

improving the quality of care tuberculosis patients receive in the primary health care system. The design of innovations to improve case-holding needs to address the multifaceted nature of treatment behaviour, tailoring the intervention to the needs of the patient. This would require a menu of potential support systems to assist the patient during treatment. It would appear that community-based DOT, when expertly managed, has the potential to provide the essential psychosocial support required to enhance adherence to tuberculosis treatment.<sup>13,16</sup> All strategies to enhance adherence to antituberculosis treatment must be designed taking into consideration the current limitations of cost-containment.

The costing study was funded by the World Health Organisation. We are grateful to the CMC for permission to conduct the study, and the nurses from Elsie's River clinics for their time and assistance in the situational analysis. We thank Mr J H Schoeman, Mr C Vundule, Dr Holger Sawert, Dr Merrick Zwarenstein, Dr Carl Lombard and Dr Josés Kirigua for their technical advice.

#### REFERENCES

1. Department of Health. Tuberculosis update. *Epidemiological Comments* 1995; **22**(1): 13-20.
2. Department of Health. *The South African Tuberculosis Programme: Practical Guidelines*. Pretoria: Government Printer, 1996.
3. Barnum HN. Cost savings from alternative treatment for tuberculosis. *Soc Sci Med* 1986; **23**: 847-850.
4. Murray CJL, Styblo K, Rouillon A. *Tuberculosis. Health Sector Priorities Review*. Washington: World Bank, 1991.
5. Nunn P, Gathua S, Kibuga D, *et al*. The impact of HIV on resource utilisation by patients with tuberculosis in a tertiary referral hospital, Nairobi, Kenya. *Tuberc Lung Dis* 1993; **74**: 273-279.
6. Sanderson PR. An economic evaluation of alternative programme designs for tuberculosis control in Uganda. *Soc Sci Med* 1995; **40**: 1203-1212.
7. Kochi A. The global tuberculosis situation and new control strategy of the World Health Organisation. *Tubercle* 1991; **72**: 1-6.
8. Iseman MD. Directly-observed therapy, patient education and combined drug formulations: complementary, not alternative strategies in tuberculosis control. *Tuberc Lung Dis* 1996; **77**: 101.
9. Wilkinson D, Floyd K, Gilks CF. Costs and cost-effectiveness of alternative tuberculosis management strategies in South Africa — implications for policy. *S Afr Med J* 1997; **87**: 451-455.
10. Zwarenstein M, Schoeman JH, Vundule C, Lombard CJ, Tattley M. A randomised controlled trial of the effect of clinic, community and once a week clinic observation on treatment outcome. Manuscript, MRC, Parowvallei, W Cape, 1997.
11. Dick J, Schoeman JH, Mohammed A, Lombard CJ. The evaluation of a community volunteer programme to enhance adherence to anti-tuberculosis treatment. *Tuberc Lung Dis* 1996; **77**: 274-279.
12. Bayer R, Wilkinson D. Directly observed therapy for tuberculosis: history of an idea. *Lancet* 1995; **345**: 1545-1548.
13. Dick J, Schoeman JH, Tibbs J, Edward R, Keyes A. An evaluation of an urban community-based programme designed to improve adherence to anti-tuberculosis treatment. Manuscript, MRC, Parowvallei, W Cape, 1997.
14. Schoeman JH, Dick J. Tuberculosis care — what does it cost the patient? (Letter). *S Afr Med J* 1998; **88**: 394-396 (this issue).
15. Dick J, Lombard CJ. Shared vision — a health education project designed to enhance adherence to anti-tuberculosis treatment. *Int J Tuberc Lung Dis* 1997; **1**: 181-186.
16. Dick J, Clarke M, Tibbs J, Schoeman JH. Combating tuberculosis: lessons learnt from a rural community project in the Klein Drakenstein area of the Western Cape. *S Afr Med J* 1997; **87**: 1042-1047.

Accepted 15 Dec 1997.

## The geographical distribution of diagnostic medical and dental X-ray services in South Africa

N M Walters, H L Zietsman, N Bhagwandin

**Aim.** The aim of this study was threefold, viz.: (i) to evaluate the availability and accessibility of medical and dental X-ray services in South Africa; (ii) to evaluate geographical information systems (GIS) as a tool for management of health care technologies; and (iii) to guide policy and develop a process to provide optimal utilisation of X-ray services in South Africa.

**Methods.** Information supplied by the Department of Health on licensed X-ray equipment was integrated with census data and processed with GIS. Four key areas were assessed, viz. distribution, accessibility, age and availability of X-ray services in South Africa.

**Results.** The analysis shows a vast inequity in the distribution of X-ray services on a provincial as well as a district level, although on the national level the distribution of X-ray services meets the World Health Organisation criteria.

**Conclusion.** GIS is a useful tool in evaluating and planning of essential health services/techniques. However, care must be taken in interpreting the data on a macro level, as this masks vast inequities on the district level.

**Recommendations.** The indicators of coverage should be expanded, similar reports should be prepared for the nine provinces, and these data should be integrated into the clinic planning programme. Radiological services should be added to and managed as part of an essential district health care technology package.

*S Afr Med J* 1998; **88**: 383-389.

Technological advances have increased our capacity to predict, prevent, diagnose, manage and monitor acute and chronic diseases. In line with the concept of primary health care, there is a need to carry out strategic planning for the utilisation of health care technology at district hospitals and other referral levels in a sustainable, equitable and cost-effective manner. Examples abound of an urban bias in the

Medical Research Council, Parowvallei, W Cape

N M Walters, PhD, MBA

N Bhagwandin, PhD

Institute for Geographical Analysis, University of Stellenbosch, Stellenbosch, W Cape

H L Zietsman, PhD

concentration of resources (facilities, technology and staff) at the expense of rural areas and other levels of health care.<sup>1</sup>

Radiological (more specifically X-ray) diagnostic services are considered an essential technology. More than 80% of the work of a typical X-ray department is straightforward radiography of the skeleton, chest and abdomen. If cholecystography and intravenous urography are included, the only remaining special studies of importance all require fluoroscopy in some form or other.<sup>2</sup> In most developing countries, 90% of the real radiographic needs of the population can be satisfied by routine radiological examinations (assuming equity, availability, accessibility and affordability).

The situation concerning diagnostic radiology services varies from country to country. The following, however, appear to be general observations regarding diagnostic radiology services in developing countries:<sup>3</sup> (i) in rural and peri-urban areas most people do not have access to diagnostic radiology; (ii) about 50% of the rural hospitals (approximately 50 beds or less) do not have diagnostic radiology services; (iii) 80 - 90% of installed X-ray equipment is in the capital city and a few large cities, with very few X-ray machines in towns with populations of 50 000 or less; (iv) of installed X-ray equipment, about 30 - 60% is not in working order; (v) diagnostic radiology services in most large-city hospitals are saturated, and patient waiting times for X-ray examinations are unacceptably long; (vi) many simple X-ray examinations are performed in university or referral-level hospitals because there is no alternative; and (vii) diagnostic radiology procedures are often conducted without due regard for their proper indication, expected diagnostic yield, and adequate performance, including limitation of dose to the patient to optimal levels.

It is clear that public health administrators require accurate and current information and guidelines for the rational planning, building, equipping, staffing and operation of X-ray departments at all levels of health care.

## Aims of the study

In order to achieve the goals of health restructuring in respect of primary health care, information on medical facilities and their characteristics, geographical distribution, accessibility and utilisation will be required for an objective assessment of the current state of affairs. Before any new facilities can be provided or existing facilities relocated, it is necessary to analyse the present geographical distribution of existing facilities and to assess it in terms of the population distribution pattern. This study addresses this issue in respect of X-ray facilities, using geographical information systems (GIS) technology. In 1994 there were approximately 7 400 diagnostic medical and dental X-ray systems in operation in South Africa, but little is known about their regional distribution or relative accessibility, the ages of these devices and their uses by various categories of medical practitioners. Basic statistics of this nature are necessary both for assessing current levels of service and for future planning.

The main purpose of this study was to analyse the availability and accessibility of X-ray services using GIS technologies and the implications for policy. By setting up a

GIS of this nature, value is added to the data by relating them to regional demographic statistics. Specific aims of the project were the following: (i) to map geographical distributions of X-ray facilities by census district and to tabulate by province; (ii) to map the relative availability of X-ray facilities in proportion to census district and provincial populations; (iii) to classify X-ray devices by age category, map their distributions by census district and tabulate per province; and (iv) to classify X-ray devices by type of medical practitioner, map by census district and tabulate per province.

## Methodology

The Directorate: Health Technology, Department of Health, made available to the Medical Research Council selected information from their records regarding licensed X-ray equipment in South Africa. The original data only contained information on the town/suburb where the facility was located. It was necessary to link this information to postal codes, which allowed the registration of the census districts and new provinces through the use of intermediary and other files. This enabled use of the geo-coded file with data on the 1991 population census, which was already in the GIS database, making it possible to compute ratios of people per X-ray machine per district. Of the 9 143 records, 1 764 could not be processed because they contained devices not used for medical or dental purposes, or had insufficient geographical references.

## Geographical distribution of medical and dental X-ray systems

### National distribution

Fig. 1 shows the distribution of X-ray machines in South Africa. It shows that X-ray machines are strongly concentrated in the urban areas of the country. The Johannesburg, Pretoria and Vereeniging complex dominates, followed by the Cape Town and Durban metropolitan areas. Table I shows that Gauteng has 37.2% of all X-ray machines but only 17% of the total population. A similar pattern exists in the Western Cape, which has 19.1% of all X-ray machines but only 9.0% of the total population. In comparison, provinces such as Northern Province (3.5%/12.5%) and the Eastern Cape (8.1%/16.5%) show large discrepancies compared with Gauteng and Western Cape. It is interesting to note that there are 108 districts where no X-ray facilities are available. In KwaZulu-Natal, 31 districts have no X-ray machines, followed by the Eastern Cape (20), Northern Province (16) and the Free State (15). These are predominantly rural areas, where large numbers of people live.

Per capita resource allocation targets are relatively crude indicators which do not take into consideration indicators of need, demographic composition, population density, levels of urbanisation and burden of disease.<sup>5</sup> However, in the

Table I. Distribution of X-ray machines per province

Province	X-ray machines				Population			No. of districts with no machines
	Medical	Dental	Total No.	Total %	Total	Rural (%)	Total (%)	
Western Cape	559	849	1 408	19.1	3 435 683	14.0	9.0	3
Northern Cape	99	85	184	2.5	720 972	26.9	1.9	3
Eastern Cape	322	275	597	8.1	6 297 079	65.6	16.5	20
KwaZulu-Natal	505	575	1 080	14.6	7 955 523	61.8	20.9	31
Free State	279	174	453	6.1	2 598 423	44.3	6.8	15
North West	213	145	358	4.8	3 222 913	52.9	8.5	7
Gauteng	1 200	1 542	2 742	37.2	6 458 332	4.0	17.0	1
Mpumalanga	165	131	296	4.0	2 634 016	67.8	6.9	12
Northern Province	150	111	261	3.5	4 756 250	90.0	12.5	16
<b>Total</b>	<b>3 492</b>	<b>3 887</b>	<b>7 379</b>	<b>100.0</b>	<b>38 079 191</b>	<b>49.7</b>	<b>100.0</b>	<b>108</b>

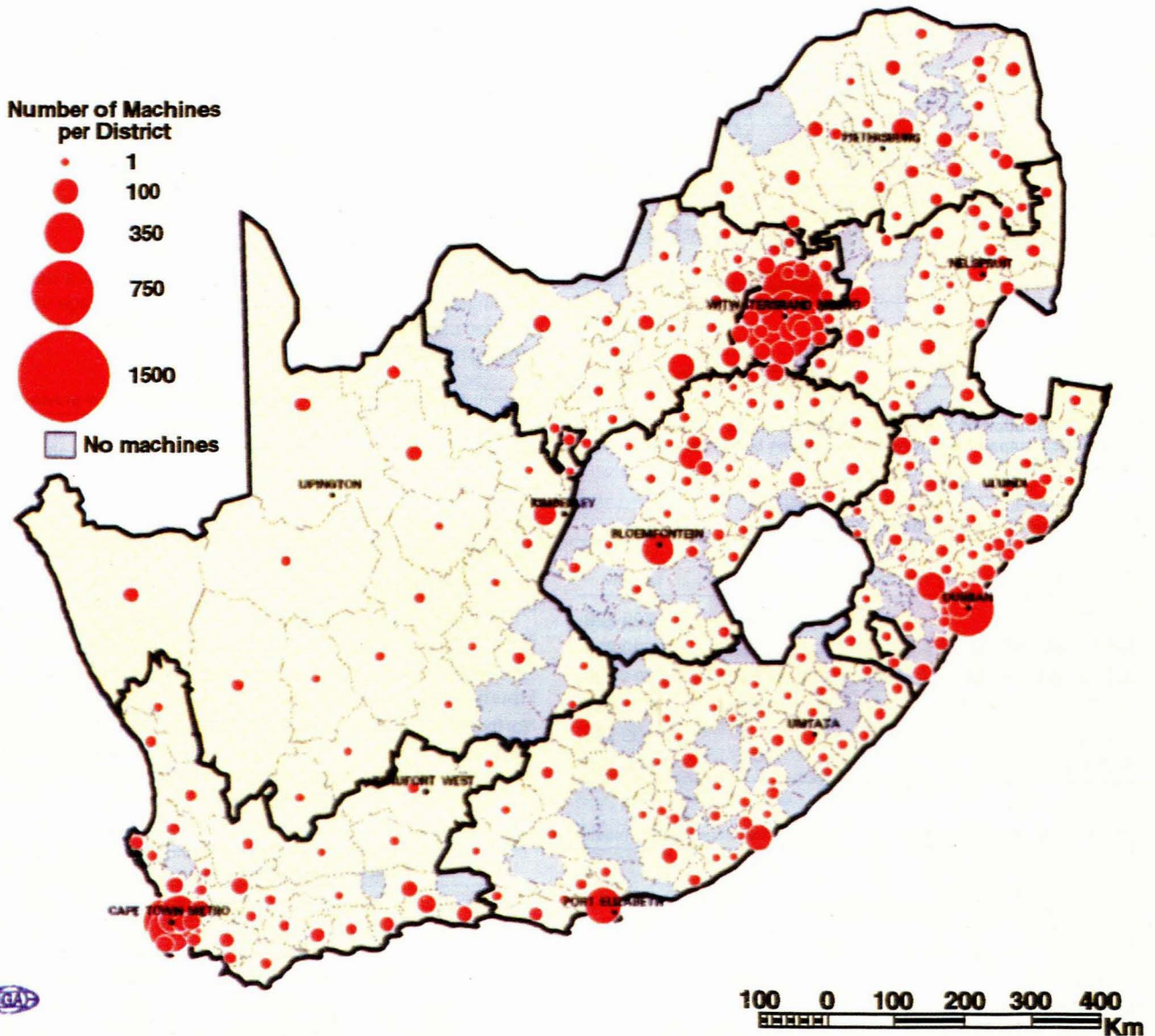


Fig. 1. Number of X-ray machines in South Africa per census district (1994).

absence of reliable data and acceptable indicators these targets do make it possible to make a prognosis of the relative magnitude of the problem. Fig. 2 shows the inequity in the distribution of X-ray sources among the provinces based on a national per capita target for both medical and dental diagnostic equipment. From Fig. 2 it is clear that there is a significant difference between the Western Cape, Gauteng and the Northern Cape compared with the others. However, in the case of the Northern Cape we must take into consideration problems associated with geographical accessibility due to the large area. The population density in the Northern Cape is 2.1 people per km<sup>2</sup> and that of Gauteng 365 people per km<sup>2</sup>. The Eastern Cape, KwaZulu-Natal, North West, Mpumalanga and Northern Province have significantly fewer X-ray systems than their respective per capita allocation targets.

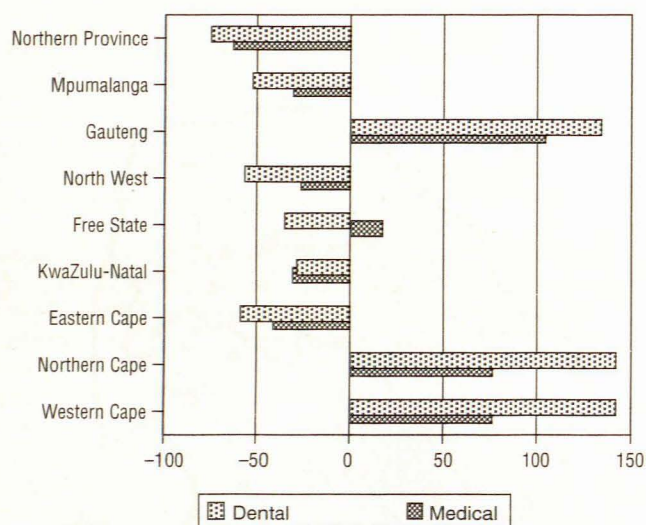


Fig. 2. Distribution of X-ray sources (medical and dental diagnostic equipment) among the provinces based on a national per capita target.

Table II. Population distribution by X-ray groups

No. of people per X-ray machine	No. of districts	No. of people
< 5 000	118	13 795 226
5 001 - 10 000	59	3 030 813
10 001 - 50 000	83	6 821 006
50 001 - 100 000	25	4 678 038
>100 000	8	2 103 783
No X-ray machine	110	7 650 325

Table III. Comparative figures regarding population coverage for medical diagnostic X-rays

WHO comparative data	Population coverage/machine	RSA coverage (medical)		
		No. of districts	Population	%
Industrialised	1 500 - 10 000	120	11 749 395	30.8
Developing category A	10 000 - 50 000	126	10 745 198	28.2
Developing category B	50 000 - 100 000	25	4 126 633	10.8
	> 100 000	115	11 457 965	30.1

### Regional availability of X-ray systems

By expressing the availability of X-ray machines in terms of the number of people per district, a relative indication of regional disparities is produced (Fig. 3). According to this measure, the districts with the highest number of people per X-ray machine are in KwaZulu-Natal, North West, the Eastern Cape and Northern Province. Over the whole country, 25 districts have between 50 000 and 100 000 people per X-ray device, 8 have more than 100 000 per device, and 110 have no X-ray facilities (Table II). In terms of population numbers, this means that 14.4 million people have very little access to X-ray facilities.

### WHO guidelines for diagnostic medical X-ray systems

The World Health Organisation<sup>1</sup> gives some comparative figures regarding population coverage. These figures are shown in Table III. The WHO data distinguish between industrialised countries and two categories of developing countries. Developing countries in category A have an advantage over countries in category B with regard to the development of health services, allowing each radiological unit to cater for a smaller percentage of the population than countries in category B. The data in category A can be considered as a *rational* target for the year 2000 for the countries in category B. (Category A represents approximately 1 billion people, while category B constitutes approximately 3.5 billion.)

The average number of people per medical X-ray system for medical systems is tabulated in Table IV. From a macro-provincial perspective all provinces have an average value for medical X-ray systems well within the rational WHO target (10 000 - 50 000).

Table IV. Number of people for medical X-ray systems per province

Province	Average population/machine (medical)
Western Cape	6 146
Northern Cape	7 283
Eastern Cape	19 556
KwaZulu-Natal	15 754
Free State	19 313
North West	15 131
Gauteng	5 382
Mpumalanga	15 964
Northern Province	28 480
National	10 905

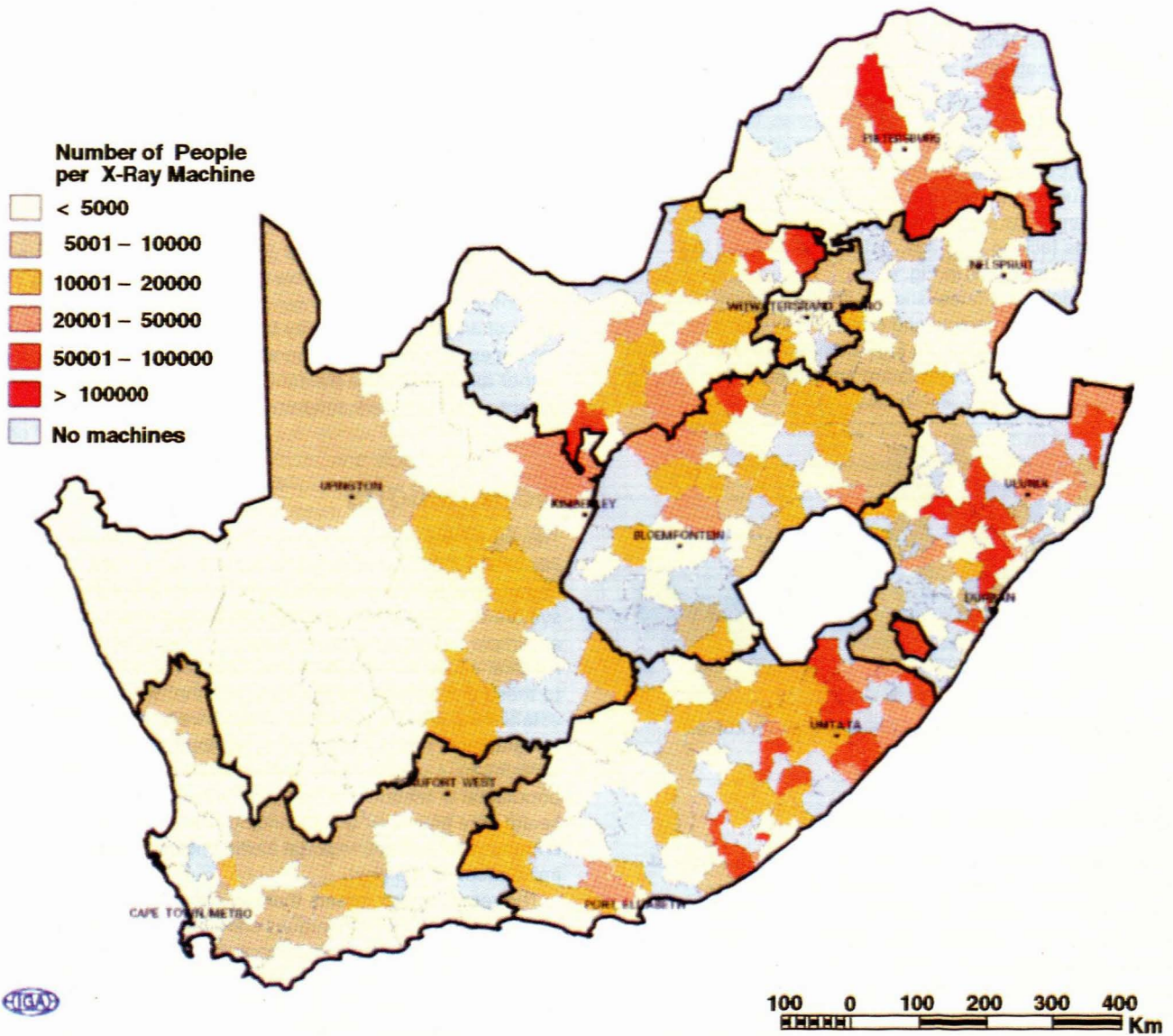


Fig. 3. Availability of X-ray machines in South Africa per census district (1994).

The national average (10 905 people/system) is close to that of industrialised countries. Even Northern Province, with a mean value of 28 480 people/system, falls well within category A. Western Cape, Northern Cape and Gauteng are considered to have values that compare with those of industrialised nations. The supply of X-ray equipment in a 'developing world' context therefore appears to be in line with WHO recommendations, even considering the large inequities among provinces, as discussed. The problem arises when sub-regional (district) levels, as shown in the right-hand side of Table III alongside the WHO classifications, are considered. From Table III it follows that approximately 30% of the population has little or no access to any facilities. Nearly 11% has unacceptable access (WHO category B). This implies that strategies will have to be developed to provide better X-ray access to at least 41% of the population. The rational and minimum WHO target for the year 2000 will therefore require more than 300 conventional X-ray systems to at least provide a coverage of

50 000 people per system.

A study<sup>6</sup> on the distribution of health facilities in South Africa revealed that the total number of hospital beds is adequate for the country as a whole, but there is an imbalance between levels of care and accessibility. The WHO recommendation of 1 000 people per clinic showed a shortfall of some 1 400 clinics, which could rise to 2 500 by the year 2000. We have shown that the same observation can be made for basic X-ray services. It is therefore imperative that the government considers the provision of basic X-ray services in many of the new health centres/clinics being planned for as part of the health plan.

## Age distribution

It was hypothesised that there may be regional disparities in the age distributions of X-ray devices. Urban areas would be expected to have more modern equipment, and remote rural

areas older and outdated devices. The pattern is not that simple, as most large metropolitan areas fall into an intermediate category, whereas both the latest and the oldest X-ray devices are found in rural districts. There is a slight regional tendency for older machines to be found in the Eastern Cape and semi-arid districts of the Northern Cape. The cost of maintenance increases rapidly with ageing equipment. This is especially relevant in remote areas where spare parts are not readily available and maintenance expertise is lacking. The age distribution of X-ray systems in South Africa is shown in Fig. 4.

International estimates<sup>7</sup> show a lifespan between 10 and 15 years for both medical and dental X-ray machines. Using this criterion, it follows from Fig. 4 that nearly a third of the installed base has to be replaced immediately.

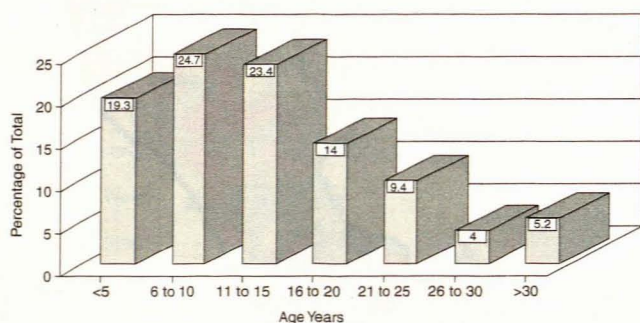


Fig. 4. Age distribution of X-ray systems in South Africa.

## Service distribution

Availability of X-ray services is influenced by the type of health care delivery system available (e.g. primary, secondary and tertiary, as well as public or private). Unfortunately the data are not classified according to the above classification, but rather on the type of service providers, as shown in Table V. From Table V, it is clear that private dentists (43.5%) and medical (public and private) institutions (29%) are the major users of X-ray equipment. Private medical users constitute only 13.3%. Using additional data from a survey conducted by the MRC,<sup>8</sup> it was possible to make an estimate of the division between private and public (Table VI).

Table VI. Public/private sector mix for X-ray systems

Health sector	Medical		Dental	
	No.	%	No.	%
Public	1 947	56	678	17
Private	1 547	44	3 211	83
Total	3 494	100	3 889	100

From Table VI it follows that 56% of all medical and 17% of dental X-rays are accessible through the public health system. Private sector services are allocated largely on the basis of an individual's 'ability to pay' and are consequently not accessible to a large proportion of the population, further questioning the equitable availability of these essential technologies and services.

## Conclusions

This study has shown that by placing existing tabular data into a GIS and by mapping and tabulating the data, important regional variations in the health care delivery system of the country can easily be highlighted. Something as simple as mapping the availability of basic essential medical equipment, such as X-ray systems, draws attention to these disparities and provides data that will be of use in establishing a more equitable health care system. A geographical perspective on the distribution of health services *vis-à-vis* the basic primary health needs of the population is essential to enhance decision making in future health care planning. GIS technology should be widely employed to address regional inefficiencies and redress imbalances of the past.

The report also suggests that per capita resource allocation using GIS techniques should be used with caution. If the significant difference in population density between provinces and rapid urbanisation are not fully accounted for, there may be a disproportionate shift of resources away from areas experiencing rapid growth. Furthermore, it is important to consider additional factors such as the burden of disease, need for health services, demographic composition, and other relevant indicators.

Probably the biggest danger in using GIS-based systems for health care service allocation is the scale and level of

Table V. Distribution of X-ray machines per type of user and province (%)

Province	Medical institution	Private radiologist	Private radiologist	Other medical specialist	General practitioner	Dental clinic	Private dentist	Chiro-practor	Other med. user	Total No.
W Cape	25.2	9.2	0.2	0.8	1.3	9.8	50.5	0.7	2.3	1 408
N Cape	41.8	4.9	0.5	0.0	0.5	16.3	29.9	0.0	6.0	184
E Cape	39.9	7.7	0.5	0.0	1.7	7.2	38.9	0.7	3.5	597
KwaZulu-Natal	31.3	9.2	0.6	0.1	1.8	7.2	46.0	1.0	3.0	1 080
Free State	41.3	6.6	0.4	0.0	2.2	8.6	29.8	0.2	10.8	453
North West	36.9	6.4	0.0	0.0	5.9	9.5	31.0	0.6	9.8	358
Gauteng	23.0	15.2	0.3	0.2	1.2	8.9	47.3	0.5	3.2	2 742
Mpumalanga	31.1	8.8	0.0	0.0	7.4	9.8	34.5	1.0	7.4	296
N Province	42.9	3.1	0.0	0.0	7.7	16.5	26.1	0.4	3.4	261
Total (%)	29.3	10.7	0.3	0.2	2.1	9.2	43.5	0.6	4.1	100.0

usage, as this study clearly shows. The analysis of X-ray systems on a provincial level clearly highlighted significant differences between provinces. Even considering these differences, the 'average' provincial service X-ray provision was shown to be adequate according to WHO criteria. Only when the sub-regions/districts within provinces were included did a disturbing picture begin to emerge. Analysing the data on a national level, but using new indicators such as age of systems and type of service delivery, provided further insights. It is becoming clear that a regional information system that records selected health information on a provincial or even a national basis may be inappropriate for rational decision making aiming to provide effective and quality health services. Restoring the equity between provinces (e.g. X-ray facilities) would have a limited impact on the availability of quality services. In fact, even the 'best-supplied' provinces sometimes have the worst examples of under-served districts, and vice versa.

Only after a systematic, multi-perspective analysis using district, provincial and national views as well as specific attributes such as age and type of service providers did the pieces of the puzzle slowly come together to create the bleak picture of inappropriate management of a fundamental technological resource such as basic radiology during the past few decades.

Our very basic approach has shown that X-ray facilities are mainly concentrated in large urban areas and that there are millions of South Africans in remote rural districts where there are either no facilities or so few that tens of thousands of people have to be served by a single device. The situation is further complicated by the fact that the private sector provides a large proportion of X-ray services and that massive replacement costs of an ageing equipment base are looming.

## Recommendations

1. This report focused mainly on a few indicators of coverage. It is important to expand the indicators as a means of measuring progress. These are: (i) *indicators of coverage* — the ratios of radiological diagnostic and therapeutic machines, radiological personnel and radiodiagnostic procedures to population; (ii) *indicators of quality of the activity* — the number of districts and the number of facilities in each district where quality assurance programmes were applied; and (iii) *indicators of efficacious and efficient utilisation of radiological facilities* — the most difficult to determine, particularly in areas with inadequate records and lack of skilled manpower. Such indicators can be expressed in simple terms as number of procedures per machine per year, or number of procedures per specialist per year, and cost per procedure. More complex indicators might be considered, such as number of procedures with a direct influence on the patient health outcome, or number of procedures that have altered diagnostic and therapeutic decisions.

2. Similar reports should be prepared for each of the nine provinces using the existing data.

3. The national and regional governments consider the use of GIS systems based on district audits and 'averaged' on a provincial and national basis for resource allocation to

provide equitable and quality services. Audits recording inappropriate information and analysed at the macro level may yield interesting information about capital assets but have very little impact on health and health outcomes.

4. The new health centre/clinic building programme of the Reconstruction and Development Programme (RDP) should, if possible, include some radiological services to try and address the intra-regional disparities.

5. Basic radiological services should be added to and managed as part of an essential district health care technology package.

## REFERENCES

1. World Health Organisation. *Clinical, Laboratory and Radiological Technology for Health Systems based on Primary Health Care* (CLR/MTP/88.1). Geneva: WHO, 1988.
2. Palmer PES. The World Health Organisation — basic radiological system. *Radiography* 1985; 51: 169-178.
3. Hanson GP. Essential X-ray services: the basic radiological system (BRS). *Trop Geogr Med* 1987; 40: 576-584.
4. Broomberg J, Shisana O. *Restructuring the National Health System for Universal Primary Health Care: Report of the Committee of Inquiry into a National Health Insurance System*. Durban: Kwik Copy, 1995.
5. McIntyre D. *An Analysis of the Geographical Distribution of Public Sector Health Care Expenditure in South Africa* (Health Economics Unit Working Paper No. 7). Cape Town: Health Economics Unit, Department of Community Health, University of Cape Town, 1994.
6. Chetty K. *The Distribution of Health Facilities in South Africa and Requirements for the Future* (Health Economics Unit Working Paper No. 5). Cape Town: Health Economics Unit, Department of Community Health, University of Cape Town, 1993.
7. GTZ. *Essential Equipment for District Health Facilities in Developing Countries*. GTZ, Division of Health, Population and Nutrition, Eschborn, Germany: June 1994.
8. Walters NM, Bunn AE. *Hi-Technology Medical Equipment: Cost Implication for Health Care in South Africa* (MRC Report: HTRG 95/001). Tygerberg, W Cape: Medical Research Council, 1995.