

REGIONALIZATION OF BLOOD

BANKING SERVICES

Executive Summary

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REGIONALIZATION OF BLOOD BANKING SERVICES

Executive Summary

The work on this grant was conducted in response to two important essentially unresolved questions facing the American blood banking community. First, why should or should not blood banking be regionalized? Second, if regionalization¹ is warranted, what are the most cost-effective ways to proceed? In addition, it was felt by many in the industry that there were serious inadequacies in the blood service system of metropolitan Chicago and there was insufficient knowledge of both the quantitative and qualitative aspects upon which to base any changes which might improve the situation.

These issues take on importance because of the high rates of outdated facing the nation, the chronic periodic shortages of blood and components, the increasing difficulty of broadening the volunteer donor base to meet rising demand and the potential economies of scale in certain blood bank activities. Many leaders in the blood banking community feel that some form of regionalization may be the answer. But what factual data do we know about these issues?

In order to understand the organization and operation of a regional system and measure its economic impact, data was gathered from the seven Chicago metropolitan blood centers and 66 Chicago area hospitals as well as five other regional blood centers from around the nation.²

The ultimate aims of the study were to provide an understanding of some of the implications of various regional structures and a basis for planned change in a region when such change is warranted. This planning takes the form of determining which blood banking functions should be performed at what locations, which donor areas and transfusion services should be assigned to which community blood centers,

¹ The definition of regionalization used in this study is the same as that given by the American Blood Commission Task Force on Regionalization. Regionalization: The coordination of blood services within a geographic area for the purpose of achieving improved effectiveness and efficiency through the voluntary establishment of cooperative arrangements. Effectiveness: The extent to which an adequate supply of blood of satisfactory quality is made available in a manner that maximally benefits patients. Efficiency: The accomplishment of several coordinated blood service units in bringing blood to patients with a minimum of friction and the minimal consumption of resources, i.e. manhours or dollars.

² The community blood centers were the Los Angeles-Orange Counties Red Cross Blood Center, Minneapolis War Memorial Blood Bank, Milwaukee Blood Center, Inc. (now the Blood Center of Southeastern Wisconsin), New York Blood Center, St. Paul Regional Red Cross Blood Center, Michael Reese Research Foundation, Aurora Area Blood Bank, North Suburban Blood Center, United Blood Services, Mid-America Regional Red Cross Blood Program, Jacob Blumberg Memorial Blood Bank of the Lake County Medical Center, and Beverly Blood Center.

how many community-blood centers should be in a region and where they should be located and how the supply and demand should be coordinated.

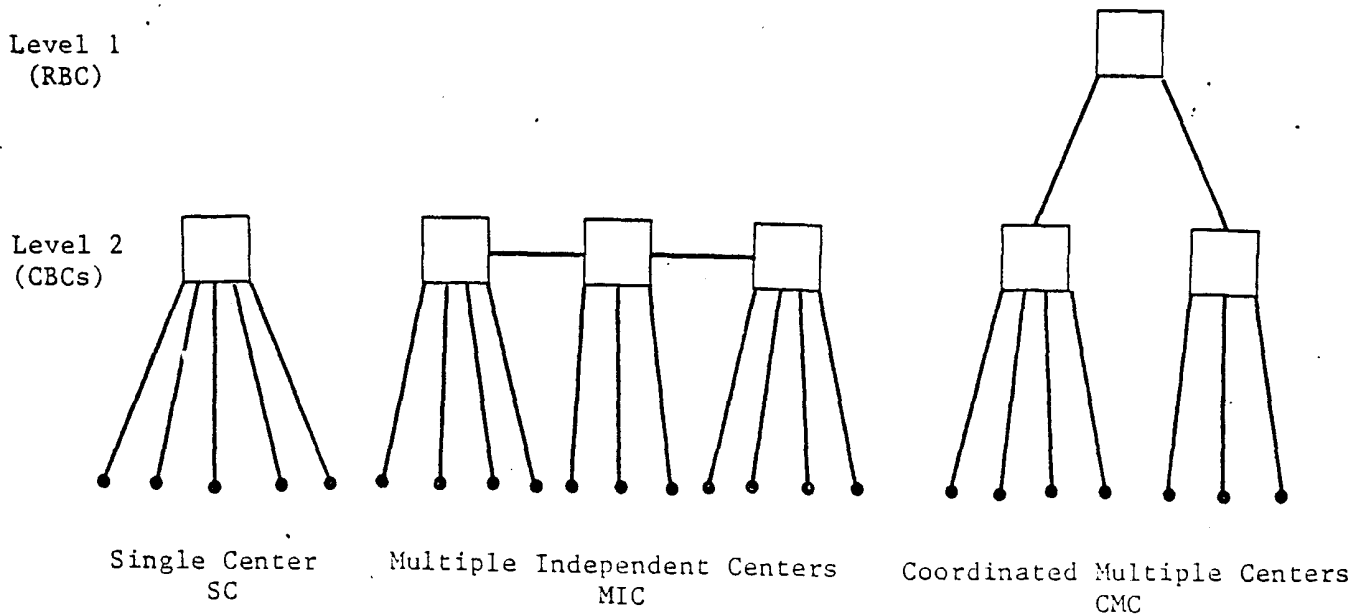
Before discussing the data and its subsequent analysis, let us consider the various regional system models and functions.

System Models

There are three basic models which alone or in combination represent most blood banking systems: (I) the single center (SC) model, a single community blood center which services the entire needs of a particular region; (II) the multiple independent centers (MIC) model, a collection of communicating community blood centers under independent control, which service the blood needs of the region; and (III) the coordinated multiple centers (CMC) model, a regional blood center which either coordinates or controls the activities of a collection of community blood centers which in turn fulfill the needs of the communities in that region. These models are depicted in Figure 1. As a general rule, as the size of a region changes due to an increase in demand or geography, the single community blood center may not adequately fill the needs of the region and one of the other two structures will tend to replace it over time.

Figure 1

Basic Regional System Models



A Single Community Blood Center for Entire Region, the SC Model

A single community blood center provides all the blood services for a network of hospitals in a specified geographical region. The managerial control of the services to the network of hospitals is exercised or coordinated through the single central facility. The degree of control depends upon which activities are performed at the community blood center or at its member transfusion services (TSs) and upon whether or not the central facility maintains "authority" over the units in the unassigned inventories at the TSs.

This is an issue of central importance since the management of inventories of whole blood and components involves a complex and often interrelated set of decisions concerning the collection, processing, record keeping, storage, issuing, and transportation of units.

A Collection of Independent Community Blood Centers for a Region: The MIC Model

Since each CBC is independent, it faces all of the management problems of the SC model and in addition, it must decide on what levels to compete against or cooperate with the other CBCs.

The additional costs of this system are (I) lack of economies of scale since CBC size is established by non-economic considerations, (II) overlapping jurisdictions for donors and transfusion services, (III) duplication of facilities, services and personnel, and (IV) confusion among donors, recipients and physicians.

A possible benefit of this system might be the independence and autonomy available to TSs to bargain for extra services (at a higher cost perhaps) and less rigid organizational rules for the system's management.

A Collection of Community Blood Centers Controlled or Coordinated by a Regional Blood Center, the (CMC) Model

This generic regional system, is an extremely flexible organizational structure with regard to the work location of the functional areas and the degrees of control/coordination exercised by the RBC. In this latter regard, the RBC could be simply a shared service for such functions as unified donor recruitment, information/data processing and/or educational training programs. At the other extreme the RBC could carry full authority for the operation of the entire system.

This flexibility stems from the addition of a third layer to the hierarchy and the apportioning of the different functions of the system between the two levels.

The functional areas which have major impact on the cost and efficiency of operation are: information systems, donor services, phlebotomy, processing, inventory management, and distribution. It is recognized that while administrative activity also contributes to cost, its component in each functional area can not be separated from the area. Table 1 illustrates some of the range of coordination/control available in the CMC model.

TABLE 1

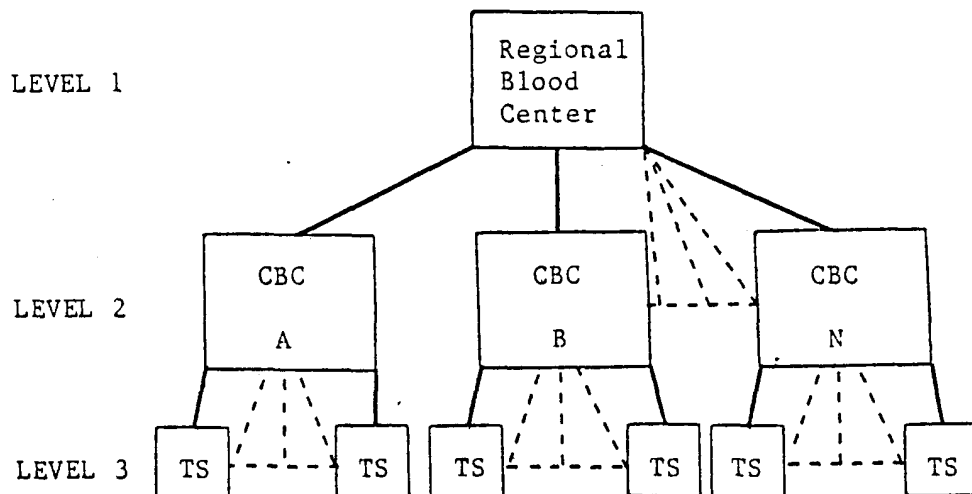
| <u>Degree of Authority</u> | <u>Activities</u> |
|----------------------------|--|
| Coordination | Gather data and disseminate to CBC's Conduct Educational Training Programs for CBC's and TS's Hold Periodic meetings for CBC directors, etc. |
| Full Control | Determine and enforce donor services policies at all levels Hire all CBC directors Approve all CBC budgets Determine all CBC functions Plan and initiate all regional changes to meet needs. |

Within this generic structure, in addition to the differing degrees of authority the performance of some of the various blood banking functions can be located at the RBC (Figure 2, level 1) and the remainder at the CBCs (Figure 2, level 2). A separation of the locations of the different functional components may be necessary to achieve overall optimalite for a given set of circumstances. The optimal separation may be affected by such factors as geography, facilities size limitations, or political considerations. The appropriate structure for any area depends on a complex interaction between the level of activity, the economies or diseconomies of scale, the cost effectiveness and efficiency as well as the interactions of the interested parties. We will now analyze the impact of size, authority, and allocation of functions on the different costs of blood banking activities in a region. The main determinants of the costs are the personnel, space, and the equipment used to carry out the activities of the blood center(s). We have concentrated primarily on the personnel costs, since they represent the largest amount of variable costs under the control of the administrator, and also since the space and equipment costs are indirectly reflected in the organizational structures and the number of personnel available to do the various tasks.

The various functional areas can be considered for assignment to either level 1 or level 2 of Figure 2. The rationale for any particular assignment of functions involves trade-offs between their utility and their cost at each level. The assignments chosen for analyses and illustrated in Table 2 represent a step-by-step allocation of functions from CBCs to the RBC. This approach was taken because it is often the case that regionalization will take place by an evolutionary change in the status quo of an existing system rather than from the development of a system de novo, or revolution. Although the analysis in this paper applies to these latter systems also. We will now discuss the regional options shown in Table 2.

The simplest form of regionalization is option 2 where the only truly regional functional activity is a coordinated donor recruitment system. This first step in moving from the MIC model to the CMC model implies that the blood centers maintain identity, continue as separate corporations and operate under separate licenses.

REGIONAL STRUCTURE



Hierarchical Regional Structure

Figure 2

Table 2

| <u>Option</u> | <u>Functions at RBC (Level 1)</u> | <u>Functions at CBC (Level 2)</u> |
|---------------|---|--|
| 1. | None | Inventory and Distribution, Processing, Phlebotomy at Center, Phlebotomy on Mobiles and Donor Services (this is equivalent to the MIC of Figure 1) |
| 2. | Donor Services | Inventory and Distribution, Processing, Phlebotomy at Center and Phlebotomy on Mobiles |
| 3. | Phlebotomy on Mobiles and Donor Services | Inventory and Distribution, Processing and Phlebotomy at Center |
| 4. | Processing, Phlebotomy on Mobiles, and Donor Services | Inventory and Distribution, and Phlebotomy at Center |
| 5. | Processing, Phlebotomy at Center, Phlebotomy on Mobiles, and Donor Services | Inventory and Distribution |
| 6. | All Functions (this is equivalent to SC of Figure 1) | None |

While this appears to be only a modest change, in order to function well, there must be single donor recruitment effort with a philosophy and approach to donors arrived at by consensus of all the participating CBCs. In addition, any information that will flow in the system must be uniform and requires that the participating blood centers be willing to share their information, gather and maintain it in an integrable form at the RBC.

It is possible that the regional coordinating center be a separate corporation formed by the CBCs for the purposes of unified donor recruitment, equitable allocation of donor sources and not be tied to any of the functional components of a "we blood bank. The format of option 2 is likely to be the logical first step in regionalization in an area where there are well developed independent blood center with a history of brisk competition. The most important disadvantage to this system is that the donor scheduling functions must interdigitate with the phlebotomy function across a structural division. The donor recruitment function must work closely with the inventory management functions to predict and meet short-term demands and with general management to plan for anticipated long-term changes in demand.

Option 3 adds the responsibility for phlebotomy on mobile blood drawings to those already housed in the RBC while the processing remains at the community blood centers. There are advantages to be gained from this seemingly artificial separation of apparently closely linked other functions such as, processing and inventory management.

Housing the regional mobile phlebotomy staff at one central location has the advantage of permitting the most efficient use of personnel and permits the easy re-allocation of staff in response to last minute changes in staffing requirements.

Similar flexibility in mobile equipment and personnel vehicle dispatching and scheduling can derive from a centrally located vehicle pool. Finally, central location of the mobile phlebotomy personnel permits closer scrutiny of performance and engenders greater consistency and a higher level of quality control than a decentralized staff with its additional layer of liaison management personnel.

The separation of mobile phlebotomy from processing simply requires the separation of delivery of blood to the processing labs from the delivery and pick up of the mobile drawing equipment.

There are disadvantages to separating the in-house phlebotomy (in option 3 this is housed at the CBC) in the area of staff education and supervision. Also there may be the requirement of separate recruiting staff for the CBC in-house phlebotomy activity.

The choice between option 3 or option 2 must be made only after assessing the trade-offs involved. These hinge on the advantages versus disadvantages of the in-house phlebotomy function at each center each responding to its individual demands.

The maintenance of the in-house phlebotomy activity under this format is more likely to derive more from the need to decrease the inconvenience to donors by eliminating long travel distances to the RBC or to take advantage of the community

identification in recruiting donors rather than the need to bring in donors for the purpose of making up type specific blood shortages. This latter activity will more likely be undertaken by the in-house phlebotomy function at the RBC. The separation of function required in option 3 has an important ramification which will have serious impact on the cost of operation and the structure of the administrative support. This is the fact that the Bureau of Biologics of the Food and Drug Administration requires that the licensee responsible for the phlebotomy be responsible for the processing. The most feasible and realistic form of implementation of option 3 (4 and 45 as well) is one in which the CBCs and the RBC all operate under one license and belong to one corporation.

Option 4 moves blood processing to the RBC while continuing in-house phlebotomy at each of the CBCs along with inventory handling and distribution. This format appears to decompose the system into a SC model with satellite donor drawing stations and blood depots. This format is one which arises when the RBC in the SC model recognizes that its service area has expanded to include geographic areas with either disproportionate increases in transportation costs or unacceptable delays in response to orders. This could arise when the services are provided in large rural areas or metropolitan areas with several travel restrictions such as rivers, bays, mountains, or other factors leading to large geographic travel times.

The maintenance of the in-house phlebotomy activity under this format is more likely to derive more from the need to decrease the inconvenience to donors by eliminating long travel distances or to take advantage of the community identification in recruiting donors rather than the need to bring in donors for the purpose of making up type specific blood shortages. This latter activity will more likely be undertaken by the in-house phlebotomy function at the RBC.

The arguments about the locus of the recruitment staff presented for option 3 hold for option 4 as well. The transportation problems are somewhat different. The RBC now has the transport functions of delivery and retrieval of mobile teams, retrieval of blood units drawn, delivery of processed blood to CBC (depots), and pick-up of unprocessed blood at CBC in-house drawing facilities. The transport function of the CBC is limited to the movement of blood between the CBC and the transfusion services allocated to it as well as the transshipment of blood among transfusion services. Option 4 has all the advantages of centralized processing with the potential economies of scale in use of staff and equipment, greater consistency, more effective quality control, etc. These benefits are affected by the greater magnitude of the transportation costs. The trade-off between these costs and benefits must be assessed in concert with all the trade-offs in the step-wise progression through the preceding options.

Option 5 moves all phlebotomy to the RBC and the CBC (now, truly, a misnomer) serves simply as a depot with very simplified function. Control of virtually all activities has passed to the RBC. The only information flow between the RBC and CBC pertains to blood in inventory levels, vehicle maintenance, etc. Again, option 5 is one which would grow from the SC model where the response to increase in demands, either of volume only or volume and geography, were problems of inventory allocation and shipment. Also, the transshipment costs among TSs would have increased to the point at which they were greater than the problems and costs of maintaining satellite blood distribution depots. Option 5 would be most applicable to an RBC with a large rural constituency of TSs.

Option 6 consolidates all functions in the RBC. In this case the RBC is a single center and there are no CBCs.

To recapitulate, these six options of the CMC (coordinated multiple centers) model of a regional blood system represent the spectrum between "option zero," the multiple independent center (MIC) model with no coordination, step-wise through increasing centralization of functions to option 6 the single center (SC) model. The constraints forcing merger and consolidation with major changes in management, image and governance grow and peak with option 3. Options 4 and 5 represent a partially decentralized form of the SC model in which the advantages of the decentralized model may outweigh the costs.

It is important to keep in mind that this study emphasizes quantifiable considerations but recognizes that there are non-quantifiable (i.e., qualitative) factors such as image, degree of market saturation and political considerations which may weigh against pure costs in the decision making process.

Not included in this discussion of the various options are the special functions such as the antibody identification or consultation service, and other functions which are characterized by infrequent and random demands for either rare products or special services, such as HLA typing, random or specific donor platelets and/or granulocytes, and rare red cell phenotypes. These services clearly are best provided in a regional setting since the most efficient provision of these services require a high level of expertise and some minimum number. Regionalization of the activities requires the least redundancy in expertise and provides sufficient numbers of the unusual services to create the critical mass necessary to maintain the availability and proficiency of the service.

Data

Data for the years 1975, '76, and '77 were requested from the 7 Community Blood Centers and 115 hospitals with transfusion services in the Greater Metropolitan Chicago (GMC) area and 5 Community Blood Centers around the nation. All community blood centers responded and 66 hospitals responded. Partial data from 45 of the non-responding hospitals was available in the responses of the CBCs with whom they have a "total service" arrangement. Some of the highlights from this data are presented below. Although limited in amount, the data will lead us to some conclusions as to why an area should or should not regionalize and if warranted, what forms of regionalization seem reasonable to consider.

This data was analyzed according to the functional areas listed earlier using regression models to determine where economies of scale exist and to predict the cost of operation of the system under each of the three basic models described earlier. Further, within each model the cost of operation of the system is assessed with the various options of hierarchical distribution of functional areas shown in Table 2. The results of the analysis of this data is presented in the section entitled "Economies of Scale."

Drawings and Transfusions

As noted in Table 3, the rate of increase in drawings from 1975 to 1976 was

greater than from 1976 to 1977. For the larger centers these rates of increase range from 7% to 11% for 1975 to 1976 and only 2% to 3.5% for 1976 to 1977. Clearly there isn't enough data to see if this levelling off reflects a national trend or just a one year variation. If there is a levelling off it may be due to a saturation of the donor market, changing therapeutic needs with a shift toward more component use and a correspondingly better utilization of the total blood resource, and/or a stabilizing in the demand for red cells.

TABLE 3
Phlebotomy

| Geographic Area | 1975 Population SMSA (000's) | 1976 Phlebotomy as of % of 1975 Population | Phlebotomy | | |
|--|------------------------------|--|------------|---------------|-------------|
| | | | 1975 | 1976 | 1977 (est)* |
| GMC | 7,015 | 4.58 | | | |
| I) all community blood centers | | | 196,763 | 234,358 | 247,871 |
| II) Reporting Hospitals | | | 50,656 | 39,704 | 35,196 |
| III) Estimates for non reporting hospitals | | | NA | 47,146** | NA |
| IV) Total (est.) | | | NA | 321,208 | NA |
| Los Angeles RC | 6,987 | 4.44 | 290,544 | 310,241 | 318,841 |
| Milwaukee B.C. | 1,409 | 5.96 | 82,908 | 83,986 | 83,944 |
| Minneapolis W.M. | 2,011 | 9.09 | 38,858 | 42,556 | 43,033 |
| St. Paul R.C. | | | 138,828 | 140,211 (est) | NA |
| New York B.C. | 9,561 | 6.50 | 572,315 | 621,600 | 636,167 |

* For most blood centers the 1977 data covered only part of the calendar year. These figures are a projection of the 1977 figures furnished by the centers.

** Estimate based on three month actual data and adjusted to twelve months by proportionality, to reporting hospitals.

It is difficult to assess whether the donor markets are saturated. In the largest SMSAs (Chicago, Los Angeles and New York) the percentage of the total donated blood to the population varies between 4.2% and 4.6%. In the smaller SMSAs (Milwaukee and Minneapolis-St. Paul) the percentage is 6% or more of the population. Except for St. Paul all the regions are net importers of blood for use by their transfusion services. Consequently, the myth that "if the percent of donated blood to the total population is 4%, the region will have enough blood for its needs" is not justified by the data. If the 1976 phlebotomy data are adjusted for the net difference in imports-exports for each region then an estimate for the percentage of the population to make a region self-sufficient is between 4.7% and 6.2% depending upon regional demands.

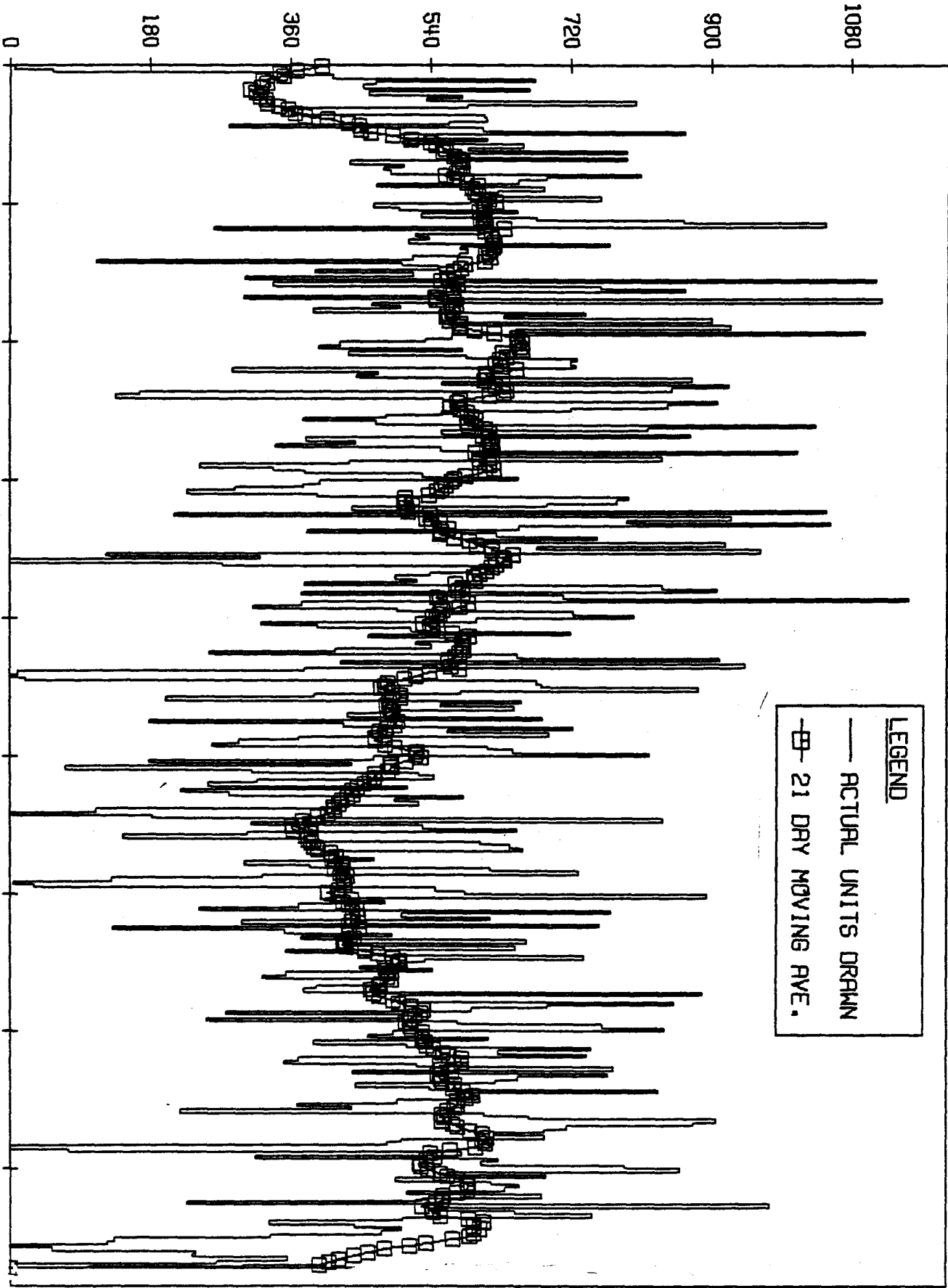
There are data which show that there are changing therapeutic needs with a shift toward more component use and a correspondingly better use of the total blood resource. Consequently, the possible stabilizing of the rate of increase in drawings may be caused by a shifting of demand from whole blood to component therapy.

On the other hand, if there is a stabilization occurring in the drawing of whole blood and if this is being caused by the leveling of demand for red cells rather than a saturation of the donor market, then from the drawing side of the picture, there may be less reason to regionalize. However, this conclusion based on the three years of data doesn't illustrate the most important aspects of regionalization, namely, (I) the great variation in daily and monthly drawings, (II) the great variation in daily, weekly, and monthly transfusions, and (III) the need to smooth these fluctuations and coordinate the drawings with the transfusion demands. It is at this point that a non-regional system tends to be inefficient. To illustrate what is meant figure 3 shows the daily fluctuations in drawings for the seven blood centers in the greater metropolitan Chicago (GMC) area. These fluctuations are not coordinated among the centers and there is no attempt to smooth the daily available supply of whole blood. Consequently, there are times when all centers have surplus; some centers have surpluses while others have shortages and all centers have shortages. If it were possible to shift some drawings and reallocate the supplies of whole blood then many of the fluctuations could be smoothed.

Figure 4 shows the daily demand for O+ blood in a major Chicago medical center. In this center other ABO-Rh groups show even greater daily fluctuations. Consequently the suppliers of this medical center (including its own donor recruiting staff) face large fluctuations in the need to maintain adequate inventory levels.

Fortunately, except for times of major disasters, the fluctuations in a region tend to average out as the daily demand of more and more transfusion services are added together. Consequently, the total demands in a region tend to be much smoother for non-rare bloods than the demand reflected in Figure 4. Because of this, a regional coordination and smoothing of donor drawings in concert with regional demand predictions and optimal inventory control policies would tend to eliminate most shortages and almost all frantic telephoning among centers and transfusion services. In addition, outdated units could be held to a minimum. It should be noted, all reporting hospitals in the GMC area with red cell demands greater than 4,000 units annually did some of their own phlebotomy and processing. In this way, these hospitals hedged against shortages at the centers.

Number of Units Drawn



LEGEND
— ACTUAL UNITS DRAWN
— 21 DAY MOVING AVE.

DAILY PHLEBOTOMY BY ALL CBCS IN THE GMC AREA

FIGURE 3

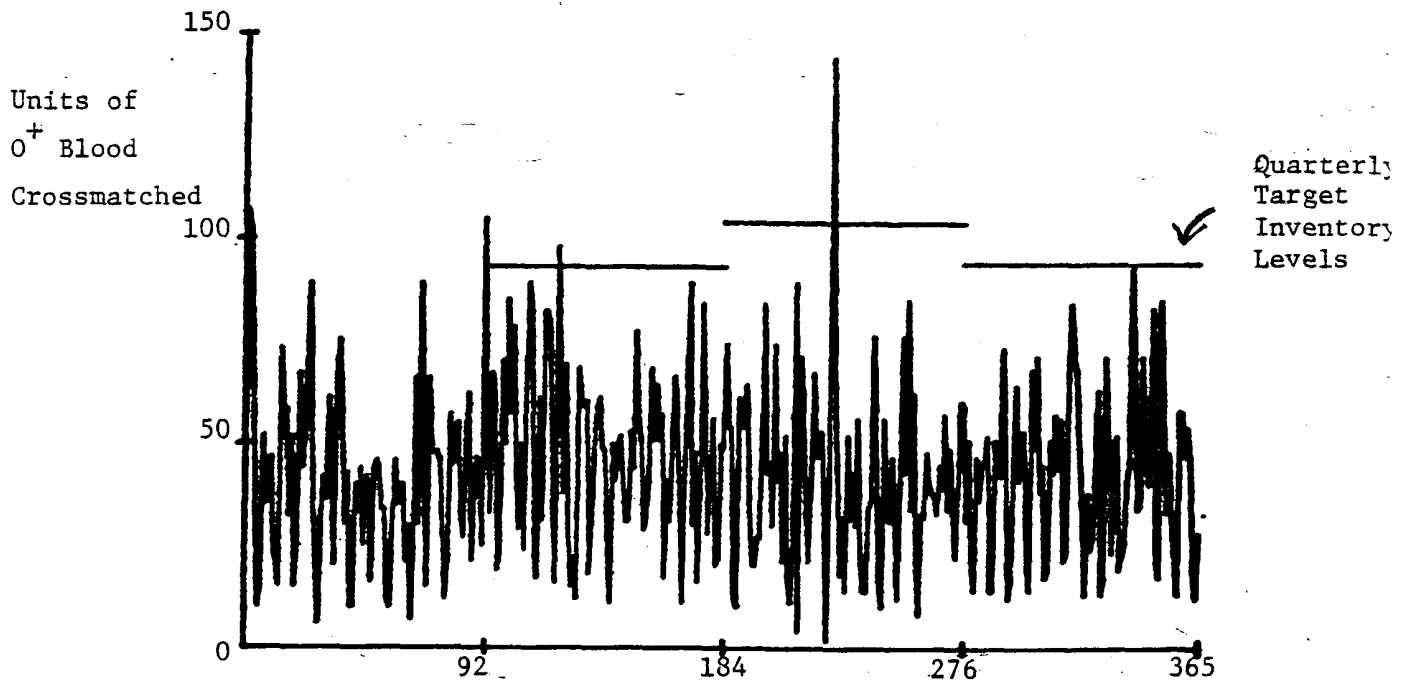


FIGURE 4: Daily Units of O⁺ Blood Crossmatched at a Large Metropolitan Medical Center (with Target Inventory Levels Indicated)

Component Production and Transfusions

Whereas the drawings of whole blood may be indicating a low growth rate, the manufacture of blood components and their use in transfusions from 1975 through 1977 has shown rapid growth. The significant changes from 1975 through 1977 concern the large increases in the quantity and proportion of packed red cells, platelets and fresh frozen plasma transfused. These changes reflect more effective utilization of the blood resource but also indicate the need for more management of this resource.

Daily demands for the various components were not collected in this study. However, in an earlier study the demand for platelets in a large medical center was analyzed and even greater variation than the demands for red cells was observed. Consequently, the smoothing of platelet demands by adding the needs from many transfusion services could aid greatly in determining the daily production of platelets.

Outdates

Some regions experience considerable more outdating of red cells than others. Since the causes of outdating involve a complex relationship among drawings, invent

levels, transfusion to crossmatch ratios, crossmatch release times, transshipment among hospitals, etc., it is not possible to say which causes are primary in a given region. The culprits are often the wide fluctuations in supply and in demand but also inventory control and distribution. In all cases systematic management can aid greatly in the reduction of outdates by : (I) coordinated donor scheduling, (II) coordinated supply of hospitals, (III) establishment of accurate target inventory levels, (IV) control of the transfusion-crossmatch ratio and crossmatch release times and, (V) transshipments to anticipate shortages or outdates.

Staffing

To analyze the staffing levels at the blood centers, several factors had to be considered. Not every center performed the same tasks or produced the same proportions of components. However, each center handled donor services, phlebotomy on mobiles and at the center, processing and inventory control and distribution. In addition, each center had administrative and housekeeping staffs.

To compare the workload at centers across functional activities with regard to different proportions of components, a study of the times required to make the different components was undertaken. Using the results of these time studies, time-weighted volumes of activity were defined for each blood bank function and each center. In this manner, it was possible to compare the activities at all the centers. The common measure used in this comparison was the manhours per weighted unit for each functional activity.

Manhours per unit rather than dollar costs per unit was chosen as the basis of measurement to compare the "costs" at the twelve CBC's in the study. Manhours remove the need to adjust dollar costs for the different wage rates experienced throughout the country. Great variation in the manhours per unit occur across centers. Some of this variation is due to economies of scale discussed in the next section, geographic distance, saturation of the donor market, style of management, and expansion dislocations.

Economies of Scale

If regionalization is to be effective it must make a positive contribution to the solution of one or more of the following: reduce costs, reduce shortages and outdates, reduce extra-regional dependencies, improve the quality of the products, and/or reduce the confusion of overlapping jurisdictions. A search for economies of scale was thought to be the most logical starting point to analyze these factors. We have already noted that by well planned operations, regionalization can reduce shortages and outdates by smoothing the supply and demand fluctuations.

As mentioned above because wage rates, depreciation, costs of supplies, rent, utilities and other costs vary greatly from one region to another, costs expressed as manhours per unit were used to derive the production function for each functional area of blood banking and for combinations of functional areas. The combinations of

functional areas are the options designated 1 to 6 in Table 2.

It was hypothesized that economies of scale exist in all functional areas with the possible exception of donor services. In donor services as the geographic area expands and the donor market reaches a saturation level, it was hypothesized that more and more donor recruiter hours are needed to obtain the additional units of blood.

It was found that the economies of scale hypothesis was reasonable for phlebotomy at the center, mobile phlebotomy and inventory/distribution and to a lesser extent administration. No strong conclusion about economies of scale could be drawn concerning processing and donor services.

When all of the functions were combined, as in a single center, economies of scale exist and are significant.

Since the study was undertaken to examine regionalization, the specific functional areas play no direct role in the evaluation of regional economies of scale (except for the two cases inventory and distribution in option 5 level 2 and donor services in option 2 level 1 where the single functional areas coincide with a part of an option). The options which correspond to specific regional organizational structures ranging from totally centralized activities to totally decentralized activities are the critical structures to be examined for economies of scale. Figures 5a and 5b show the least squares regression curves. These curves clearly exhibit economies of scale. In particular, at the lower volumes (10-50,000 red cell units annually), the economies of scale are very significant. From 50-75,000 units economies of scale are not as dramatic. Above 75,000 units the curves tend to flatten out but still show some small economies of scale; caution should be exercised in using the curves much past 200,000 units since they were derived with only four data points.

Essentially this analysis leads to two related conclusions. First, a regional system with community blood centers which are operating below 50,000 annual red cell units can realize significant economies of scale by increasing volume; this increase in an MIC region could come about by merger of small centers with larger centers. These economies of scale come from a more efficient utilization of space, equipment and vehicles, specialized skills and learning curve effects. Second, for all options a regional system with one community blood center is more economical than two, two are more economical than three, etc. The example in Table 4 shows that for option 1 (an MIC region) none of these community blood centers should operate at less than 50,000 red cell units annually. Thus a regional with slightly over 200,00 units annually is operated most economically with one center. The costs of two or three community blood centers (even if all are over 50,000 units) rises rapidly.

Similar results hold for all options as shown in Table 5 for the examples where a region has 2, 3 or 7 community blood centers.

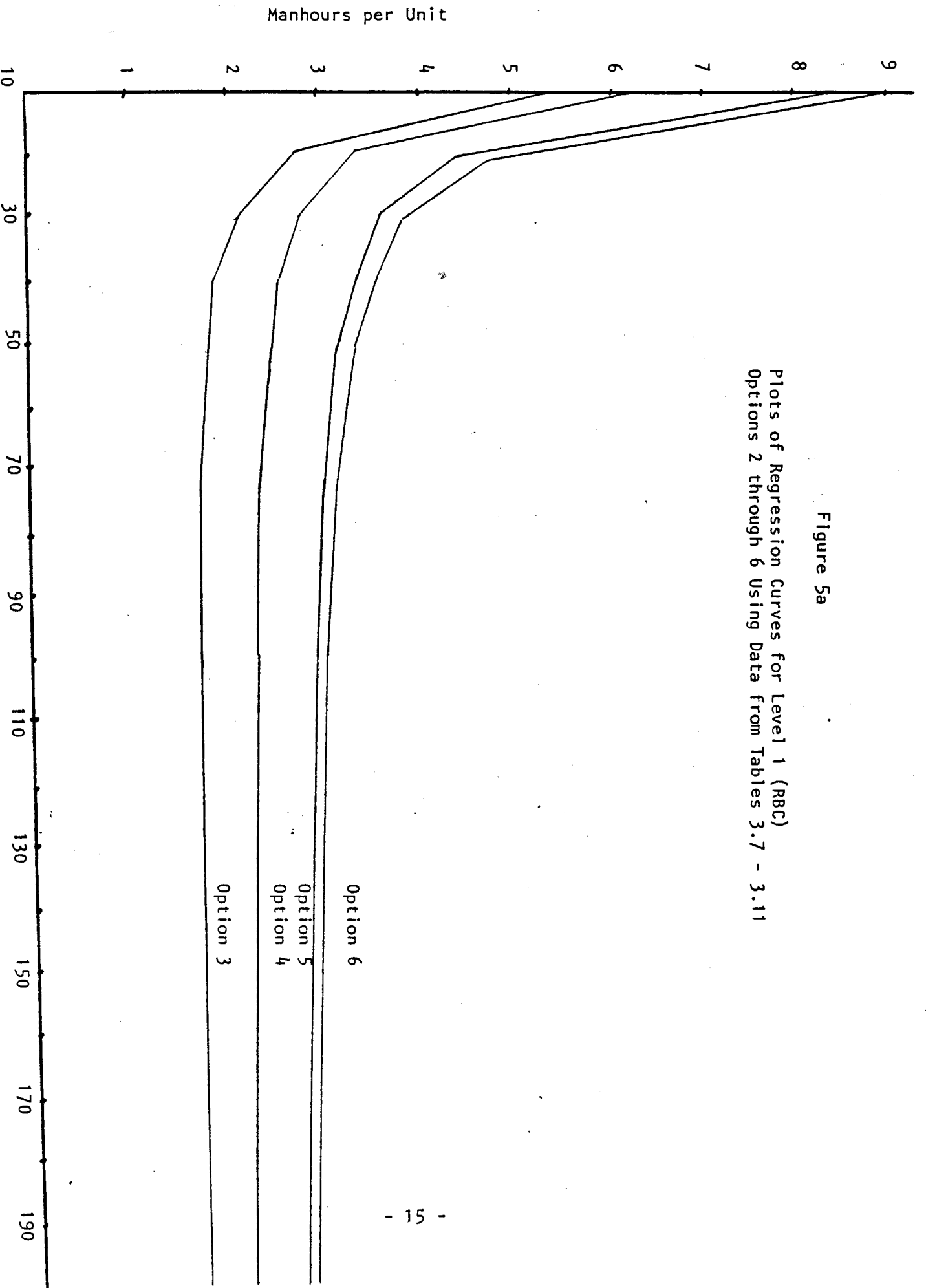


Figure 5a

Plots of Regression Curves for Level 1 (RBC)
Options 2 through 6 Using Data from Tables 3.7 - 3.11

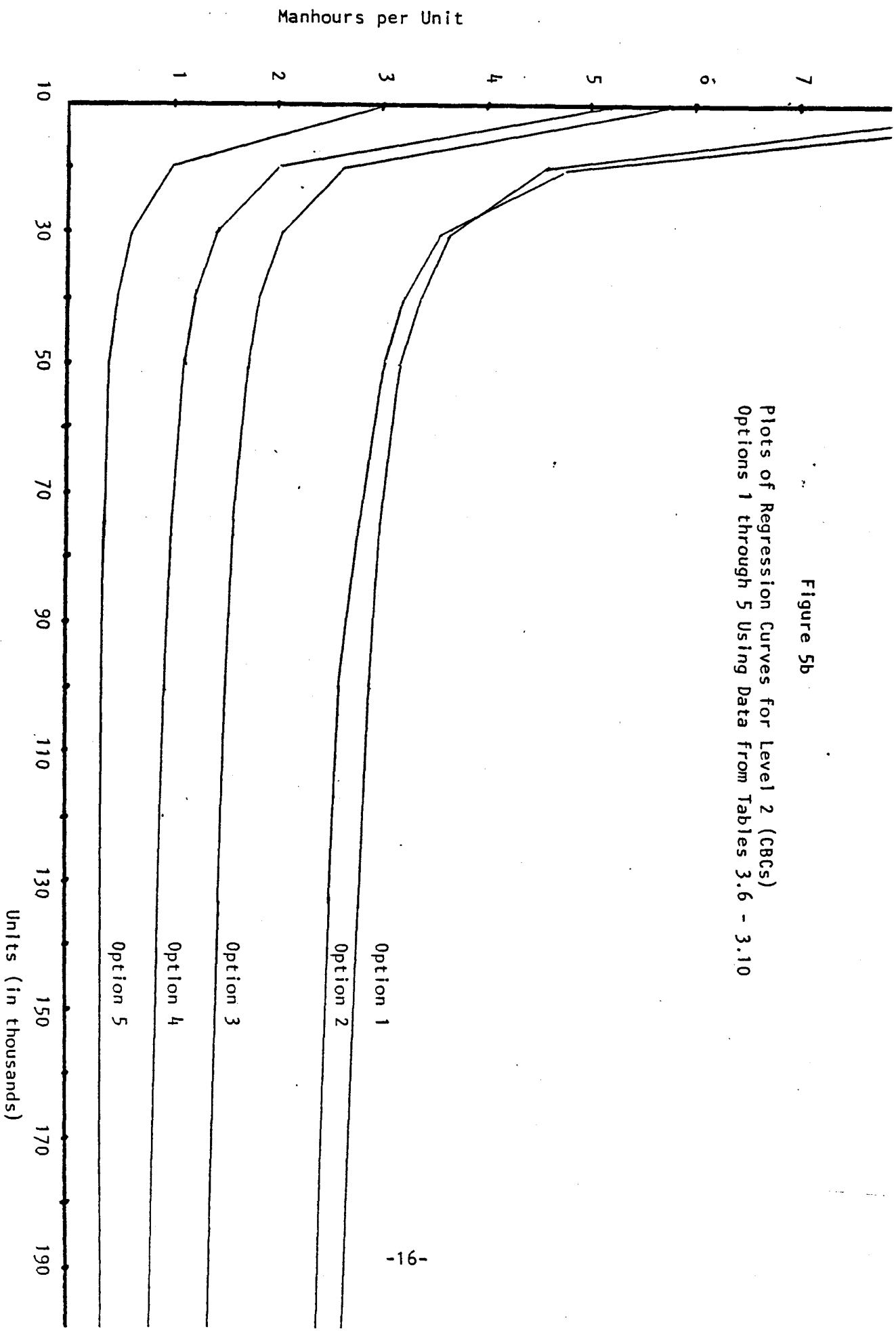


Figure 5b
 Plots of Regression Curves for Level 2 (CBCs)
 Options 1 through 5 Using Data from Tables 3.6 - 3.10

TABLE 4
 Example of the Manyears Needed in A Regional System
 Drawing 234,000 Red Cell Units Annually
 Using Option 1

| <u>Number of Centers</u> | <u>Annual Volume at Each Center</u> | <u>Total Regional Manyears</u> | <u>Difference</u> | |
|------------------------------|---|------------------------------------|-------------------|-------------------|
| | | | <u>Net</u> | <u>Cumulative</u> |
| 1* | 234,000** | 302 | | |
| 2 | 117,000 | 332 | 30 | 30 |
| 3 | 78,000 | 349 | 17 | 47 |
| 4 | 58,500 | 365 | 16 | 63 |
| 5 | 46,800 | 380 | 15 | 78 |
| 6 | 39,000 | 396 | 16 | 94 |
| 7 | 33,000 | 415 | 19 | 113 |
| 8 | 29,250 | 435 | 20 | 133 |

* Option 1 when it has only one center is the same as option 6.

** Note: The seven Chicago community blood centers handled 234,000 weighted units in 1976 and used 416.5 manyears. However not all of the seven centers are of equal size as the example above has assumed.

Table 5

Example of the Man Years Needed in a Regional
System Drawing 234,000 Red Cell Units Annually
Using Options 0 through 6

| <u>Option</u> | <u>Man Years at RBC (Level 1)</u> | <u>Man Years at CBCs</u> | | | <u>Total System Man Years RBC Plus</u> | | |
|---------------|---------------------------------------|--------------------------|--------------|--------------|--|--------------|--------------|
| | | <u>2CBCs</u> | <u>3CBCs</u> | <u>7CBCs</u> | <u>2CBCs</u> | <u>3CBCs</u> | <u>7CBCs</u> |
| 1 | 0 | 332 | 349 | 415 | 332 | 349 | 415 |
| 2 | 35** | 304 | 324 | 405 | 339 | 359 | 440 |
| 3 | 186 | 172 | 184 | 230 | 358 | 370 | 416 |
| 4 | 235 | 103 | 113 | 155 | 338 | 348 | 390 |
| 5 | 296 | 37 | 40 | 64 | 333 | 336 | 360 |
| 6* | 302 | 0 | 0 | 0 | 302 | 302 | 302 |

*Option 6 means there is only one RBC and no CBCs.

**Includes 31 man years for donor services, plus 4 man years for information processing.

In each example the total system manyears are minimized with one center (option 6) but if two at more centers are preferred for some reason (political, geographic, historical etc.) then option 5 or option 4 is a better organizational structure for the region than are options 2 or 3. Option 1 compares favorably with options 5 or 4 only when there are two CBCs.

The donor services functional area did not exhibit statistically significant economies or diseconomies of scale for the survey data from the twelve community blood centers. There may be several reasons for this inconclusiveness but two of the main reasons may be that (i) donor services manhours per unit recruited must be explained by a wider variety of independent variables such as the physical size of the region, the saturation of the donor market, the number of large, medium and smaller donor groups, the demographic characteristics of the population, and (ii) the competition for donors. Each of the five non-Chicago community blood centers had a reasonably well defined donor region with no competition from other centers. The Chicago community blood centers often find themselves in a competitive situation with extensively overlapping donor area.

In another study we analyzed the labor costs of collection and donor services from the American National Red Cross (ANRC) program operations reports for 1974-5 and 1975-6 for all their centers. In this analysis, some weak economies of scale were observed in donor recruiting and collecting for volumes of activity up to 150,000-200,000 units and it appears that diseconomies arise above these levels. Since the ANRC data were in dollars and since it wasn't possible to tell whether the ANRC data used the same definition as in this study involving the twelve community blood centers, we could not use these results directly in this study.

Possible Regional Structures and Their Benefits

In the preceding discussion some benefits of a regionalized structure were shown to be: smoothing of the supply of blood from donors and a reduction in competition for donors, smoothing of the demands faced by a community blood center for blood and components by averaging the demands from many transfusion services, economies of scale by operating community blood centers at levels above 50,000 units annually. These benefits would lead to reduced shortages, outdated and costs.

The economic benefits of different regional structures were also examined with a location-allocation distribution model which takes as inputs the locations of transfusion services in a region, the distances separating them and their whole blood and component needs. The user then specifies the number of community blood centers to be evaluated (from 1 to 10) and their locations. In addition, the user specifies the desired option from Table 2 to be evaluated. The allocation of hospitals to the centers was made using the transportation-location-allocation model for regional blood banking developed as a part of this study. An example of one run of the computerized model is shown in Figure 6.

In this figure, the loops indicate which transfusion services are assigned to which community blood center to meet the demands for blood at minimal cost.

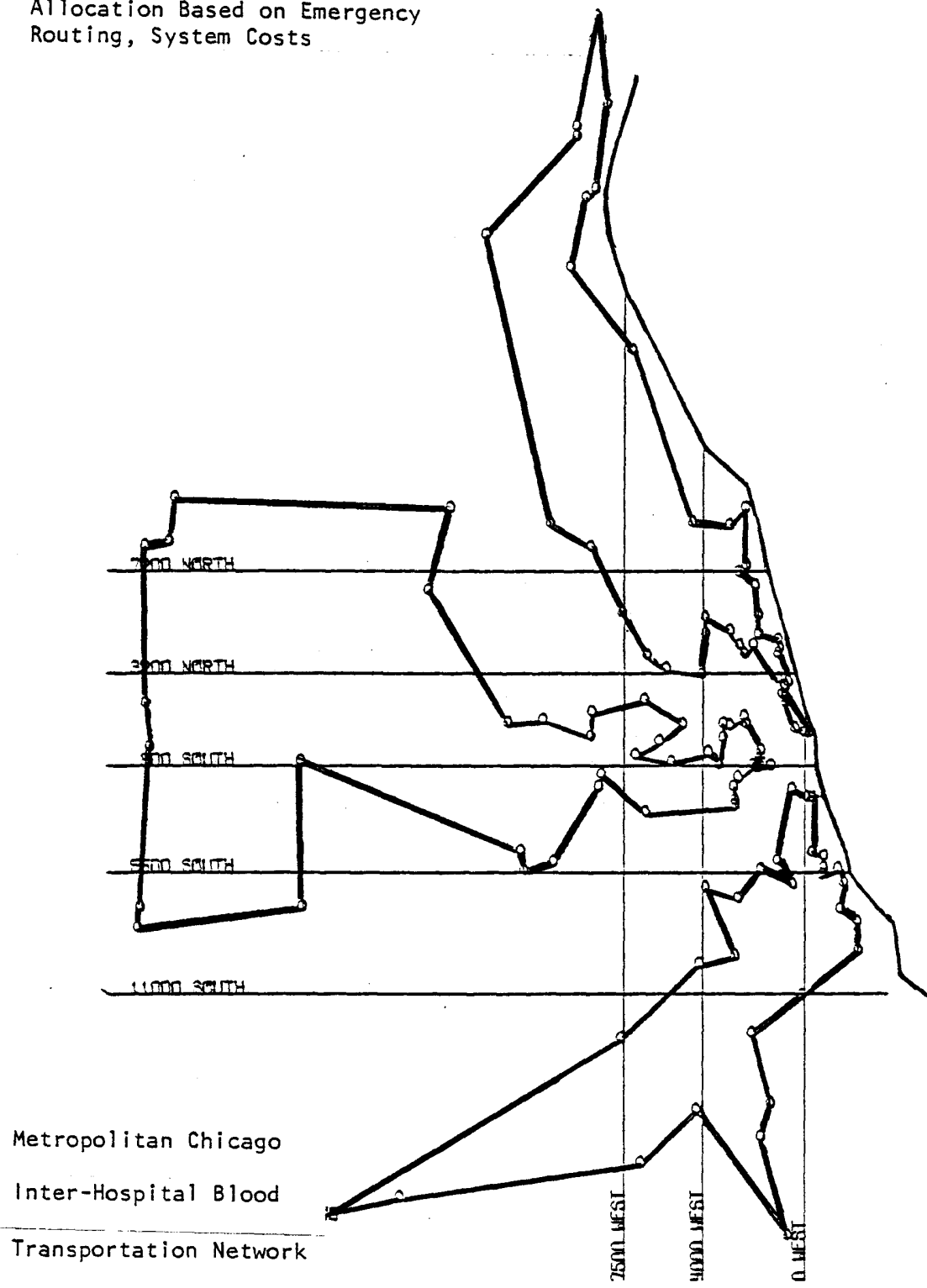
A second model was developed to allocate the supplies of blood to each community blood center. This model takes as inputs, the allocation of transfusion services with their demands given in the previous model and the available supplies of blood in the GMC by zip code area and then assigns the supplies to the centers in such a way as to meet the demands in each center and minimize costs of collection. Figure 7 illustrates the results of the supply assignment model corresponding to Figure 6.

Equipment and Space

In addition to manpower needs to operate the various regional systems, space and equipment are also needed. The study concluded that these later needs tend to be proportional to size once a community blood center exceeded 50,000 red cell units annually. That is, above 50,000 units as the size of the blood center doubled its equipment and space needs tended to double.

This doubling of space needs tends not to be proportional in all functional areas. In some areas such as processing there are some economies of scale; however, there are additional space needs in larger centers for such expanded activities as conferences, education and research which often are not performed at smaller centers.

Allocation Based on Emergency
Routing, System Costs



Metropolitan Chicago
Inter-Hospital Blood
Transportation Network

Figure 6

Figure 7

Allocation of Donor Regions to
CBCs for the CBC Systems Shown
in Figure 6



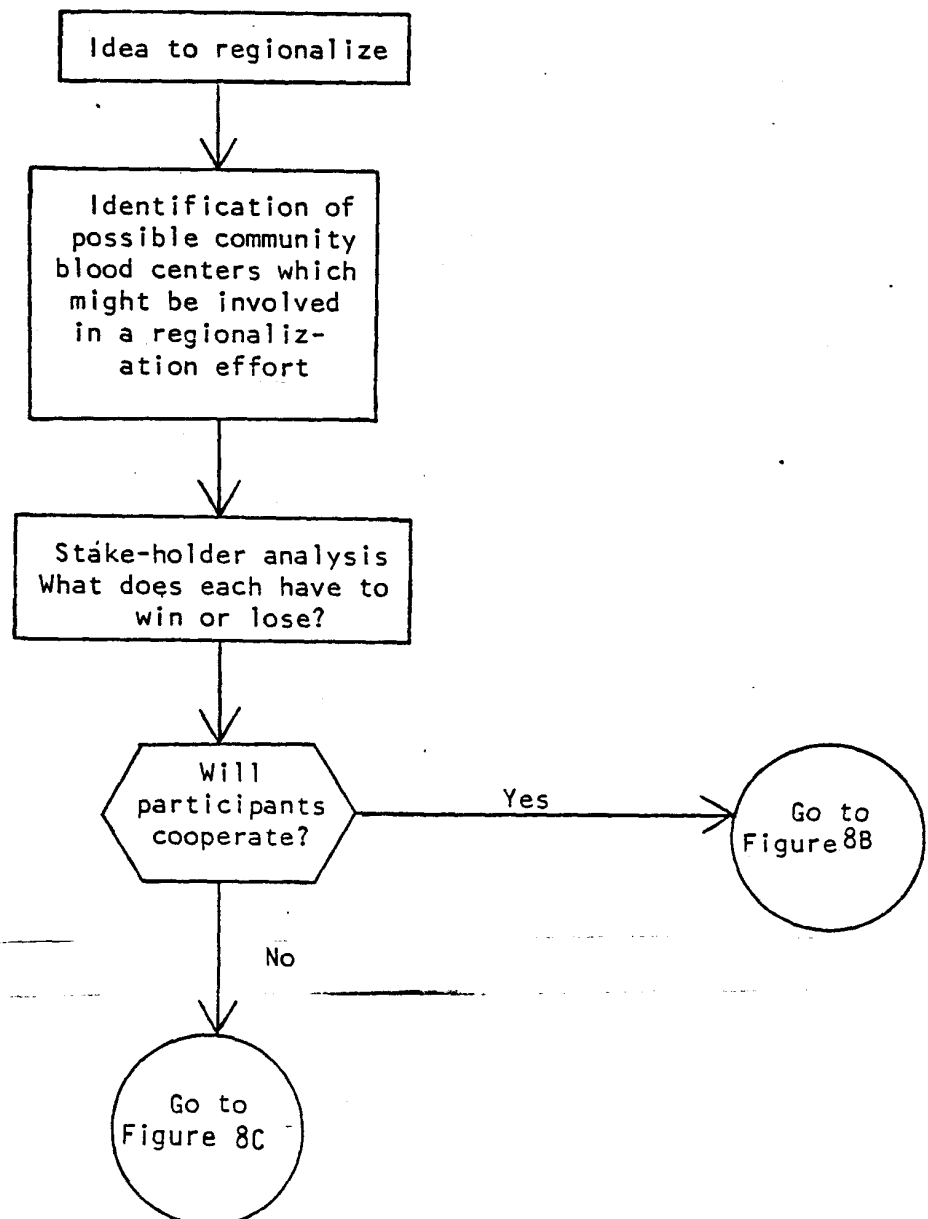
Implementation of Regionalization

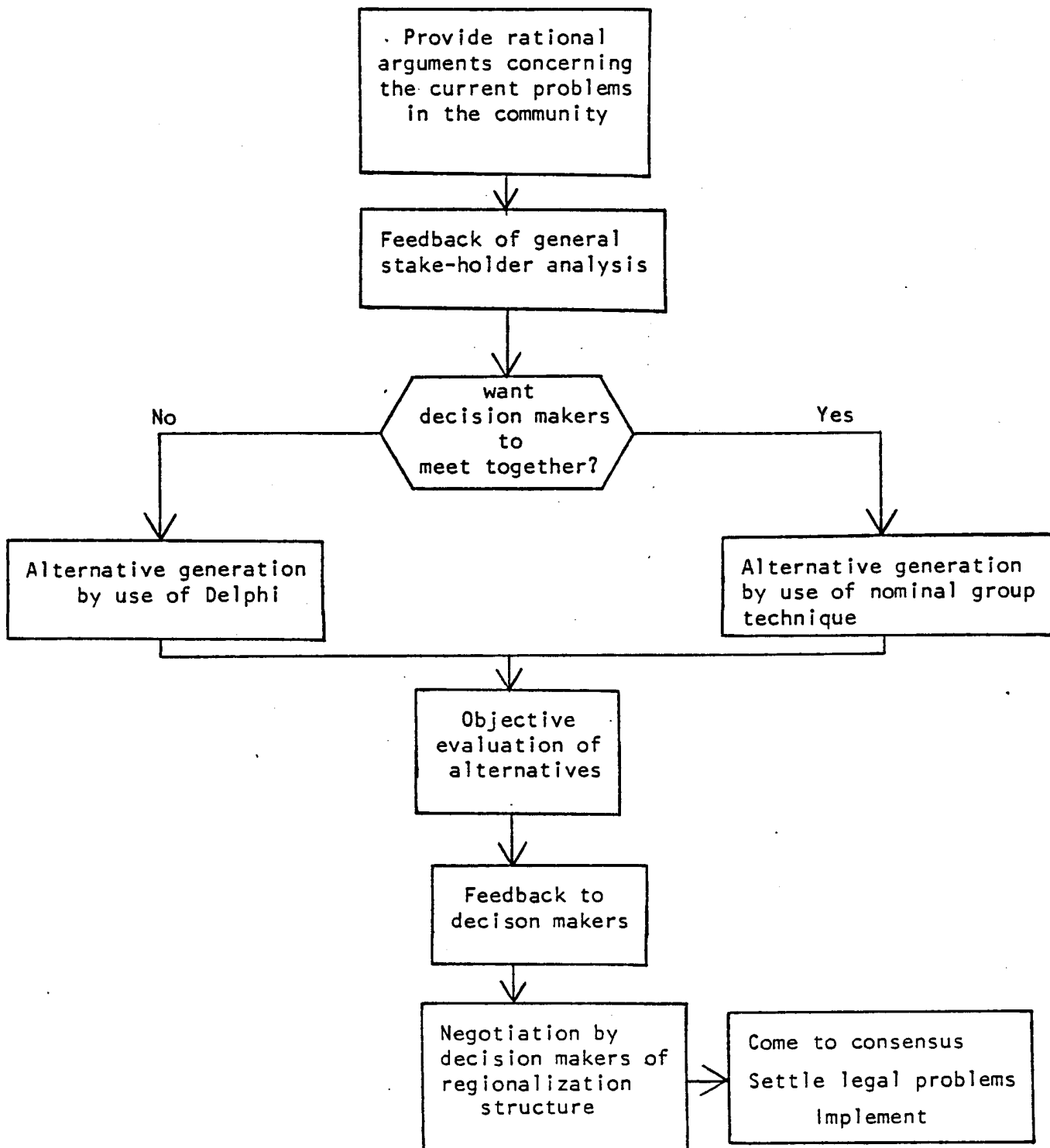
As mentioned earlier, regionalization may take many forms. Also there are many approaches to the implementation of any of these forms. A general schema is given in Figures 8 a, b, c, for an implementation process. This is only one approach and under the particular circumstance in a region others may be preferred.

This model has some parallels to encouraging mergers or holding companies in business in the sense that it is necessary to identify each organization's needs and the ability of any new structures to meet these needs. However,

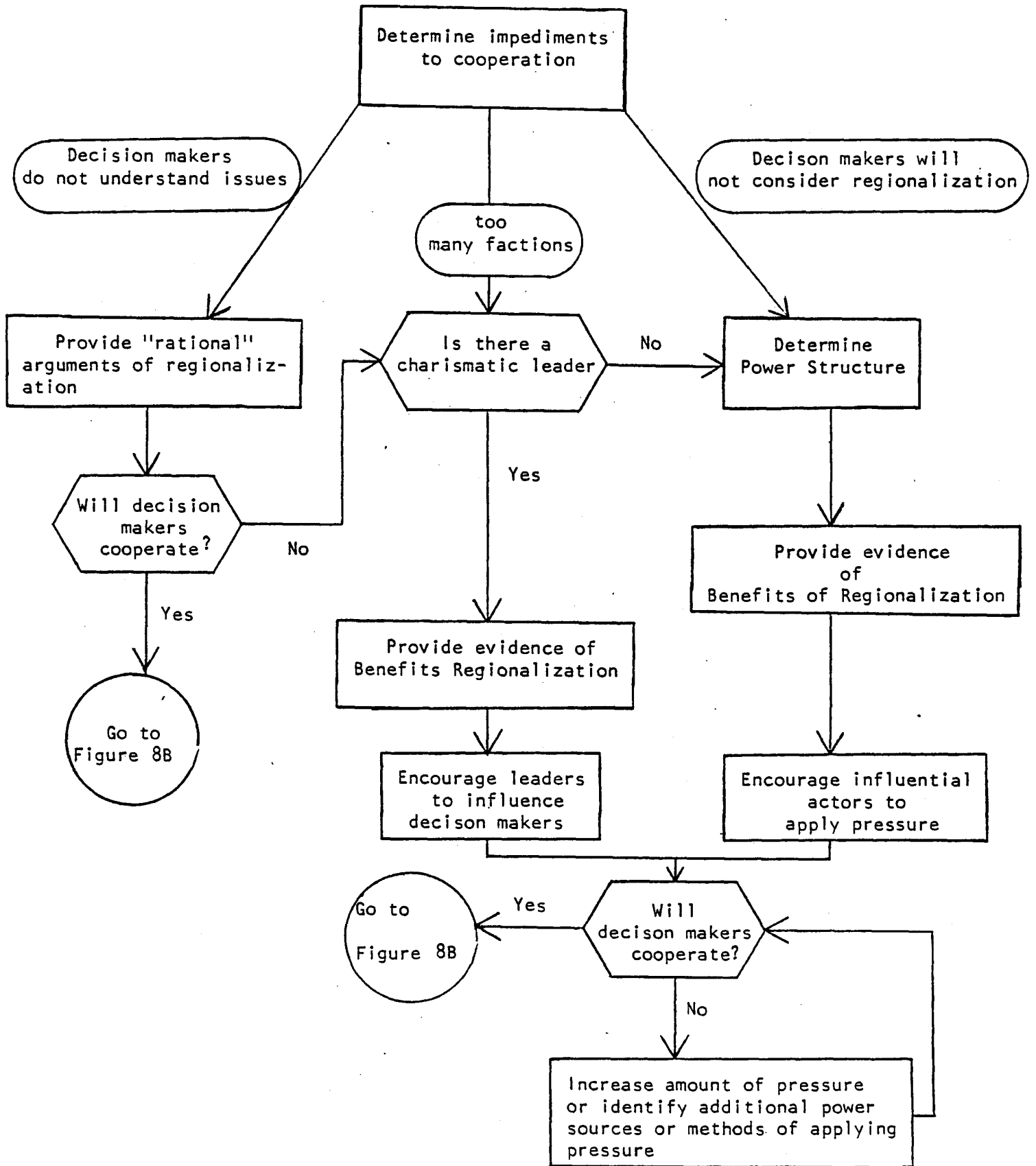
IMPLEMENTATION OF REGIONALIZATION

Figure 8A





IMPLEMENTATION OF REGIONALIZATION
Figure 8B



IMPLEMENTATION OF REGIONALIZATION
Figure 8C

in blood banking and indeed in not-for-profit enterprises in general the perceived loss of autonomy and prestige may be greater than the added benefits of efficiency, decreased costs, better provision of services or more uniform supply of blood. Furthermore, many of these latter benefits are actually experienced by the transfusion services, the patients, and the physicians and not the community blood centers themselves. That is the "benefits" go to the users and the "costs" to the centers. The model suggested in Figures 8 a,b,c attempts to take this aspect of regionalization into consideration.

Operating Policies

Regardless of what regional structures exists or evolves, there are certain operating policies which have been shown in this study to be better than others.

Transfusion Service Policies

In a decentralized region where control of the blood inventories passes to the transfusion service upon shipment from a blood center, the transfusion service should maintain its target inventory level for each ABO-Rh type at the amount given by

$$S_{ABO,Rh}^* = 6.03 (d_M)^{.7604} (p)^{.1216} (D)^{-.0677}$$

where d_M is the mean daily demand for the ABO Rh type

p is the transfusion/crossmatch ratio

D is the crossmatch release period.

(For small transfusion services or rarer bloods, S^* is about 7-8 days transfusion needs and for larger usage bloods, S^* is about 4.5-5 days supply.)

In a centralized region where control of red cells remains at a community blood center, the target inventory level at each transfusion service should be about 5-10% below the level of $S_{ABO,Rh}^*$ computed above for each ABO, Rh type.

This reduction in target levels is possible since the red cells may be transshipped from one location to another to anticipate shortages or outdates.

Furthermore, the transfusion service should establish a cross match period of one day and should try to operate with as high a transfusion to crossmatch ratio as possible, preferably close to 1:2.

Unless there is a medical requirement for fresh blood such as open heart surgery or there is gross overordering of blood by certain medical specialties, all blood should be crossmatched and transfused on an oldest first basis. In the case of gross overordering if the physician behavior can't be modified, then the youngest blood should be crossmatched in these instances of small transfusion/crossmatch ratios.

Finally, unless there is a blood shortage situation, double crossmatching is not cost effective and should be avoided as a regular practice.

Community Blood Centers

The community blood center should maintain a target inventory level for each ABO-Rh type which reflects the average transfusion demands, T, in its area, the number of transfusion services it serves, N, the average transfusion/crosssystem, D. For example if $p = \frac{1}{2}$ and $D = 2$ then

$$S_{\text{ABO,Rh}}^* = 3.14 (T)^{.72} (N)^{.93} \\ \text{center}$$

The center should ask its transfusion services to keep p as high as possible and D as small as possible in so far as good medical practice allows.

The optimal allocation policies to be followed by a center when there is not enough supply to meet all requests is send each transfusion service the same ratio of amount received to amount ordered

or send the amount which equalized the probabilities of shortage at each transfusion service.

The optimal transshipment policies to pick up units at one location and deliver them to another are: (i) if information on demand probabilities and inventories are available tranship units to meet a shortage if the shortage probability at T.S._i - shortage probability at T.S._j $\geq \frac{\text{transport cost j to i}}{\text{outdate cost at j}}$;

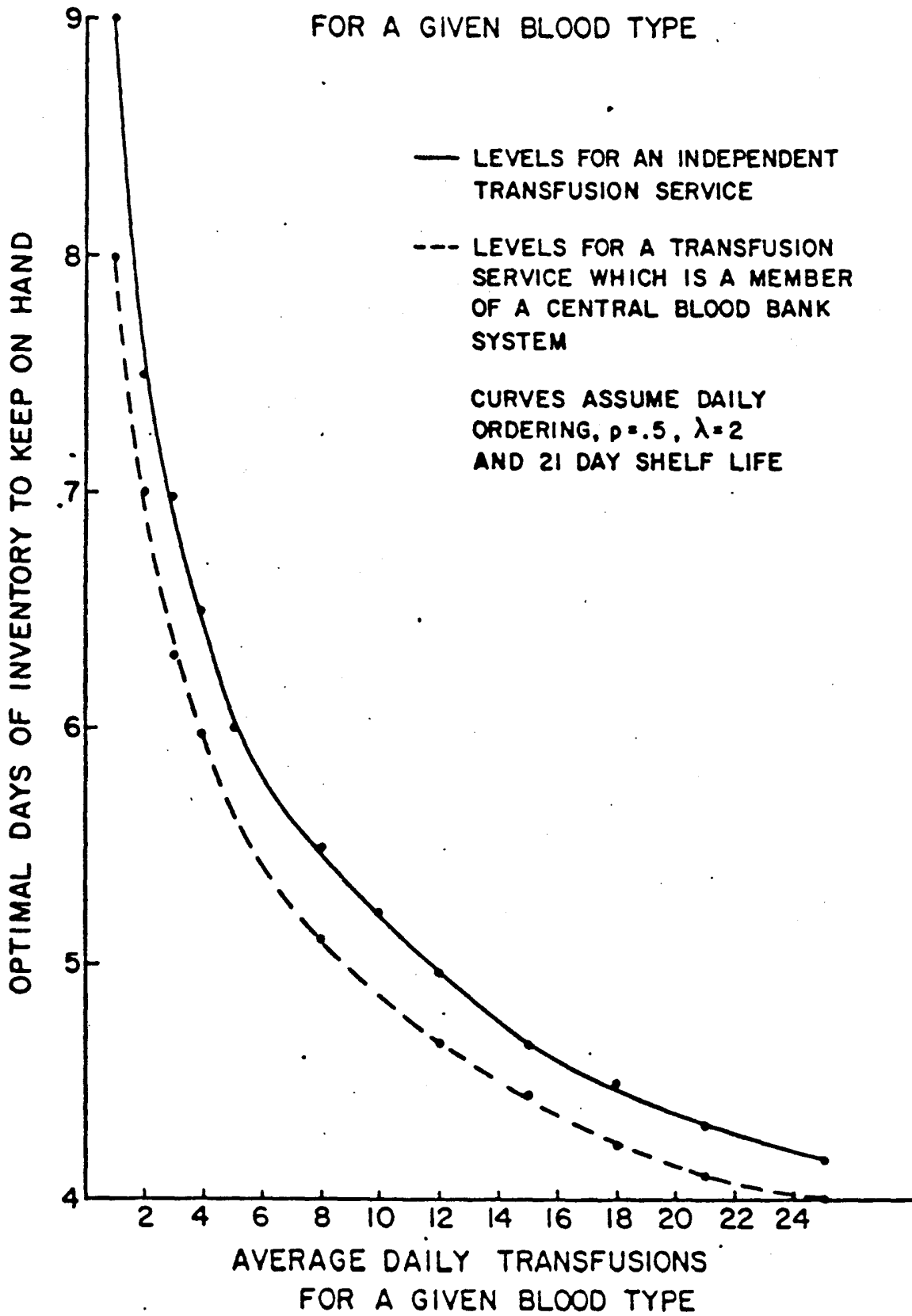
(ii) if information not available, then recycle old units from low probability use transfusion service to high probability use transfusion service (similarly for shortages).

For the TSs which are inventory controls locations for a CBC, the optimal target inventory level at each TS should be about 5-10% lower than at the TS if it were independent and not an inventory control member of the CBC. (see Figure 9).

In the case of all inventories at the RBC, CBCs and TSs, forecasting of red cell and component needs should be done with adjustments made for quarterly changes for red cells and shorter time period changes in demand for other components. Our studies have found that a Box-Jenkins time services can provide a good forecast for red cells by ABO, Rh type.

Figure 9

OPTIMAL DAYS OF INVENTORY TO
KEEP ON HAND TO MEET TRANSFUSIONS
FOR A GIVEN BLOOD TYPE



Conclusions

The results reported in this paper represent an analysis of the data available. With a larger data base a more complete analysis could be performed which could include more explanatory variables and hopefully have stronger statistical significance. Our results are strongest for blood centers smaller than 200,000 red cell units annually. Above that level, our data and national data in general are scarce.

Some of the conclusions found in this study are:

- Centralized donor activities can smooth large fluctuations in supply and reduce competition for supply and shortages.
- Centralized coordination of inventories can smooth demands for blood and components and reduce outdated.
- Economies of scale can be realized for operations above 50,000-75,000 red cell units annually. Furthermore, there are economies of scale at even higher levels of operation but the rate of improvement is decreasing.
- Assignment of functions to the two different hierarchical levels of operation makes an impact on the costs of operation.
- The lowest costs are with a single RBC and no CBCs, option 6. This is followed by option 5.
- All community blood centers in a region should operate above the 50,000 annual unit level if the region is large enough to permit this.
- There may be diseconomies of scale in operating community blood centers above 500,000 units annually but there is not enough data to have confidence in this conclusion.
- A transportation-location-allocation model is available to study the location of community blood centers and the transfusion services assigned to them in a minimum cost manner.
- An assignment model is available to assign donor areas to community blood centers in a minimum cost manner.
- An implementation strategy is suggested for undertaking the process of regionalization if desired.
- Policies are given for the optimal inventory management of the different hierarchical levels of blood bank operations.