

# **Economies of Scale in Blood Banking**

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My topic is the strategic issues in the regionalization of blood banking and the economies of scale that exist in various forms of regionalization. We became interested in this problem because of the regionalization aspects of the National Blood Policy of 1974. The National Blood Policy defines regionalization as 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. This definition does not address questions of regional boundaries, size, economies of scale, organizational structures and arrangements or other aspects of regional activities. Consequently, the National Blood Policy raised two major issues in our minds about regionalization: one, why should or should not particular blood banks, or blood banking in general, be regionalized; and, two, if regionalization is warranted, what are the most cost-effective ways to proceed? These two general issues led us to conduct the research I will describe to you now.

## **Analysis of Regionalization**

At the beginning of our research, there were some strategic questions underlying the general issues raised above that had to be answered. First, if regionalization is warranted, how many community blood centers (CBCs) should be in a region? Second, where should those CBCs be located? Third, what blood banking functions should be performed at what locations? Fourth, how should the supply and demand be assessed and coordinated? Fifth and finally, how should the management of the different functions be coordinated?

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(The work underlying this presentation was conducted by William P. Pierskalla, PhD, Richard Sasseti, MD, Morris Cohen, PhD, Joanne Consolo, MBA, Jane Garvey, MS and Mark Goodfriend, MS.)

Many factors affect the answers to these questions. Some of these factors involve the central banks—the number, locations and sizes; their satellites—the number, locations and sizes; their boundaries—geographic, political or population, and the demographics of the populations; the types of donors—their ethnic or racial and other characteristics; the users and types of components used; and the network configurations concerning distribution and communication. Many operation policies also affect regionalization: policies of ownership of blood, ordering, cross-matching and recycling, administration and component therapy.

To look at these questions and factors, we analyzed regionalization in terms of the activities that are actually conducted in a blood center. The functions that we chose to look at were: information systems, donor services, phlebotomy (both mobile and in-house), processing, inventory management and distribution and general administration.

### Economies of Scale

We first analyzed the economies of scale in the operation of these functions. A general short-run economies of scale curve is given in Figure 1; what it implies is that, if your blood bank finds itself at a low volume of operation, as you increase the number of units in that operation, the average cost per unit will start to drop. However, at some point, it is necessary to add staff, equipment and space, and then the average cost will rise in the short run. Over time, as the number of units produced continues to expand, the average cost will again start to drop. As production increases, you get these jumps whenever you make a major change or a change in the operational process by adding new facilities, equipment or staff.

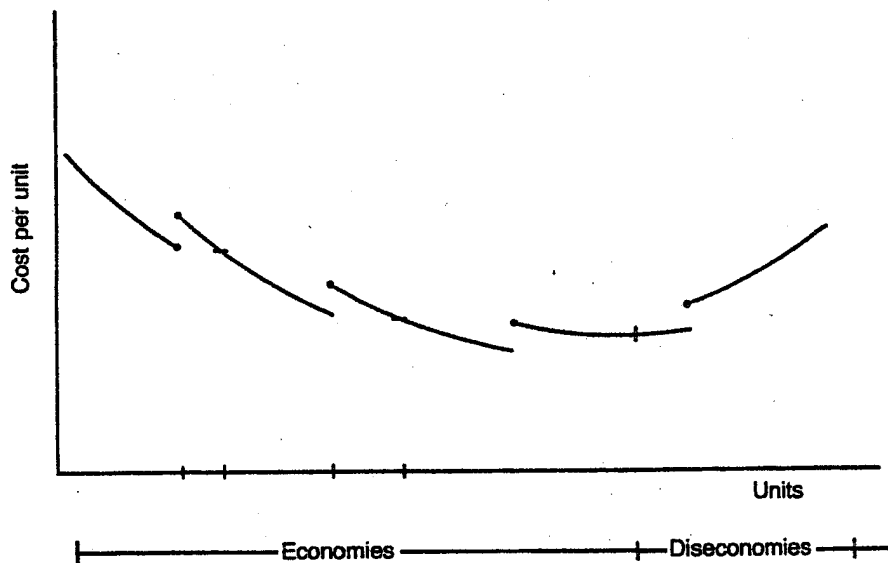


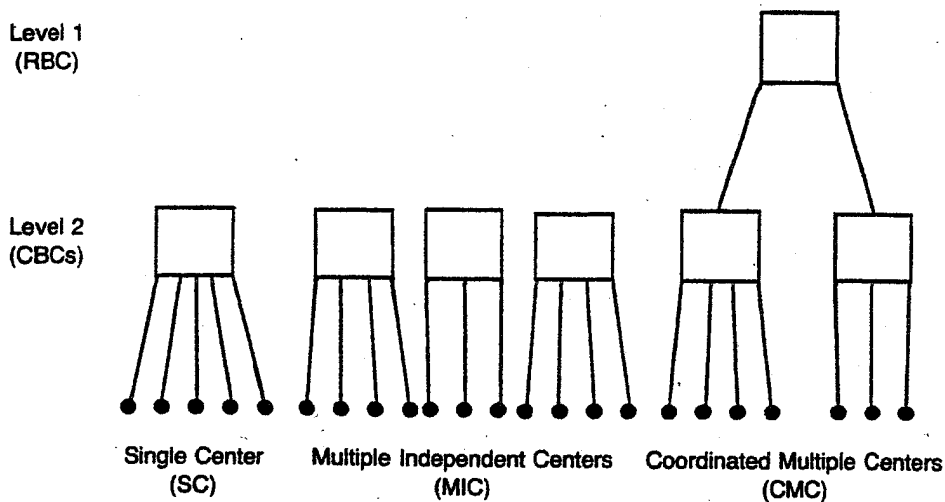
Figure 1. Economies/diseconomies of scale with "jumps" at expansion points.

There are other economies, also, which are often lumped into economies of scale, but which are due to experience or learning effects rather than to a more efficient use of capacity. Organizations with a large production often have lower costs due to the effects of both scale and experience. Experience effects are based on the notion that, as people repeat the performance of tasks, they become more and more proficient and efficient. Also, over time, there is more work specialization and method improvement as the quantity of output grows. This experience curve effect has been demonstrated in many diverse industries: steam turbine generators, integrated circuits, boiler chickens, Viscose rayon, primary magnesium, long-distance telephone, air conditioners and electric shavers, among others. One of our objectives was to discover whether there were economies of scale and experience in blood banking.

**Structure of Blood Banking Regions**

*Single Center*

To begin the analysis, we needed to define the structures of blood banking regions. It became apparent that there were many models for these structures. The first and simplest is a region having a "single center" (SC) with many transfusion locations being served by that center. The SC model is shown in Figure 2. This particular organizational structure is common in the United States. In its region, an SC usually has a close relationship with its customers and with its donors. Also, it is often well-coordinated because it is the only show in town.



**Figure 2. Basic regional system models.**

### *Multiple Independent Centers*

Another model we looked at we have called "multiple independent centers" (MIC). This model was well-exemplified by the Chicago region, which had, at that time, seven independent blood centers. This model does not have many advantages other than maximizing competition, which may yield lower prices for its products and/or better services. It has the disadvantage of overlapping constituencies, both on the transfusion service and on the donor sides. It also has duplication of facilities and, frequently, serious leadership and image problems in a region.

### *Coordinated Multiple Centers*

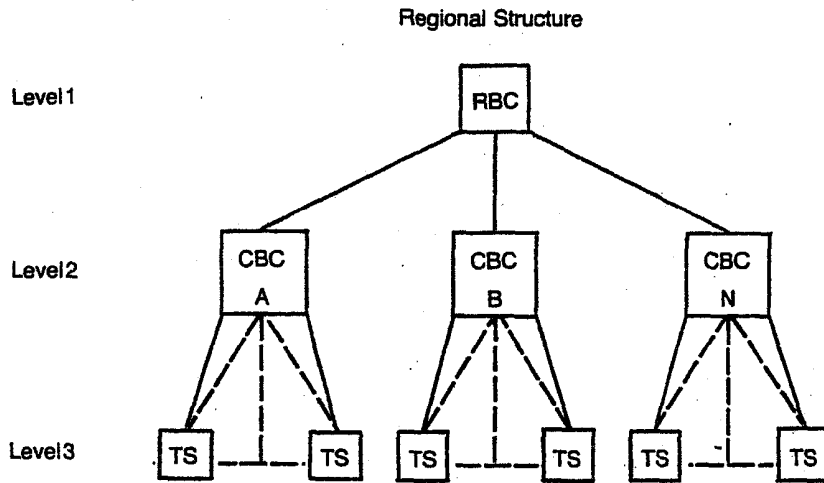
The third major model we examined we call the "coordinated multiple center" (CMC), shown in Figure 3. This model comprises a regional center at Level 1, CBCs at Level 2 and transfusion services (TS) or transfusion locations at Level 3. This model is exemplified by a region, like Los Angeles, where the Red Cross had two community blood centers with regional control of both, or New York, which at the time had four CBCs also with regional control.

### *Six Functional Options of the CMC Model*

The structure of a region might affect the economies of scale, so we next studied which of the functions of blood banking should be performed at what levels in a CMC. We gathered data from five CBCs around the United States and seven in the Chicago region. The centers around the country were New York, Milwaukee, Minneapolis, St. Paul and Los Angeles-Orange County. We also gathered data in the Chicago region from 66 hospitals with transfusion services and hospital blood centers. To determine which functions should be performed at Level 1, the regional blood center (RBC), and which at Level 2, the CBCs, we then defined six options representing different regional configurations of the functions. The first option would have no RBC, and the CBCs would perform all services, ie, the MIC option. The second option would be an RBC that had only information systems and donor services. In this option, the RBC would do all the recruiting for and planning of the mobile phlebotomies, but not actually do the phlebotomies. The other functions—phlebotomy, processing, inventory handling and distribution—are all done at the CBC level.

In the third option, the mobile phlebotomy is also moved to the regional center, but the in-house phlebotomy remains at the CBCs. This option coordinates the donor services with the mobile phlebotomy. All of the functions of processing remain at the CBCs. This option has the drawback that a common license is required to perform phlebotomies at the regional level.

The fourth option moves the processing to the RBC but keeps the in-house phlebotomy at the community center. The only other functions of the community center are inventory management and distribution. Consequently, the CBC is now more a depot than a blood center, but it does still perform a phlebotomy function.



Allocation of Functional Areas to Options Representing Different Regional Organizational Structures		
Options	Functions at RBC (Level 1)	Functions at CBC (Level 2)
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

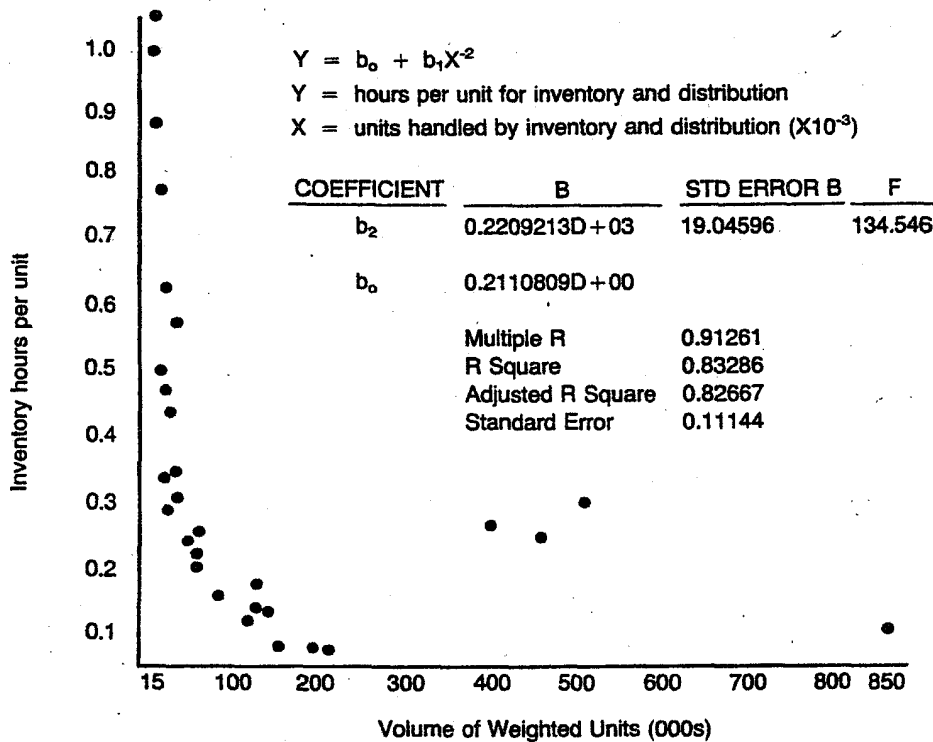
**Figure 3. Coordinated multiple centers—regional structure and chart of options for functional allocations.**

The fifth option moves the in-house phlebotomy function out of the CBC, so that the center is now clearly just an inventory depot. A good example of an Option 5 system was the St. Paul Red Cross, which had rural inventory and distribution locations scattered throughout its four-state service region, while all of the other functions were performed by the St. Paul Blood Center.

The sixth and last option considered is one that basically says, "We don't want any CBCs. Let's do everything with the regional center and not have CBCs at all." This option is the single center (SC) model.

**Analysis of Data From Options**

In order to analyze the six options, we had to be able to compare the data from each center in some common way. We could not use the costs of performing each function, because costs varied so much by region, due to different regional wage factors. Instead, we conducted industrial engineering manpower loading and time-and-motion studies of the performance of different functions in the blood centers. Based on these studies, workload measurements were comparable across all of the blood centers in terms of the man-hours used to perform the functions. An adjusted equalized unit of work was thus defined for a blood center and used to compare the Los Angeles, New York, Minneapolis, St. Paul, Milwaukee and Chicago systems, based on workload measurements rather than on dollar costs.



**Figure 4. Economies of scale in inventory and distribution.**

Figures 4 and 5 illustrate the average man-hours per unit to perform the inventory and distribution and the processing functions, respectively, at the blood centers over the 3 years of the study. In Figure 4, the very small centers, operating at about 12,000 units, generally had a very high inventory and distribution workload per unit. Centers with very large operations, say, 100,000 units annually, had very low inventory and distribution workloads per unit. Applying a nonlinear regression curve to this data gave a very good statistical fit. There are clear economies of scale in inventory and distribution in blood banking, and those economies of scale are statistically very significant.

Figure 5 illustrates the data and the nonlinear regression curve for the processing function. Again, there are economies of scale, but they are not nearly as strong. Processing is one of the weaker such functions of blood banking. At the time of this study, the processing function did not use capital and labor as efficiently as did inventory and distribution. With the highly automated processing function of today, this result may be different. We performed the data analysis and regressions for all of the other functions as well. The greatest economies of scale were in inventory and distribution, the next greatest in general administration, then phlebotomy, processing and, the

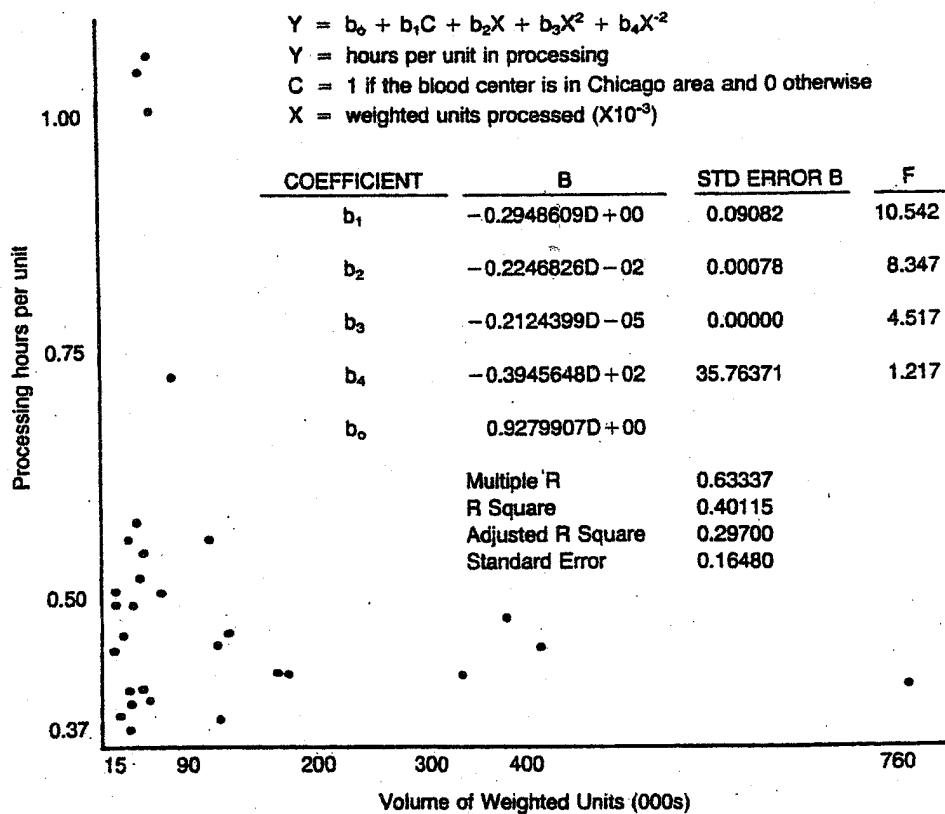


Figure 5. Economies of scale in processing.

very least, donor services. We had hypothesized even before we did this study that donor services would have very few economies of scale, mainly because, in order to increase the number of donations, it is often necessary to intensify the recruitment process, so there may even be diseconomies of scale.

Although we discovered economies of scale in most of the functional areas, the most important question was still unanswered—namely, are there economies of scale in the different regional configurations represented by the six regional options? The answer is yes, but some options are more economical than others.

Figures 6 and 7 illustrate the data and the nonlinear regression curves for each option at the RBC and at the CBCs, respectively. In each case, with the exception of Option 2 for donor services at Level 1, the RBC, the different options yield economies of scale.

Using the workload curves given in these two figures, we then asked, "What would it take to run a region using 234,000 red cell units annually?" (We chose a volume of 234,000 units to illustrate the economies of scale in a region because that was the number of units used in Chicago at that time.) Table 1 gives the answers. For Option 6, with only one center, we found that to operate a region with 234,000 units annually would take 302 man-years of effort. On the other hand, if there were seven centers, each operating at the average amount of 33,000 units annually, it would take 415 man-years of effort

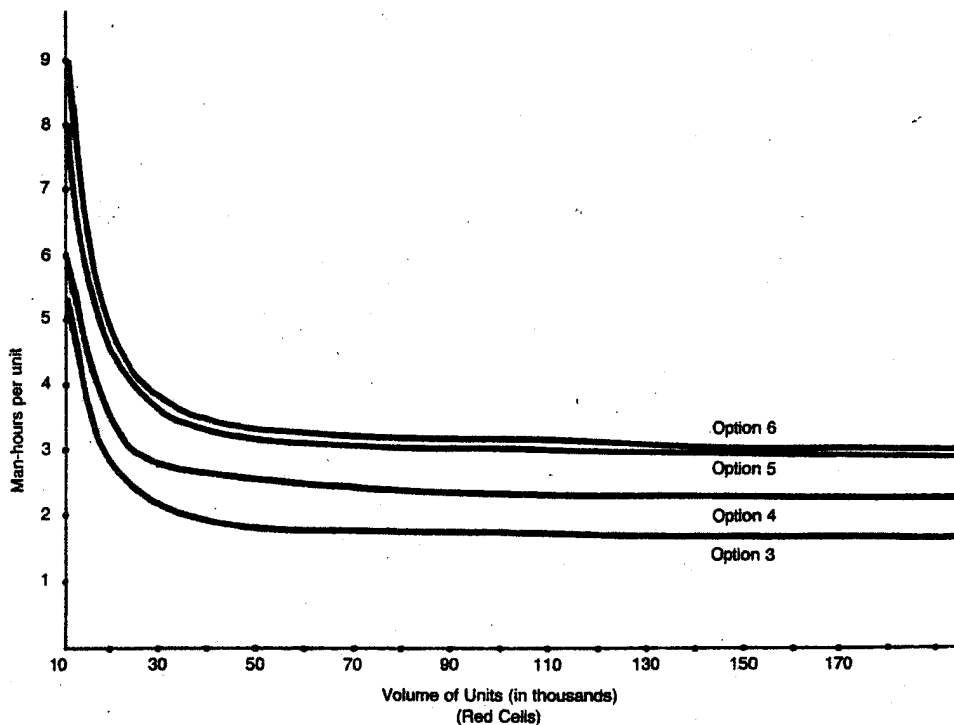
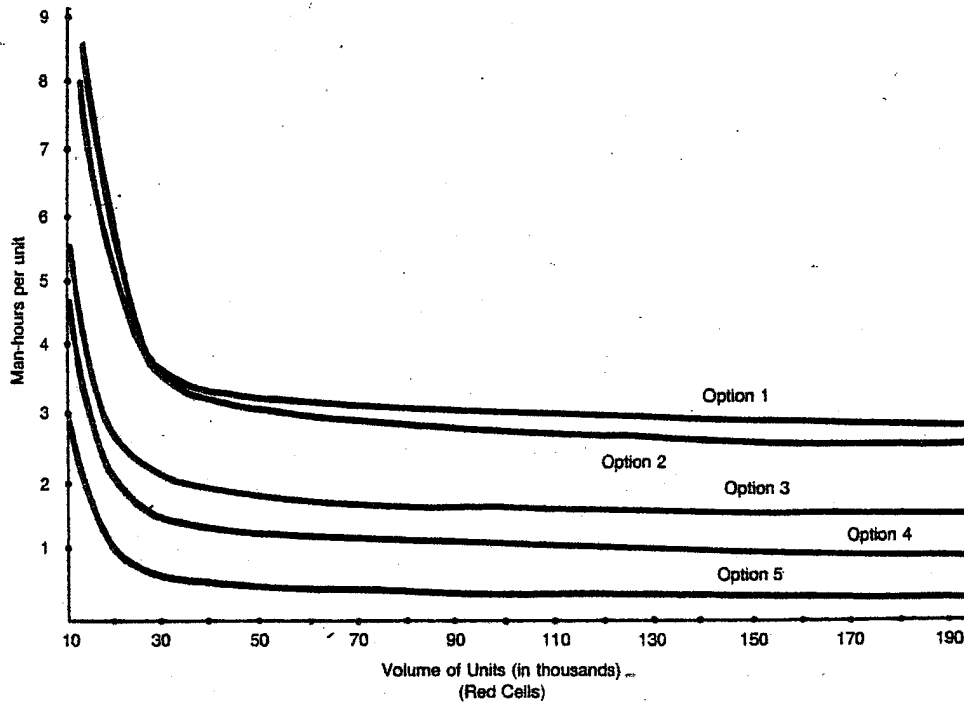


Figure 6. Plots of regression curves for Level 1 (Regional Blood Center) options 3 through 6.





**Figure 7. Plots of regression curves for Level 2 (Community Blood Centers) options 1 through 5.**

to run the same region, or 113 more man-years of effort than with one center. And, in fact, with seven centers in Chicago at that time, they were expending 416.5 man-years of effort to run the region. Our study indicates that they could save approximately 113 man-years, or several million dollars, annually in a region of this size, by having only one regional center rather than the seven weakly coordinated centers.

Another perspective on economies of scale can be based on the number of man-years of effort, in terms of all six options, in a region that has three CBCs. Table 2 illustrates these results. As in Table 1, Option 6—just one RBC and no CBCs—requires 302 man-years to run the region. However, under Option 5, with a regional center doing most of the activities of blood banking and the CBCs (depots) doing the inventory and distribution, the regional center itself needs 296 man-years and the three CBCs need 40 man-years. Thus, the total requirement for the Option 5 system is 336 man-years. If there is a choice between operating with Option 6 or Option 5; then, the most economical choice would be Option 6. However, in case of political, geographic or physical constraints, such as found in New York City or St. Paul, where there are significant travel-time problems, Option 5, which keeps most of the work at the regional bank and uses CBCs as depots for distribution of the inventories, is a reasonably economical organizational structure.

**Table 1. Example of the man-years needed in a regional system drawing 234,000 red cell units annually using option 1\***

Number of centers	Annual volume at each center	Total regional man-years	Difference	
			Net	Cumulative
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	33,429	415	19	113
8	29,250	435	20	133

\*The seven Chicago CBCs handled 234,000 weighted units in 1976 and used 416.5 man-years. However, not all of the seven centers are of equal size, as the example above has assumed.

In Table 2, the man-years rise until Option 3, where there is considerable fractionation between the RBC's functions and the CBCs' functions. The functions are divided about half-and-half, and this option represents the least economical form of regionalization.

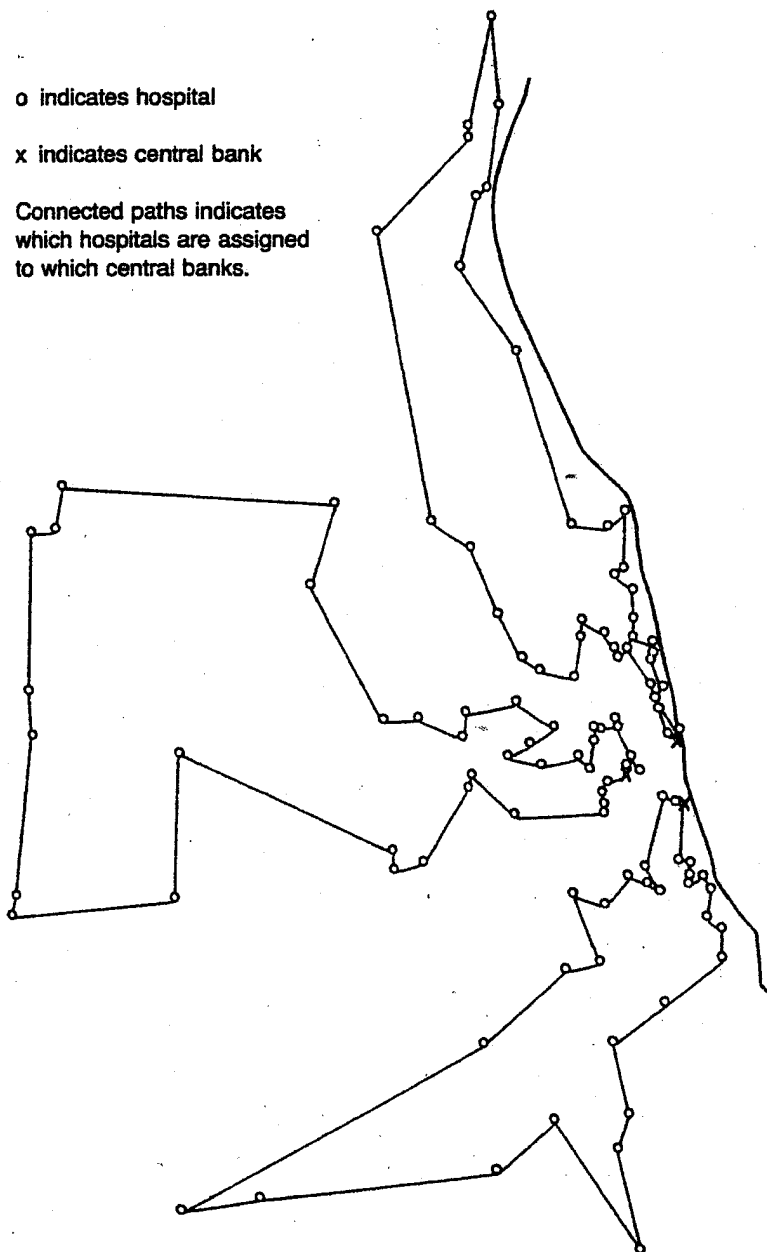
In general, for various-sized regions with various numbers of CBCs, the economies of scale curve that yields the most cost-effective regional structure is the SC model. The next most cost-effective structure is Option 5 of the CMC model. Then there is usually some variation of the CMC model in which Option 1 vies with Option 4 as the next most cost-effective option. In most cases, CMC model Option 3 is the least cost-effective regional structure.

**Table 2. Example of the man-years needed in a regional system drawing 234,000 red cell units annually using options 1 through 6\***

Option	Man-years at RBC (Level 1)	Man-years at 3 CBCs (Level 2)	Total system man-years
1	0	349	349
2	31	324	355
3	186	184	370
4	235	113	348
5	296	40	336
6	302	0	302

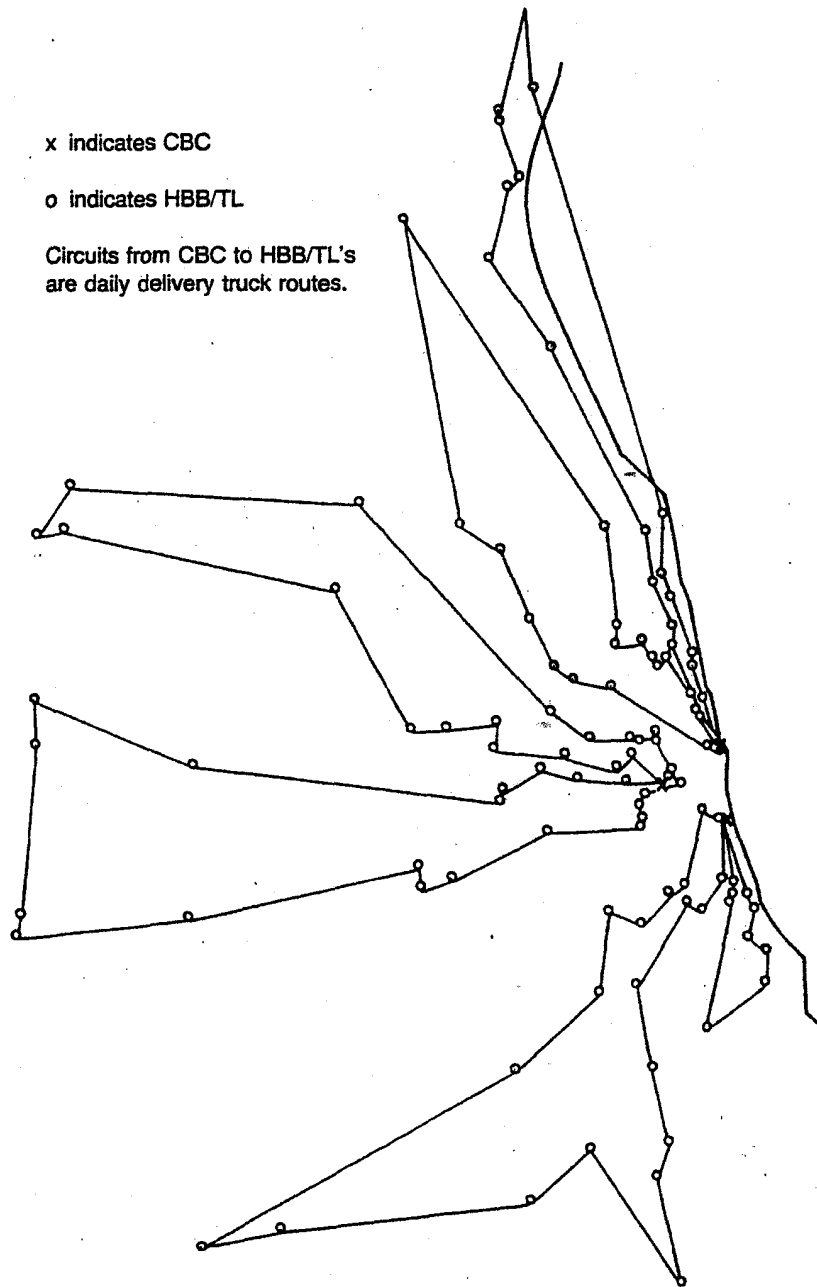
\*Assume an RBC and three equal-size CBCs of 78,000.

In the regionalization study, we looked at two other regionalization issues besides the optimal regional organizational structure. First, we wanted to find the optimal location of CBCs and allocation of hospital blood banks in relation to the CBCs in a region. To accomplish this, we developed a computer program and entered the data from the Chicago area. Figure 8 illustrates the



**Figure 8. Allocation based on emergency, periodic and system costs for the metropolitan Chicago inter-hospital blood transportation network.**

situation of three CBCs in Chicago and the optimal allocation of the 100-plus hospitals or transfusion locations to them. The first CBC would service all those hospitals in Subregion 1. The second would serve Subregion 2 and the third, Subregion 3. The computer program allows for changing the number of



**Figure 9. Allocation based on emergency routing system costs for the metropolitan Chicago inter-hospital blood transportation network.**

centers in a region and for moving the center locations around on the map. It then develops the different optimal subregion configurations for the new locations.

Next we asked, "What would be the best number of delivery trucks and their routes if the region had those three systems?" Figure 9 shows the answer to the question. The number of trucks and their routes minimized the total cost of transportation and distribution.

And, finally, we asked, "What would be the best donor assignments for the same three CBCs to meet all of the needs of the hospitals in each subregion?" Figure 10 illustrates the optimal donor areas for each subregion of hospitals and transfusion locations.



**Figure 10.** Allocation of donor regions to CBCs for the CBC systems shown in figure 8.

In summary, the general objective of this work was to develop a strategy for regionalization if regionalization is warranted. How should you structure and organize a region? What are the costs? How should you subregionalize optimally? Our conclusions concerning these strategic issues are:

- Economies of scale can be realized for blood bank operations, becoming most effective above 50,000 to 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.
- A transportation-location-allocation model can be used to study the location of CBCs and the transfusion services assigned to them at minimum cost.
- An assignment model can be used to assign donor areas to CBCs at minimum cost.

The study also investigated many tactical regional issues, such as how to get the blood and blood products through the system and how to handle assigned inventories, crossmatched times and allocation of scarce units when there isn't enough blood throughout the system to go around. These tactical issues have not been covered in this paper but are discussed in the papers noted in Suggested Readings.

### Suggested Readings

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