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THE EASTERN PROVINCE BLOOD TRANSFUSION SERVICE : A CASE STUDY

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ABSTRACT

An analysis was made of the location of the nine blood banks in the Eastern Province Blood Transfusion Service. The banks were considered as the vertices of an undirected graph. The cost of collecting and distributing blood was assumed to be proportional to the distances between vertices, and to the population of each district. The 9-median of the graph was calculated and the corresponding cost compared with the cost of the actual configuration, which turned out to be about 3% higher.

Key Words: Blood bank, p-median.

1. INTRODUCTION

This case study originated in an attempt to apply operations research methods to health services in South Africa. A study of the literature led us to a decision to concentrate on a specific aspect, namely the management of blood transfusion services. A meeting was therefore arranged with the top management of the Western Province Blood Transfusion Service at their headquarters in Cape Town. The initial meeting was attended by the Medical Director as well as the Scientific Director. This was followed by several rounds of discussions with the Chief Technical Controller and other staff members.

During these meetings it became clear to us that the South African blood transfusion services were already operating at high efficiency with respect to almost all the criteria discussed in Section 3. While this was gratifying from a national point of view, it did mean that there were no obvious and/or easy problems to be tackled.

One of us later visited the Natal Service and held discussions with the heads of the Administrative, Technical and Donor Divisions. This visit was also important because of the Natal Service's connection with the National Blood Fractionation Centre. Letters were also exchanged with the Chief Administrative Officer of the Eastern Province Service, who at that time was also the Secretary of the National Blood Transfusion Council. All these administrators, like their Western Province counterparts, were very cooperative and obviously proud of the efficiency of their respective services. With their assistance we were able to obtain an overview of the operations of South African blood transfusion services.

As a result of the contacts described above, we decided to investigate the question of the optimal location of blood banks. In the next two sections some background information is given on the operation of a blood transfusion service. The rest of the paper is devoted to a detailed description of the application of the p-median technique to the location of blood banks in a specific service.

2. DESCRIPTION AND DEFINITIONS

A blood bank is an organization which collects, processes, stores and distributes blood. Its main purpose is to ensure that the right type of blood is available when needed for transfusion into patients who have lost blood, whether through accidents or during operations in hospitals. Blood has a limited storage life of approximately three weeks, after which it may be turned into various other products, such as plasma, albumen, immunoglobulin and fibrinogen. A secondary purpose is to control the inventory of fresh blood in order to minimize the loss through ageing, taking into account the demand for the other products.

In a certain geographical area blood banks tend to coordinate their activities in order to minimize shortages, ageing of blood and running costs. In order to discuss the ways in which this may be done, it is convenient to define the following terms.

Central blood bank: an organization which collects, stores and distributes blood, and sometimes processes blood as well.
Regional blood bank: a central blood bank which serves as headquarters for a number of central blood banks in a certain geographical area.

In a *centralized system* the collection and distribution of blood is controlled by a number of central banks, but all blood is sent to the regional bank after collection to be processed, and returned to the central banks for storage and distribution. In a *decentralized system* the regional bank administers the recruitment of donors, plans the collection programme, and is responsible for quality control, maintenance of equipment and long term planning, while the central banks handle the collection, processing and distribution of blood.

There are seven licensed blood transfusion services in South Africa. Some of these, for example the Western Province Service, are centralized systems. Others, for example the Natal and Eastern Province Services, are decentralized systems.

3. CRITERIA FOR THE OPERATION OF A BLOOD TRANSFUSION SERVICE

The performance of a blood transfusion service can be evaluated in terms of several criteria [1], which have been used in previously reported investigations. We discuss some of these criteria under headings suggested by a motto of the Natal Blood Transfusion Service: "Safety, efficiency, and economy."

Safety of patients

(a) Minimize fatalities due to blood transfusion.

The South African blood transfusion services have excellent records in this regard. At the time of our study (which was before the advent of AIDS) some of the services were proud to report that they had had no fatality at all in their entire history.

(b) Minimize post-transfusion allergic reactions.

(c) Minimize the transfer of disease.

With regard to (b) and (c) the blood transfusion services have laid down very thorough procedures to screen donors regularly. Cross-matching is done to safeguard recipients.

Efficiency

(d) Meet all requests for blood.

The only real problems arise in the peak holiday seasons. Special requests to the community of blood donors usually have the desired effect. Some services have extensive mobile blood donation facilities.

(e) Provide high quality blood.

(f) Minimize wastage.

An adequate rough measure of blood quality is the age of blood at transfusion. One obvious way to decrease the average age of blood in the inventory is to use an "oldest-unit-issued-first" (FIFO) issuing policy as far as possible. Research in the USA has shown that significant improvements can also be obtained by rotating unused blood at a certain age (typically seven days) to hospitals with high usage frequency [7]. Variants of this method were used by at least some South African blood transfusion services even before the publication of the research mentioned above. However, some outdating of blood is inevitable in South Africa because of the composition of its population. For example, the percentages of the various blood groups in new donors differ significantly between the respective population groups. There are also marked differences in the percentages of donors and of recipients between the respective population groups. This inbalance must necessarily lead to the outdating of certain blood groups. Fortunately the South African blood transfusion services have access to adequate facilities for blood fractionation. This means that outdated blood need not be wasted since it can be fractionated for further use.

Economy

(g) Minimize the production costs per unit involved in the processing of blood.

This goal must be weighed against the other goals concerning the safety of patients. It should also be kept in mind that blood donors in South Africa donate their blood free of charge.

(h) Minimize the costs involved in the collection and distribution of blood.

This was the only criterion for which we could find no supportive evidence of the performance of a typical South African blood transfusion service. We assumed that the services are already functioning at near optimal efficiency with regard to the other criteria, and therefore decided to concentrate on a study of the optimal location of blood banks for a specific service.

4. OPTIMAL LOCATION OF BLOOD BANKS IN THE EASTERN PROVINCE BLOOD TRANSFUSION SERVICE.

An extensive literature survey which we conducted had shown that the published techniques for optimal location of blood banks were designed mainly for restricted areas of high population density. As an example of a different situation, namely an extensive area of relatively low population density, we chose to study the Eastern Province Blood Transfusion Service. This service has its headquarters at Port Elizabeth and is an example of a decentralized service. At the time of the study it had nine central banks which provided cross-matching, storage and processing facilities. The central banks were located at Port Elizabeth, Grahamstown, Uitenhage, Humansdorp, Somerset East, Graaff-Reinet, Cradock, Adelaide and Middelburg.

The positions of these central banks had not been determined by scientific analysis, but by the natural growth of the Service. When we approached the Service for permission to conduct the study, keen interest in our project was expressed and the full co-operation of the Service was promised. Had the study indicated that significant cost savings could be obtained by changing the status quo, this could form the basis for appropriate decisions by the Service.

The central banks provide blood as required at hospitals and clinics in the region and they also organize donor clinics for blood collection at various points in the region. We assumed that the cost involved in the collection and distribution of blood is a function of the distance covered as well as the supply and demand of blood at the hospitals and clinics. Furthermore we assumed that the number of units of blood collected and used in a district is proportional to the population of that district. We used the latest available census results, which for the Eastern Province were grouped into 22 districts. For each district we selected the town with the largest population and used the total population of the district divided by 10 000 as the "weight" of the selected town (Table 1). The 22 towns included the 9 towns (numbers 1 to 9) where central blood banks were actually located.

Table 1 : Weights of districts in the Eastern Province

Districts in the Eastern Province		Weights
1.	Port Elizabeth	40,770
2.	Grahamstown	6,973
3.	Graaff-Reinet	3,320
4.	Cradock	3,530
5.	Somerset-East	2,700
6.	Uitenhage	9,273
7.	Humansdorp	2,761
8.	Adelaide	1,400
9.	Middelburg	2,061
10.	Hankey	2,025
11.	Joubertina	1,252
12.	Alexandria	3,303
13.	Port Alfred	2,958
14.	Bedford	1,506
15.	Pearston	0,578
16.	Jansenville	1,160
17.	Steytlerville	0,591
18.	Aberdeen	0,860
19.	Murraysburg	0,589
20.	Hofmeyr	0,663
21.	Noupoort	0,896
22.	Kirkwood	2,607

The selected towns in the region and the roads connecting them form a weighted graph in an obvious way. Floyd's algorithm [2] was employed to obtain the shortest distances between all pairs of vertices in the graph (Table 2).

Suppose a central blood bank and the towns served by that bank have been identified. The sum of the products of the weight of each town and the shortest distance between that

Table 2: Shortest distances (km) between towns in the Eastern Province (numbered as in Table 1)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
2	127	0																			
3	262	280	0																		
4	247	177	139	0																	
5	190	153	127	107	0																
6	34	133	228	253	196	0															
7	83	210	307	330	273	79	0														
8	221	113	208	105	81	227	304	0													
9	345	275	106	98	205	334	413	203	0												
10	69	193	288	313	256	60	25	287	394	0											
11	175	302	387	422	365	171	92	396	493	121	0										
12	103	54	334	231	207	137	186	167	329	172	278	0									
13	153	57	337	234	210	187	236	170	332	222	328	50	0								
14	199	94	186	83	59	205	282	22	181	265	374	148	151	0							
15	243	206	74	160	53	249	326	134	180	309	417	260	263	112	0						
16	181	280	81	220	164	147	226	245	187	207	306	284	334	223	111	0					
17	180	279	164	303	247	146	225	328	270	206	223	283	333	306	194	83	0				
18	259	326	46	185	173	225	304	254	152	285	348	362	383	232	120	106	125	0			
19	352	370	90	229	217	318	397	298	196	378	477	424	427	276	164	171	254	136	0		
20	311	241	203	64	171	317	394	169	113	377	486	295	298	147	224	284	367	249	293	0	
21	386	316	147	139	246	375	454	244	41	435	534	370	373	222	221	228	311	193	237	154	0
22	81	180	201	300	243	47	126	274	307	107	218	184	234	252	231	120	119	198	291	364	348

town and the central bank can be taken as a measure of the distribution costs involved in operating the blood transfusion service. If p central banks are located in such a way that the total S of all the sums of products for all the central banks is a minimum, we have a so-called p-median [4]. In the general theory the central banks need not be located only at the vertices of the graph but could also be located at points on the edges of the graph. However, a well-known theorem of Hakimi [3] guarantees that a p-median can be located at p vertices of the graph.

One of us developed a computer programme to calculate p-medians. A branch-and-bound algorithm [5] was used, and the programme was run on a Univac 1100 computer at the University of Stellenbosch Computer Centre. Typical run times for problems for up to 10 medians and with approximately 20 nodes were less than 2 minutes. Initially a 9-median with S = 1030 was determined for the Eastern Province Service. The only differences between this 9-median and the actual locations of the 9 central banks at that time were that Adelaide and Somerset East were discarded in favour of Alexandria and Bedford. As can be seen from Table 1, the positions of the central banks in the 9-median are not identical with the 9 towns with greatest weights in the region. This illustrates the point that a 9-median is not solely determined by the weights associated with the towns, but also by the distances involved. In terms of the weighted sum S, the 9-median was only 3% better than the actual locations. In view of the uncertainties in and age of our data, we could say that the actual locations were optimal for all practical purposes [6].

The p-median technique can be used to answer other questions as well. For example, if a central bank at Alexandria were to be added to the actual 9 central banks, the sum S would diminish by 19%. This decrease in distribution costs must be balanced against the capital costs of the new bank.

On the other hand, if the economic situation should force the service to close down a central bank, a decision could be based on an 8-median. The calculations showed that it would probably have been best to close down the central bank at Adelaide. The sum S would increase by 16% .

The geographical boundaries of the Eastern Province Blood Transfusion Service have changed since the time of the study, which makes it difficult to compare our analysis with the developments since then. Although the study did not lead to any change in the actual system in the Eastern Province at that time, it did provide valuable insight into the problem and the satisfaction of confirming the high standards that are achieved in the operation of an essential health service in South Africa. It was also the first application of which we are aware of the theory of p-medians to the problem of the optimal location of blood banks.

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