

The integration of IAM and GIS technologies to support decision making in the planning and procurement of physical infrastructure for the treatment of drug-resistant Tuberculosis in South Africa

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Abstract

While positive progress was being made in the latter half of last century in the treatment of the Mycobacterium tuberculosis (TB) epidemic across the world, the emergence of new drug resistant forms – multi drug-resistant TB (MDR-TB) and extensively drug-resistant TB (XDR-TB) threatens gains made and has raised the spectre of a resurgent and more virulent TB epidemic. Co-infection with HIV/Aids, a common phenomenon in South Africa, adds substantially to the risk of infection and numbers of patients, making control more complex and demanding. With both a high TB burden and incidence, South Africa is one of the most negatively impacted countries in the world.

The real additional burden of hospitalising M(X)DR-TB patients, the urgency of the need for such accommodation, disease specific requirements for long-term acute and post-acute M(X)DR-TB care, the need to plan within an existing service strategy and limitations on available resources (budget, staff and infrastructure), requires that a new, more integrated approach to strategic planning and the provision of accommodation be developed.

This paper provides an overview of new processes and a toolkit being developed in South Africa to support decision making in the planning, procurement, management and operation of physical infrastructure for the treatment of patients with M(X)DR-TB. Use is made of a new Immovable Asset Management (IAM) framework and tools being developed as well as of GIS technologies. Links are also made to facility and risk assessment tools developed for facilities benchmarking and post-occupancy evaluation. While the toolkit is being specifically developed to address the M(X)DR-TB epidemic in South Africa it is envisaged that it will have a wider application in health infrastructure planning and management.

Where this paper focuses on integrated service and facility planning for M(X)DR-TB patients, the Congress paper “Hospital design to accommodate Multi- and Extensively Drug-Resistant TB patients” will focus on the design of such facilities.

Background

Mycobacterium tuberculosis (TB) is an airborne infectious disease that is curable. While TB can occur in different organs of the body this paper will focus on pulmonary TB (disease of the lungs), its most common manifestation. Individuals identified as tuberculosis patients must, prior to commencement of their treatment, have had an examination of their sputum performed to determine whether or not they are infectious cases of tuberculosis. The examination consists of microscopic examination of a specimen (smear microscopy). If micro-organisms are detected by this method then the

patient is said to have smear positive tuberculosis. Such patients are normally provided a standardized home based short-course anti-TB treatment. In order to ensure that patients complete their medication they are normally put onto an outpatient support programme where independent observers verify that they have taken their medication on a daily basis (directly observed treatment support programme or DOTS).

If after five months of treatment the smear tests remain positive, the patient is then registered as a treatment failure, and sputum specimens are sent to a diagnostic laboratory for culture and drug susceptibility tests, after which the patient is started on a retreatment regimen. TB culture and drug susceptibility is an expensive and slow diagnostic technique.

Retreatment patients are usually hospitalised until the patient's sputum is tested negative by the diagnostics laboratory. Should a drug resistant diagnosis of the specimen be made, the patient is then identified as have contracted drug-resistant TB.

Drug-resistant TB has developed through patients defaulting on treatment (patient management and adherence), problems with medication or treatment management or by co-infection, allowing the disease to mutate and become immune to first line drugs. Multi-drug resistant TB (MDR-TB) is defined as a patients resistant to at least two of the most potent first-line drugs (Isoniazid and Rifampicin). Treating MDR-TB takes longer and requires drugs that are more toxic, more expensive, and are generally less effective.

The problem of drug resistance in TB has been compounded by the emergence of extensively drug-resistant (XDR) TB, defined as MDR-TB in association with in vitro resistance to any of the fluoroquinolones plus one or more of the injectable second-line anti-TB drugs. Patients with XDR-TB are extremely difficult and expensive to treat and exceptionally high mortality (exceeding 90%) has been recorded in XDR-TB patients with HIV co-infection in South Africa. Both MDR- and XDR-TB can be passed directly, through the normal airborne infection route, to non-infected people.

The impact of TB in South Africa is exacerbated by the vulnerability of people with HIV and Aids, leading to high co-infection rates, dramatically increasing the severity of impact. During the past 10 years in South Africa the incidence of TB has increased in parallel to the increase in the estimated prevalence of HIV in the adult population. Currently there is an estimated HIV prevalence of 30% (based on antenatal surveys), a TB incidence of 680/100 000 population, and a 2006 co-infection rate of 53%. A far higher HIV prevalence rate of 73% was recorded amongst MDR-TB cases at the provincial referral unit at King George Hospital in KwaZulu-Natal in 2007.

While the Department of Health has an extensive programme for the management of TB including clear policies, treatment guidelines and monitoring systems, the size and rural nature of much of the country and high levels of poverty in many of these areas have resulted in sufficient levels of defaulting from treatment that, together with difficulties in tracing contacts of TB sufferers, have allowed an increase in the drug resistant strains of TB.

There is an international campaign to reduce the impact and spread of TB, and various targets and programmes have been instituted through the WHO and the WHO Stop TB

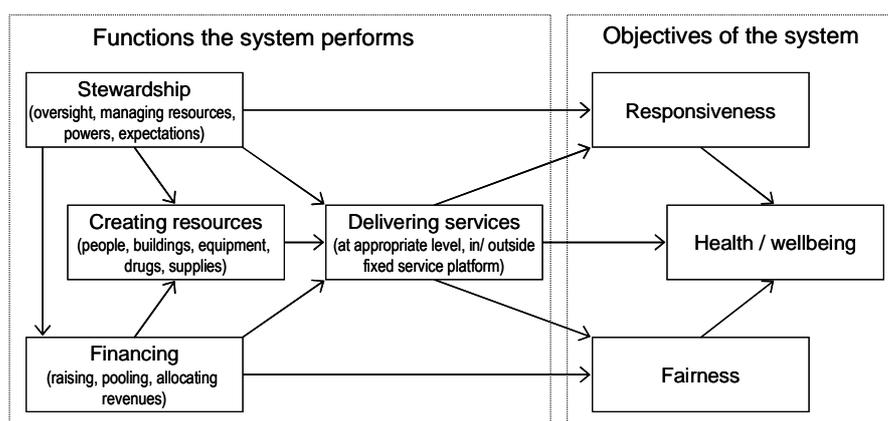
Partnership and regionally (WHO-AFRO Regional Committee). In South Africa TB was declared a national crisis in 2005.

Drug resistant TB requires longer treatment and isolation from other TB patients and the general public in order to stop the spread of those strains. To achieve these objectives substantial additional capital and operational funding has been made available to increase the number of units providing treatment of drug resistant TB, to improve infection control measures in existing and new facilities to protect staff and other, as yet uninfected patients, visitors and other TB sufferers, and to improve the whole treatment chain.

The need for Integrated Planning

Figure 1 provides an overview of the major components of a health system. All functional components need to be in place and in balance in order to achieve the objectives required, i.e. a service that is responsive to the required health needs of the population in a fair and equitable manner. Key potential constraints to service delivery are the availability of resources and inadequate systems (stewardship).

Health System Performance Framework



Adapted from: World Bank, 2000, Schneider et al, 2007

Figure 1: Health system performance framework

The same functions and components need to be in place to achieve the TB and M(X)DR-TB programme objectives, i.e. the successful treatment (health and wellbeing) of those affected with TB in a system that is responsive to the needs of the broader community in a manner that is equitable and fair. To achieve these objectives services need to be delivered in an appropriate mix of delivery modes, either within the fixed infrastructure or as outreach community based services. Services need to be supported by the necessary resources – including people, buildings, equipment, drugs and supplies. Stewardship including the development of appropriate strategies, managing resources and expectations and assigning the necessary powers is the responsibility of the national and provincial health departments whose tasks also include sourcing and allocating the necessary financing.

The stewardship role in South Africa is complicated by a division of responsibility between national, whose primary role is policy development and advisory and the executive role of the second tier provincial governments. There is also a historic split

between second tier provincial and third tier local government services with many of the primary level services delivered at local authority level.

Effective planning requires sound, current information, an effective policy and regulatory framework and integrated systems. A current concern is that while attention has been given to policy and the regulatory framework, the implementation framework is fragmented; implementation systems are inconsistent, there is a lack of current, consistent and standardised information and in many cases, a lack of adequate trained capacity to support the implementation process.

There is ongoing pressure to provide additional facilities and additional services for the care of drug-resistant TB patients. This needs, however, to be balanced against the total cost of service provision and the need to integrate TB services within the full framework of public health service delivery. A major strategic planning initiative in health services is currently to look at the whole issue of affordability of services within the context of a developing country economy.

Infrastructure for the treatment of TB and drug-resistant TB

South Africa has a public health estate in excess of 4 000 facilities including some 428 hospitals. Of these 35 facilities are designated as special hospitals for TB services. Most of these belonged to the SA National Tuberculosis Association (SANTA), a non-governmental organisation and have recently been taken over and are currently run by the government. Although originally designed for normal TB and mostly with large open nightingale type wards, many are now used for a mixture of drug-resistant and non-responsive or recurrent TB patients.

TB services, however, are not restricted to TB hospitals – case finding is undertaken at all primary health facilities and hospitals, treatment is initiated and supported at most facilities and TB services require local and central laboratory services and drug supply chains. Figure 2 illustrates the various contact points for the whole TB treatment chain.

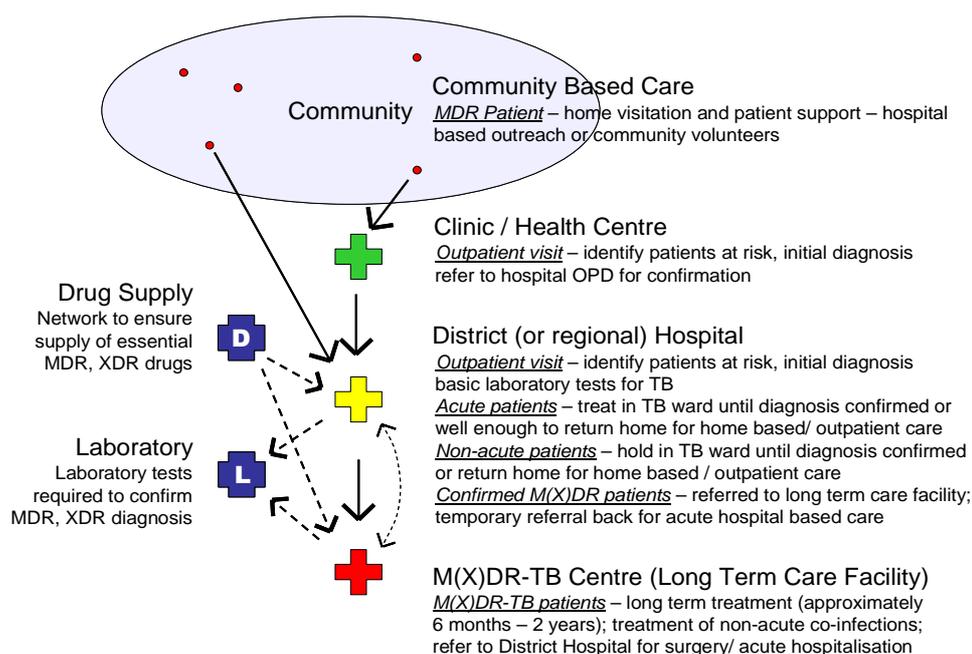


Figure 2: Contact and service delivery nodes for TB patients and services in South Africa

Most new patients are identified through the primary health-care network at clinics, health centres or district hospitals. As TB is a notifiable disease, all cases are recorded in the national TB register which tracks patients through their treatment. Currently the system is a paper record at point of entry and treatment that is then captured electronically and consolidated into the national TB Register. A new web-based system is currently being tested through a pilot project in the Eastern Cape Province.

While much of the current media and planning attention focuses on drug-resistant TB, this is an extension of the normal TB disease and the more effective the whole system the lower the pool of patients and potential for defaulters to convert to drug-resistant TB, the fewer opportunities there will be to transmit drug-resistant TB. Planning for the treatment of drug-resistant TB cannot be seen in isolation from normal TB services, nor can it be isolated from other health service delivery.

The use of GIS in the Public and Health Sectors in South Africa

GIS is used in a wide range of initiatives to support spatial decision making across all sectors of government in South Africa. The CSIR has been involved in the development of the Geospatial Analysis Platform (GAP), a common, mesoscale (roughly 7km by 7km zones) geo-spatial platform for the assembly, analysis and sharing of economic, development and demand information. GAP is being used, inter alia, to support the development of the National Spatial Development Perspective and the Regional Industrial Development Strategy. While the focus of the system is on economic related analyses, the system is being expanded to add a greater demographic capability and health data can easily be added. For the purpose of the development of a toolkit this was seen as an ideal GIS platform to develop and demonstrate the concept and its potential.

The substantive current focus of GAP – referring particularly to the "how much is where" type of question, is mainly on disaggregated human/economic activity and population variables – such as magnitudes of economic activity or persons below the minimum living level. The broad nine economic sectors (Gross Value Addition – GVA) are all disaggregated to mesozones. The main focus for demographic indicators has been on the distribution of individual and households per mesozones as well as the distribution of the poor (persons living under the minimum living level – MLL) per mesozone.

A more detailed socio demographic profile per mesozone is currently being prepared to indicate classifications related to:

- Gender
- Age groups
- Income groups
- Education levels
- Mobility – transport mode, and
- Access to municipal services (water, electricity, sanitation).

The need for more detailed data disaggregation has been identified through projects related to local facility planning. Microzones – the nesting of four microzones in each current mesozones, have been created during a pilot project in Mpumalanga Province and the methodology will be used for similar areas elsewhere, allowing more accurate definition of settlement patterns.

The mesozones are also linked to a strategic national road network and associated analysis tools, forming the third main component of GAP. The use of this component makes it possible to:

- construct a variety of inter-zonal distance and travel time matrices using a GIS-based network analysis routine;
- estimate quantities of economic and other human activities within specified distance or travel time ranges (e.g. undertake proximity counting); and
- calculate a range of accessibility and related measures (including “functional urban accessibility measures” based on measured distances or travel times to the nearest town of a specified hierarchical order).

Facility catchments, based on the current travel time and modal norms and standards, can be calculated using the linked zone sets and the facilities as destinations. Figure 3 illustrates a typical catchment area analysis undertaken for the Gauteng Province. Population profiles within catchments can also be calculated and studied.

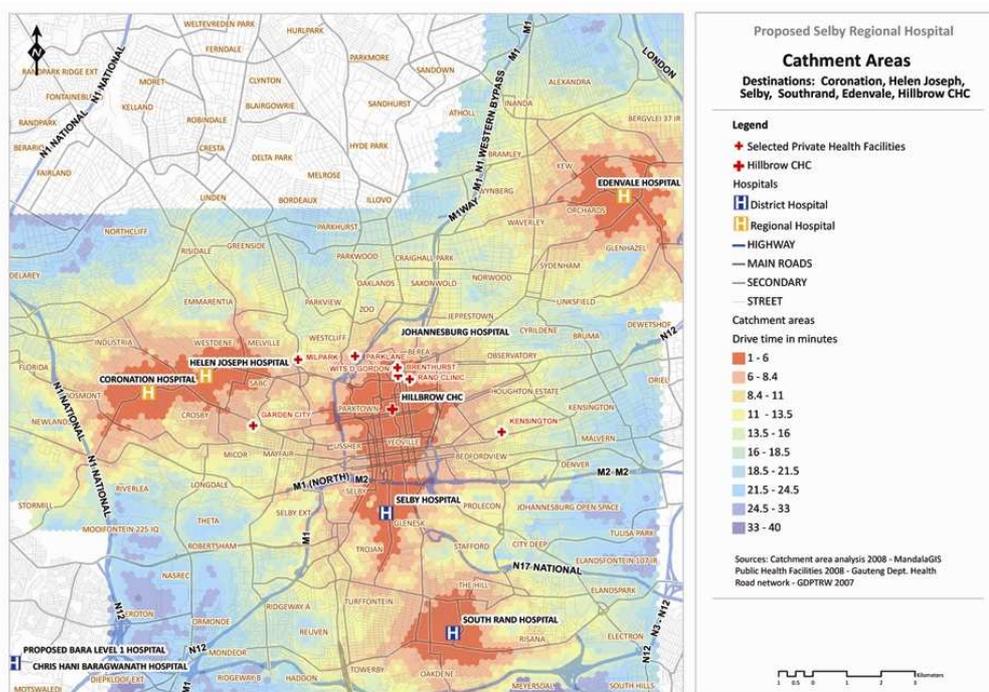


Figure 3: Catchment area analysis for central Johannesburg public hospitals

Populations (based on relevant profiles) can be counted based on their proximity to facilities. Proximity can be calculated on travel time, cost or distance. Proximity counts give a very good indication of access to densely populated areas, patterns and their relative location against the provision of services.

The incorporation of environmental, climate, rainfall, surface water conditions and a range of relevant spatial datasets, makes it possible to study the relationships between health issues with external environmental factors.

With the inclusion of public facilities of all government departments in the geographic database, it will be possible to study the spatial relationship between facilities and to plan for the effective sharing of facilities.

Although most of the accessibility calculation procedures make use of current norms and standards (travel time, cost, etc.), the base on which calculations are done can also serve to study and establish new relevant and appropriate norms and standards based on the specific conditions in an area. This can also be related to the specific budgets for facilities in order to do planning.

Links have been made to other specific studies such as the household transmission study undertaken by the Italian National Institute for Health in co-operation with the KZN Department of Health. This study has plotted over 3 000 M(X)DR-TB cases in the Msinga sub-district in KZN (the area served by the Church of Scotland Hospital, the centre of the recent outbreak of XDR-TB in South Africa) in studies to establish the source of the outbreak. This data is also being used to support the community outreach support programme. Figure 4 shows the growth of MDR- and XDR-TB over the last three years.

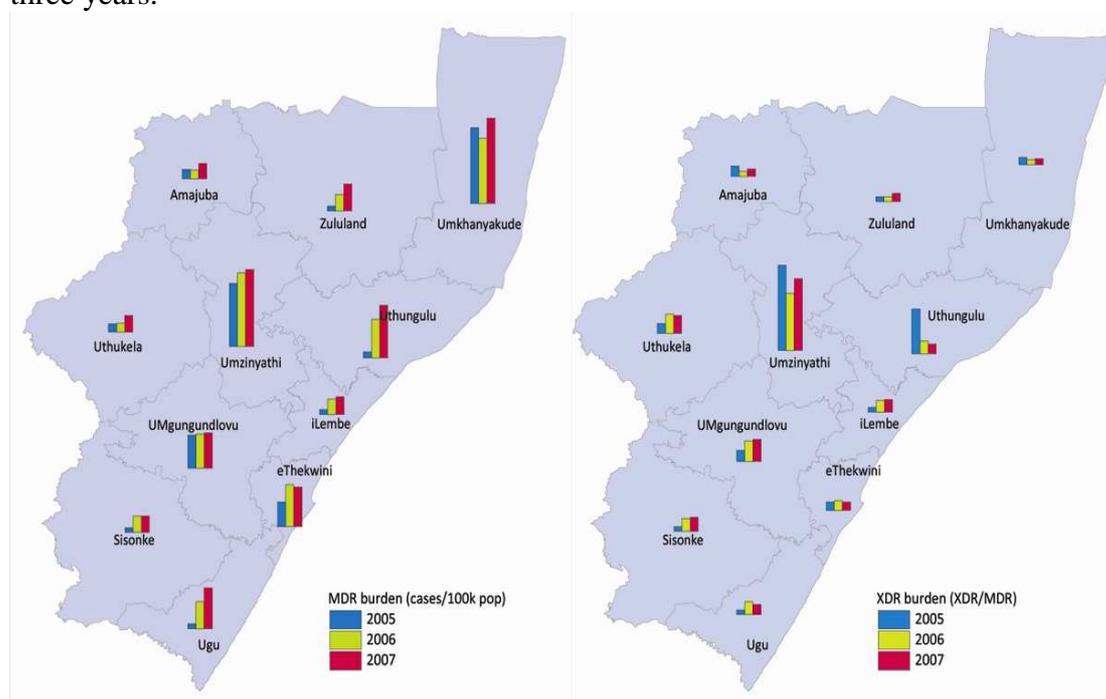


Figure 4: Growth of MDR- and XDR-TB in KwaZulu-Natal Districts over the 2005-2007 period

Immovable Asset Management in the Health Sector

There is currently no single system of immovable asset management in use in South Africa although some attempts have been made to introduce an integrated framework and system nationally and at provincial level. In 1995/96 a full assessment was undertaken for the national Department of Health of all public sector hospitals and health centres in South Africa by the CSIR using the PREMIS suite of software. This initiative led to the introduction of the Hospitals Reconstruction and Rehabilitation programme (HR&R) in which national funding was made available to rehabilitate the countries hospitals. Later this programme was evolved into the current Hospitals Revitalisation Programme. However, while some provinces (including KwaZulu-Natal and Limpopo) maintained their use of the IAM software to assist strategic service and capital planning, the opportunity to introduce and maintain a consolidated asset register and assessment framework was not taken up.

The Government Immovable Asset Management Act (GIAMA), introduced by the national Department of Public Works in 2007, now provides a consolidated framework for user (client departments) and custodian (usually works departments) to manage public facilities. Together with the Public Finance Management Act (PFMA) it provides a high level framework for the consolidation and upkeep of immovable asset registers and for the regular assessment of facilities as input towards defined strategic planning, acquisition, operation and maintenance and disposal processes. However, details of its application in specific sectors and especially the link with strategic service planning still need to be developed.

There are currently two major health service planning initiatives nationally: the District Health Information System (DHIS) and the Integrated Health Planning Framework (IHPF). The former focuses on health-service information and consolidates information from all district health-service facilities (primary health clinics and district hospitals) into a national database. The IHPF is an ambitious national Department of Health initiative consolidating basic data from all health facilities and basic-service indicators (drawn from DHIS), against capital, operating and staffing resources in order to provide a framework and information resource for strategic planning. The system is linked to a GIS. Neither system is linked to a full IAM system providing current qualitative and operational data on the health estate.

One of the primary concerns and challenges with any qualitative assessment data on infrastructure is to maintain its currency. While support for this is now being provided by the new GIAMA legislation, KZN have been maintaining and updating a profile of their estate over the last 10 years using PREMIS. It is the only province with a 10-year record of the change in the extent, condition and suitability of their estate. This information is critical to enable life-cycle planning, management and ongoing benchmarking of the estate. Figure 5 shows the current application of PREMIS in KZN against the facility life cycle.

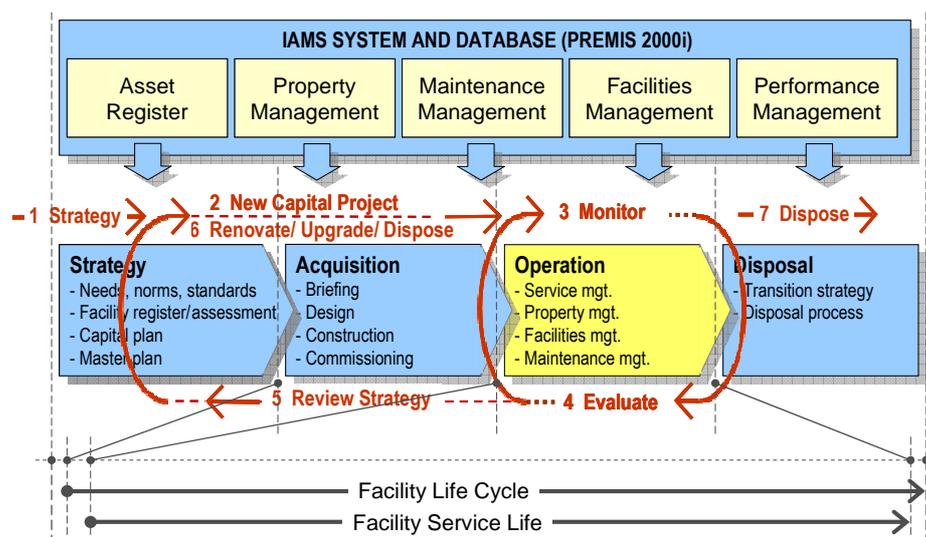


Figure 5: Facility life cycle showing work phases and primary tasks and designed role of PREMIS IAMS software

An integrated approach to service and infrastructure planning and management for M(X)DR-TB

The CSIR was approached late in 2007 to provide strategic support to the national Department of Health and the Provinces in the roll-out of a substantial capital funding programme for the expansion and revamping of infrastructure for drug-resistant TB recognising the high risk of airborne disease transmission, the need to provide safe accommodation and the urgency of the need. One of the set of sub-projects was to develop and pilot a strategic planning framework, database and GIS planning tool for TB facilities. The programme is funded by the US Government through CDC-South Africa on behalf of the South African Department of Health.

The initiative is linked to a new national DOH infrastructure research programme and TB work in KwaZulu-Natal (KZN) province and PREMIS implementation projects in the KZN departments of Works and Health.

The project involves the consolidation of available TB and M(X)DR-TB service and infrastructure related data into a database, setting up links to a GIS platform that provides relevant spatial, demographic, economic, access and epidemiological information and the development of a front end enabling querying and reporting functions. The toolkit needs to support and enable the implementation of the current (2007-2011) National Tuberculosis Strategic Plan for South Africa.

The following development objectives were set for the toolkit:

- to build on available systems rather than seek to develop new technology
- to construct the toolkit in such a way that it will enable maximum benefit of IAM and GIS technologies
 - including, in IAM, the consolidation and maintenance of a fully legally compliant immovable asset (IA) register, tracking of IA performance and consolidation of resources used in managing and maintaining the estate, and
 - including, in GIS, enabling interactive planning and analysis including linking and display of IAM related data on maps with various backgrounds, proximity locational optimisation analyses, and accessibility and mobility studies
- to provide a common interactive platform for use across intra- and inter-departmental boundaries in such a way that it would support and encourage integrated planning between different role players in service and infrastructure planning and procurement
- to initially use and build on available data and databases rather than require the sourcing of new data and the creation of new databases
- to provide short-term deliverables that will have a positive impact as well as having a long-term vision and goal with a clear incremental development pathway
- to provide a platform initially for M(X)DR-TB planning but to plan in the longer term to support broader integrated health service and infrastructure planning, and
- to use clear graphic means and colour to convey complex data in a readily understandable fashion across discipline, management, administrative and professional boundaries.

Integrated service and infrastructure planning and management requires ongoing monitoring and evaluation of the existing estate, benchmarking and performance assessment to enable and support ongoing strategic planning, budgeting, acquisition, operational management and disposal of assets. Figure 6 shows a concept set of performance indicators developed around three high level indicators:

- *fit for purpose* focussing on issues related to the situation, physical design and layout of the facility. Fit for purpose issues are durable and costly to change
- *fit for service* focussing on issues related more to the current state of the facility and how it is being used. These issues are alterable and can be more readily changed, albeit at a moderate cost, and
- *usage* issues focussing on the activity currently accommodated or the current cost of operation or resources required to operate the facility. These issues are more transient in nature and can be altered by changing the usage – adding a ward or opening another facility nearby – or managing the facility more efficiently.

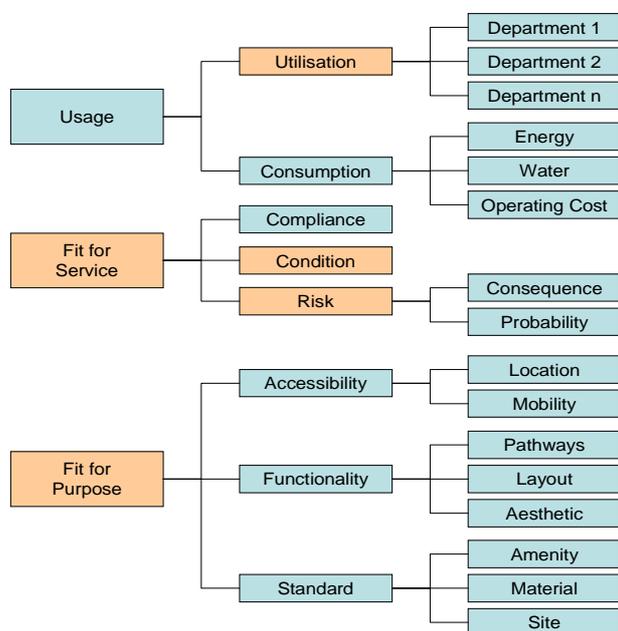


Figure 6: Concept set of facility performance indicators highlighting initial set of primary reporting indicators

Each of the second tier indicators can be assessed individually or can be built up from sub-sets of indicators or separate full assessment processes. There is a full assessment process, for instance, built up around condition, using assessment at element level (floors, walls, roofs, finishes, separate mechanical and engineering systems) at site and individual building, floor, zone or space level. A separate risk assessment toolkit has also been developed by the CSIR for TB facilities focussing on airborne disease transmission.

This performance indicator set provides the framework around which physical assessments of the facility can be undertaken and provide the benchmarking necessary for performance management as part of the ongoing cycle of monitoring and evaluation. All assessments are undertaken on a similar 5 point rating scale from 5, very good to 1, very bad. Figure 7 shows the application of this scale for condition assessments and how

this can be used to develop a framework for maintenance management and budgeting. Use is made of colour to make issues clearly visible to decision makers.

Rating	Condition	Maintenance Type	Budget Type		
5	Very Good	Preventative Maintenance	Maintenance Budget	Normal Maintenance (Planned & unplanned)	
4	Good	Condition-based Maintenance			
3	Fair	Repairs	Maintenance Budget	Capital Works Budget	Backlog Maintenance
2	Bad	Rehabilitation			
1	Very Bad	Replacement			

Figure 7: Five point condition assessment rating scale showing linkage to maintenance and budget types (after Mc Duling, Abbott)

The current set of facility and condition assessment data in PREMIS is used to assist in the development of zero-based capital and maintenance budgets. A new health facility TB risk assessment tool has been developed as part of the support programme to the Department of Health and is being piloted on a number of hospitals. The data will be consolidated into PREMIS along with further functional assessment data to provide the basic set of data necessary to drive the pilot IAM/GIS programme. Links are being made to the spatial databases already in GAP and to new layers currently being sourced. Figure 8 illustrates a mock-up of one of the front-end screens envisaged showing facility location against a background of people below MLL (minimum living level). Different types of facilities are illustrated – including the full range of facilities involved with TB services and a hypothetical risk profile for unspecialised health facilities and specialised TB hospitals. Various combinations of assessment data can be called up and viewed interactively against a range of spatial backgrounds. Specific access, catchment and proximity studies can also be undertaken using the mesozone data.

More detailed facility reports can be retrieved and displayed by selecting a specific facility on the screen as illustrated in Figure 8. This report shows a hypothetical full assessment profile for the selected district hospital.

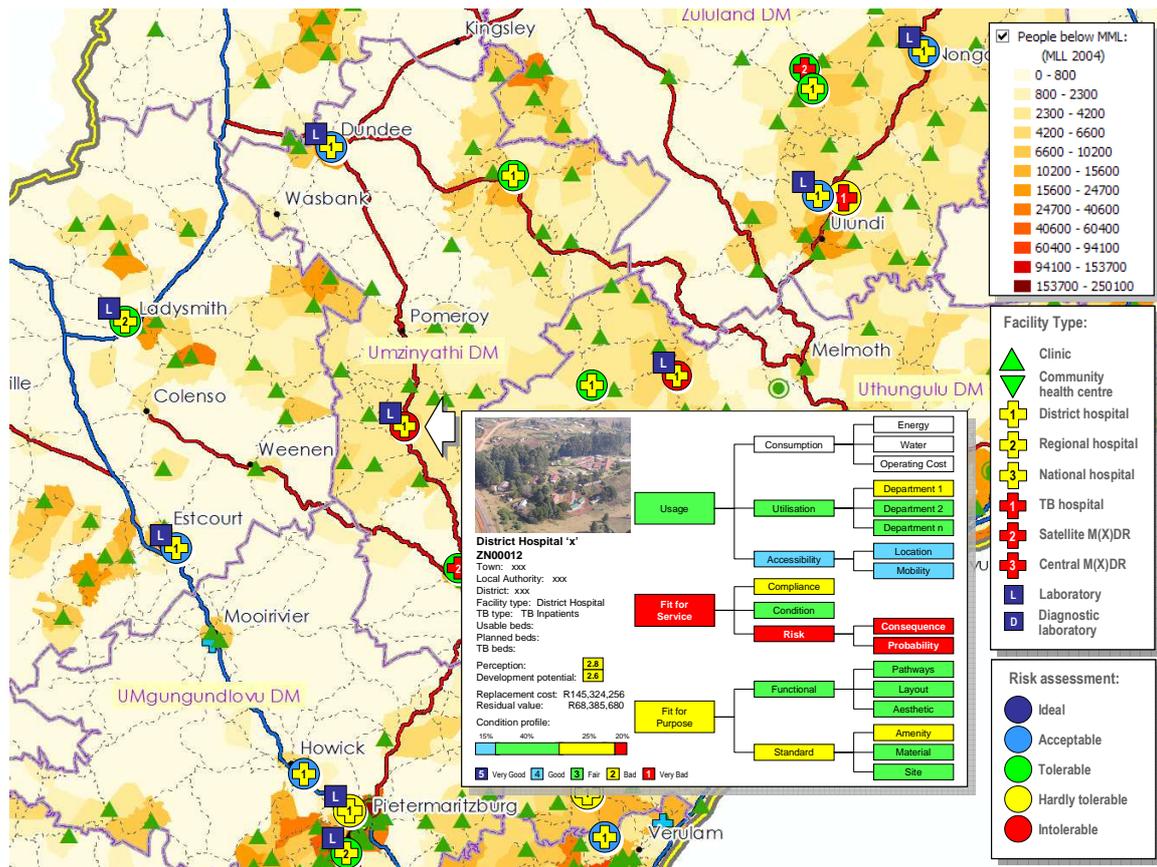


Figure 8: GIS mapping for a hypothetical district hospital showing illustrative data for a facility with a high risk profile

Another module in the toolkit will provide a planning and costing analysis set of interactive reports allowing the user to retrieve current facility bed allocation, usage and qualitative assessment data and to test various scenarios for the expansion or upgrading of services. The system will report initial capital and operating cost implications for proposed extensions to the portfolio for different types of facilities sufficient to enable the user to review the resource implications of alternative service strategies and to building annual budgets.

Conclusion

Effective infrastructure planning requires, amongst other things, current information. The lack of current, consistent and standardised base data, information collection and analytic processes has the consequence that strategic planning for public sector social infrastructure is ad hoc and contingent. The situation is further compounded by a shortage of skills widely faced by the South African civil service.

Notwithstanding the challenges that will doubtless be encountered in establishing and sustaining it, an integration of IAM and GIS technologies to support decision making in the planning and procurement of physical infrastructure for the treatment of drug-resistant Tuberculosis in South Africa would be valuable to many stakeholders. If rolled out broadly to users in different provinces it would also provide a standardised and consistent means of planning and reporting service data and for the assessment of service plans. A further potential advantage is that it will facilitate the consolidation of funding applications to National Treasury by providing consistent quality data.

In order to effectively address the challenges faced by the urgent public health threat posed by M(X)DR TB, the role of infrastructure, not as insular components, but as complex systems must be understood. To effectively achieve this, IAM and GIS technologies, combined may have a key role to play.

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