customer Integras involves two separate issues: (1) ensuring that maintenance parts arrive within the predetermined time window of eight hours; and (2) ensuring that service personnel can travel to customer locations within the same time interval.

Retzlaff-Roberts and Amini (1998) addressed the first problem, the issue of part inventory and its probabilistic nature. The second issue, determining the best strategy to ensure that service personnel arrive within the eight-hour time window, is addressed in this article. Since service personnel perform their work at the customer location, there is no office or other facility. Thus the domiciles are being located rather than an actual “facility” but the issues involved are the same as when locating facilities. The decisions are to determine (a) how many service personnel domiciles are needed; and (b) geographically, where to locate these domiciles. These decisions are to be made with the objective of keeping the related total capital and operational costs at a minimum while meeting the challenging customer service requirement.

Location Decisions

The domicile selection problem belongs to a class of important managerial problems with strategic and operational implications referred to as Facility Location. This problem class is concerned with the location of one or more facilities/sites in a way that optimizes a certain objective including minimization of transportation cost, providing equitable service to customers, capturing the largest market share, etc. Business applications encompass location of warehouses, plants, emergency centers, retail outlets, service facilities and/or personnel, hospitals, fire stations, police stations, etc. In general, a location model can be applied to any scenario that involves finding the best location(s) for any object(s). For the latest survey of facility location applications and methods see Drezner (1995).

When many locations are involved, and the decision includes choosing how many sites in addition to determining the locations, the situation becomes complicated because of the large number of alternatives. Finding the best alternative can be difficult unless a mathematical model is used. Modeling allows for identifying location trade-offs in a systematic fashion and finding the best overall strategy for the entire system.
The Modeling Process

Service coverage must be provided to customers within the very limited time window of eight hours. Clearly the objective is to minimize the number of domiciles required. The maximum distance a domicile can lie from a customer depends upon the mode of transportation. Using air transportation, it might be possible to have a single domicile centrally located in the U.S., having a service technician and a private jet on standby at all times. However this was not considered a very practical approach. Instead, service personnel travel by car, which was the existing company practice. This requires a decentralized approach, with service personnel spread throughout the U.S. Technicians were already in various U.S. locations to service earlier Roche products. However these locations had been chosen in the past for a variety of reasons which may have little or nothing to do with the new Integra environment.

The main objectives here are to determine: (1) whether the service personnel at their current geographic locations can provide eight-hour service coverage for current and future customers; and (2) where the domiciles should be to provide adequate maintenance coverage for current and future Integra installations.

The modeling task begins with preparation of two geographic maps. The first shows the current locations of service personnel and Integra installations. The second map shows a five-year forecast for potential new customer installations, for purposes of identifying where domiciles will need to be in the future. A verbal statement of the two optimization models may be expressed as follows:

Current Model: Determine the minimum number of service personnel domiciles and their locations such that eight-hour service coverage can be provided to the current customers.

Future Model: Determine the minimum number of service personnel domiciles and their locations such that eight-hour service coverage can be provided to current and future customers.

Two versions of each model are considered which differ by the set of candidate locations for domiciles. Candidate locations are those sites that will be included as potential domiciles. This leads to four models as shown in Table 1. In the first version the candidate locations are the current service personnel domiciles. Considering only the current domicile locations provides an answer to the question “What is the best we can do using the current locations of service personnel?” This scenario would entail no personnel relocation or new hiring and involves models 1 and 3 as shown in Table 1.

The second version ignores the current domiciles and is open to all Metropolitan Statistical Areas (MSAs) and Consolidated Metropolitan Statistical Areas (CMSAs) with populations of more than 600,000. There are 68 of these in the continental U.S. (The World Almanac, 1997). The reason for choosing these as the candidate domicile locations is that, with a few exceptions, most of the current and future customers of Integras are concentrated within the major metropolitan areas. This set of candidate locations answers the question “Where should the domiciles be?” This involves models 2 and 4 as shown in Table 1.

<table>
<thead>
<tr>
<th>Customer Coverage Needs</th>
<th>Current Domiciles</th>
<th>Metropolitan Areas</th>
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<tbody>
<tr>
<td>Current</td>
<td>Model 1</td>
<td>Model 2</td>
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<tr>
<td>Future</td>
<td>Model 3</td>
<td>Model 4</td>
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Table 1: Combinations of Coverage Needs and Candidate Domiciles
Each of these four different scenarios involves developing and solving a mathematical optimization model. In general, an optimization model includes one or more objectives and a set of constraints that represent the limitations of the real system, all of which are expressed by mathematical functions. All four models here have the same single objective - to minimize the total number of domiciles. The constraints imposed on this objective include the requirement of providing service coverage to customers. These constraints are developed to ensure that each customer location (be it current or future) can receive eight-hour coverage from at least one domicile.

Then it is impossible or infeasible to provide eight-hour coverage to this customer location, given the set of candidate domiciles under consideration.

Figure 1 shows an example geographic area with two customer locations shown within their eight-hour service radius and five candidate service domiciles. The customer at location 1 can receive alternative service coverage from any of the three candidate domiciles within its eight-hour service radius, whereas it is infeasible to provide an eight-hour service time window for customer at location 2 from any of the five candidate service domiciles.

Mathematical representation of this constitutes the constraint sets for the four models. In this type of model a yes/no decision is being made for each candidate domicile to determine which candidates to choose. This is represented mathematically by decision variables that are either equal to 0 (representing "no") or 1 (representing "yes"). As a result these are known as Binary Integer Programming models. For more details on the integer programming models see Winston (1995).

**Model Recommendations and Analyses**

Having the four models developed, in the next phase they are solved by a mathematical programming package, LINDO (Shrage [1991]). LINDO is designed to solve linear, integer, and quadratic programming problems. While the first two models provide analysis for the current customers, the last two models capture a long-term view of the operation and include the current and potential future installations. Model objectives, recommendations, and analysis are presented as follows:

**Model 1: Analyzing the current domiciles for serving the current customers**

**Objective:** Given the current service personnel domiciles and current Integra installations,
determine the minimum number of the service personnel domiciles from which 8 hour service coverage can be provided to all installations.

**Recommendations:**

- The current domiciles are not capable of providing eight-hour service coverage to 17% of the current installations.
- Of the Integra installations for which service is possible within eight hours (83%), the model analysis suggests that only 38% of the current domiciles are required. These domiciles have a heterogeneous coverage load. Some cover only one customer and others might provide coverage to many installations.
- Geographic locations of the remaining domiciles (62%) render them unnecessary.
- Alternative service coverage from more than one domicile are available to 23% of the installations.

**Analysis:** The first model has identified the inefficiencies of the current system in providing the targeted service quality to the current customers. The results suggest that relocation of the current domiciles is necessary to provide service coverage for all current customers. The relocation decision should be made in concert with homogeneous coverage load for the current domiciles. Also, such a decision must consider alternative service coverage to minimize the chance of a longer service time window when multiple installations covered by a single domicile require maintenance simultaneously. The alternative service coverage scenario becomes more important as the product goes through its life cycle and the time between the breakdowns decreases.

**Model 2: Analyzing metropolitan areas for serving the current customers**

**Objective:** Given the 68 metropolitan areas as potential service personnel domiciles, and the current Integra installations, determine the minimum number of the metropolitan areas from which eight-hour service coverage can be provided to all customers.

**Recommendations:**

- The current domiciles are not capable of providing eight-hour service coverage to 8% of the current installations. This means 8% of the current installations are in areas remote enough to be outside the largest metropolitan areas.
- For the current installation that can be served by the MSAs (92%), only 20 of the 68 metropolitan areas are needed as domiciles to provide service coverage. These domiciles have a heterogeneous coverage load. Some cover only one customer while others might provide coverage to many installations.
- The remaining 48 metropolitan areas are not needed as domiciles.
- Alternative service coverage from more than one domicile is available to 17% of the Integra installations.

**Analysis:** Comparing Models 1 and 2 suggests that Model 2 reduces the service coverage inefficiencies from 17% to 8%. Also, it provides a plan for relocating the current domiciles such that the quality of service is further enhanced. In addition, the company needs to devise a plan to improve service coverage for the 8% of installations in the remote locations. This might be achieved by an expensive proposition, having a dedicated domicile for each of these remote areas. A more reasonable alternative might be to offer a different service time window to the customers in these locations.

**Model 3: Analyzing the current domiciles for serving current and future customers**

**Objective:** Given the current service personnel domiciles, current Integra installations, and regional Integra installations forecast by year 2000,
determine the minimum number of service personnel domiciles from which 8 hour service coverage can be provided to all current and future installations.

**Recommendations:**

- The recommendations presented for Model 1 are valid for this scenario.
- The continental U.S. is divided into nine regions. Five-year aggregate regional sales forecasts are prepared. These forecasts provide no information about specific locations of future installations. However, additional service domiciles are required to provide eight-hour service coverage to future installations.

**Analysis:** When the results of Models 1 and 3 are compared, it is obvious that without a domicile relocation plan the inefficiencies of the current coverage scenario are extended into the future. As further installations are added to the system, the degree of service inefficiencies is increased. A combination of domicile relocation and additional domiciles must be considered to extend service coverage to the regions with sales growth. In the first attempt, a relocation plan should include 68% of the current domiciles that cannot be utilized for an eight-hour service time window. Next, and if necessary introducing additional domiciles, should be studied the enhanced service quality provided to the future customers and customers in the remote locations.

**Model 4: Analyzing the metropolitan areas for serving current and future customers**

**Objective:** Given the 68 metropolitan areas as potential service personnel domiciles, the current Integra installations, and Integra installations regional forecast by year 2000, determine the minimum number of metropolitan areas from which eight-hour service coverage can be provided to all current and future customers.

**Recommendations:**

- The recommendations presented for Model 2 are valid for this scenario.
- The continental U.S. is divided into nine regions. Five-year aggregate regional sales forecasts are prepared. These forecasts provide no information about specific locations of future installations. However, additional service domiciles are required to provide eight-hour service coverage to future installations. This might include domiciles in non-metropolitan areas.

**Analysis:** When results from Models 2 and 4 are compared, it is obvious that without a domicile relocation plan the inefficiencies of the current coverage scenario are extended into the future. The Model 3 analysis is valid for this model too. Knowing that a domicile relocation might interrupt the current maintenance operation and also may be costly, it is recommended that the relocation plan consider the fourth scenario as a basis for making such an important decision. In such a plan, relocation of 68% of the unutilized personnel for an eight-hour service time window needs to be addressed. Also, if necessary, additional non-metropolitan domiciles should be considered for providing service coverage to the growing number of customers. A negotiation process with the customers in the remote locations might be initiated to study the possibilities of a different service coverage target. Most importantly, to create a “reasonable” customer service expectation, it is essential that the marketing and maintenance operations communicate and coordinate their efforts. Managing customer expectations becomes a more important issue as the number of Integra installations increases and the product moves through its life cycle.

**Summary and Conclusions**

The results from the models show that the current
domicile locations are both inadequate and excessive at the same time. They are inadequate in that 17% of the current customer locations cannot be covered within the eight-hour time window, using the current domiciles. New locations are needed to provide coverage for these customers. The current domicile locations are excessive in that 62% of the current domicile locations are not needed. Clearly, strategic relocation of personnel is needed.

The expenses of establishing and operating a domicile are largely fixed. Therefore it is most cost effective for Integra installations to be grouped geographically so that several can share coverage from the same domicile. For a single Integra installation in a remote area, service coverage is an expensive proposition. Either a domicile can be established in the area or a longer time window can be negotiated with the customer to allow a technician to travel farther. A cost effective service operation with the goal of enhancing customer service quality requires coordination of efforts organized by sales and service support units. For many products a sale is a sale regardless of the customer location, but because of the significant expense of supporting Integras, a sale in a remote area is far different from a sale in an area where support is already available. A strategic plan to geographically focus sales efforts is needed in order to facilitate a coordinated growth plan.

This study has shown an example of how location decisions can be made for the multifacility case when the objective is to provide coverage of customer regions with the minimum number of service sites. This involves determining both the number of sites and their geographic locations. It is critical for organizations to have a clear understanding of the strategic and operational implications of location decisions. The location decisions impact capital and operational costs as well as the customer service quality. A systematic approach, such as the one presented in this study, provides opportunity to look into the trade-offs between economic aspects of these decisions without sacrificing the customer service quality. Also, a scientific method to location decisions can provide a multilevel customer service policy that is based on a sound economy and allows effective management of the customer service quality expectations. Implementation of a successful multilevel customer service policy requires close coordination of the sales and service support organizations.

While the facilities being located in this application are domiciles, a wide variety of other types of facilities can be located using the same approach, such as distribution centers, sales offices, medical facilities, etc. Facility location decisions can have a variety of other objectives such as minimizing transportation costs, maximizing market share, minimizing total inventory and logistics costs, etc. However, regardless of the application or objective of a location study, the use of mathematical optimization models can be essential for analyzing the big picture and finding the best solution for the overall system.

References


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