

THE USE OF SPATIAL PLANNING TECHNIQUES FOR EMERGENCY SERVICES OPTIMAL LOCATION DETERMINATION

Dr P C Lombard and Mr J G C van der Merwe
Africon Engineering International
PO Box 905, Pretoria 0001
Tel: 012-427-2727; Fax: 012-427-2640; e-mail: paul@afriicon.co.za

1. INTRODUCTION

The democratisation of South Africa in 1994 had significant effects on the provision of services at local level, *inter alia* due to the unification of local structures. This required realignment in the way that municipal services are provided.

Most local and regional authorities in South Africa were and are still faced with the task of integrating physical jurisdictional areas for the provision, maintenance and operation of basic municipal services such as water, sewage, electricity and waste collection and disposal. Other services, where the responsibilities are less clearly defined, also have to be addressed. One such example is emergency services provision.

Following the devolvement of functions and responsibilities through the assignment of various legislation to provincial and local government bodies the Rustenburg District Council (RDC) embarked on a process of restructuring of services provision in conjunction with other municipalities within its area of jurisdiction.

The RDC area comprises of 6 Magisterial Districts with a total population of approximately 640000. The current population density is about 28.8 persons / km², over an area of 14186 km². Huge disparities exist in terms of available services and service levels between the former RSA and mainly rural Bophutatswana areas that now form part of its area of jurisdiction.

The restructuring process also need to be dealt with within the framework of a myriad of complex and often confusing legislation, whilst the rationalization and transformation of local government will also have a significant impact on service delivery.

Services that need to be addressed include:

- Fire fighting and rescue services
- Medical emergency services
- Ambulance services

- Special services (disaster management)
- Training
- Support services (Financial, administrative etc.)

Key problems identified included *inter alia*:

- The lack of standardised service delivery policies and by-laws and procedures.
- Overlapping geographical areas of service delivery between respective authorities and service stations because of historical reasons, which contributed to inefficiency.
- Inadequate supportive infrastructure (road conditions, road signage, fire water, communication systems etc.)
- Inadequate funds, as these services are mainly subsidised with little opportunities for cost recovery.
- Community expectations.
- Poor condition of service facilities.
- Lack of service stations to achieve optimal coverage and service levels.
- Insufficient co-ordination and co-operation between service providers, authorities, private sector services and communities.
- Lack of policy decisions in terms of the provision of combined / integrated services and or separate services (split between Fire and Rescue and Medical emergency and Ambulance services).

To inform the process of institutional and financial restructuring to address the above concerns, it was necessary to determine as a point of departure on a technical level, the optimal service delivery requirements in terms of the optimal location of the respective services. The resourcing requirements of such facilities within the framework of this unique environment and specific service level standards and parameters also had to be considered [1].

The purpose of this paper is therefore to illustrate at the hand of the RDC example the application of Geographic Information System (GIS) technology, coupled with transportation planning techniques, to establish optimal locations of emergency services, for a required level of service. The following aspects will be addressed:

- A definition of emergency services and associated aspects
- The methodology and approach that were followed in the case of the RDC to establish the optimal location of emergency services facilities in the new jurisdictional area, with emphasis on the following:
 - The creation of a GIS database of relevant information to assist in analysis
 - Demand determination, risk classification and Standardised Demand Profile
 - Definition of reaction standards for emergency services
 - Determination of coverage contours to establish levels of service
 - Combination of emergency services demand and supply to arrive at an optimal and equitable solution.

- The results from the analysis and interpretation
- Current institutional changes and the wider application of this methodology to meet the needs that the enabling legislation implies.

2. BACKGROUND TO EMERGENCY SERVICES PROVISION

Emergency services include medical emergency services as well as fire and rescue services.

Medical emergency services are provided in response to medical emergencies. It usually constitutes paramedical assistance, in some cases augmented by ambulance transport to a hospital. Fire and rescue services refer to fire prevention, fire fighting and the rescue and treatment of persons involved. In many emergency situations both services are provided or needed.

These services are typically rendered from a station that is located in an optimal location. When determining optimal locations it is necessary to have an understanding of the standards that the various types of services should adhere to.

The station locations for medical emergency services depend on the ability to react to calls within a specified time limit. The frequency of calls is a determining factor, and stations should be located in close proximity to call concentration areas, as well as optimally in terms of the location of care facilities.

Fire and rescue services should conform to additional standards, due to responsibility for fire prevention and spreading. The SABS Fire Protection Code (SABS 090-1972) [2] provides a classification of land uses in various categories, as well as minimum reaction times.

The challenge in finding optimal locations for emergency services stations therefore lies in matching the demand profile for each category with the minimum service time required, taking cognisance of the constraints of the region served in terms of land use and socio-economic development patterns.

The RDC area incorporated several stations with varying types of facilities, staffing and levels of service that can be provided, but concentrated mostly in one part of its jurisdictional area. A restructuring exercise was therefore needed to establish an optimal realignment of these facilities and services provided, to ensure a more equitable approach.

3. METHODOLOGY AND APPROACH

The study area has a wide variety of land uses. This varies from the predominantly urban nature of the town of Rustenburg and other centers such as Mogwase, to extensive agricultural, mining and tourism land uses, the latter located at resorts such as Sun City and the Pilanesberg Game Reserve. It also has a relatively high-density semi-rural residential component. This posed a specific challenge in terms of various levels of service required as well as protection needed due to high infrastructure investment costs.

Due to the spatial nature of the problem, it was decided to use Geographical Information System (GIS) technology, interfaced with transportation planning techniques, to find optimal locations for stations. More sophisticated models exist that can be used in more complex environments and to deal with more comprehensive needs than stated above. However, this approach was decided on, using basic available tools to meet client needs within budgetary constraints.

3.1 Creation of a GIS database

The first step was to create a GIS database with all relevant data. This included the following:

- *Cadastral and topographical data*, to indicate national, provincial and lower order boundaries of the study area
- *Land use data*, capturing the wide variety of land uses occurring in the study area, and taking cognisance of future and potential growth areas [3]
- *Communication, education and health infrastructure*, to indicate the access to public telephones and health services
- *Transportation infrastructure*, incorporating the road management system of the North West Province, and indicating the type of road, surface type and condition, as needed for travel time determination
- *Current emergency services location*, for defining the current levels of service

The various data sets were imported into Arcinfo for further analysis purposes on a single platform.

3.2 Demand determination, risk classification and Standardised Demand Profile

The location of emergency services stations is directly related to the distribution of demand. In this case, demand was defined as the number of calls received in a certain category and the area risk classification, and requesting reaction to an emergency.

The study area was divided into squares of eleven by eleven kilometres, to simplify analysis. A two-month sample was obtained from the records of all stations, indicating the origin of demand as well as the type of land use or incident involved.

The results from the survey indicated the following:

- The majority of calls (about 90 per cent) was related to medical emergencies, and the balance for fire and rescue emergencies
- The majority of medical emergencies was situated in residential areas

- The majority of fire and rescue services emergencies were related to residential areas, and road traffic accidents
- In general the southern part of the study area, where more economic activity and higher urban residential densities are located, had a higher need for emergency services, as expected.

This data was then used to develop the expected annual distribution of calls over the study area, by assigning an expected call ratio to each of six source categories. These categories were especially important for classification of areas in high or medium to low risk areas, in terms of SABS 090-1972.

At this stage it was found that the more remote areas, although having high population densities in rural settlements, did not contribute significantly to the call statistics. This was due to the lack of communication infrastructure, distances to existing stations, and possibly also a low level of unawareness of emergency availability and procedures. It was therefore assumed that significant latent demand exists in these cases, and a Standardised Demand Profile (SDP) was developed for all areas including remote locations, by applying ratios per land use type around existing stations and applying these to the whole region. Figure 1 presents the SDP for medical rescue services as depicted by the GIS for the whole study area.

3.3 Definition of reaction standards for emergency services

Reaction standards play a crucial role in determining the optimal location of emergency services, for obvious reasons.

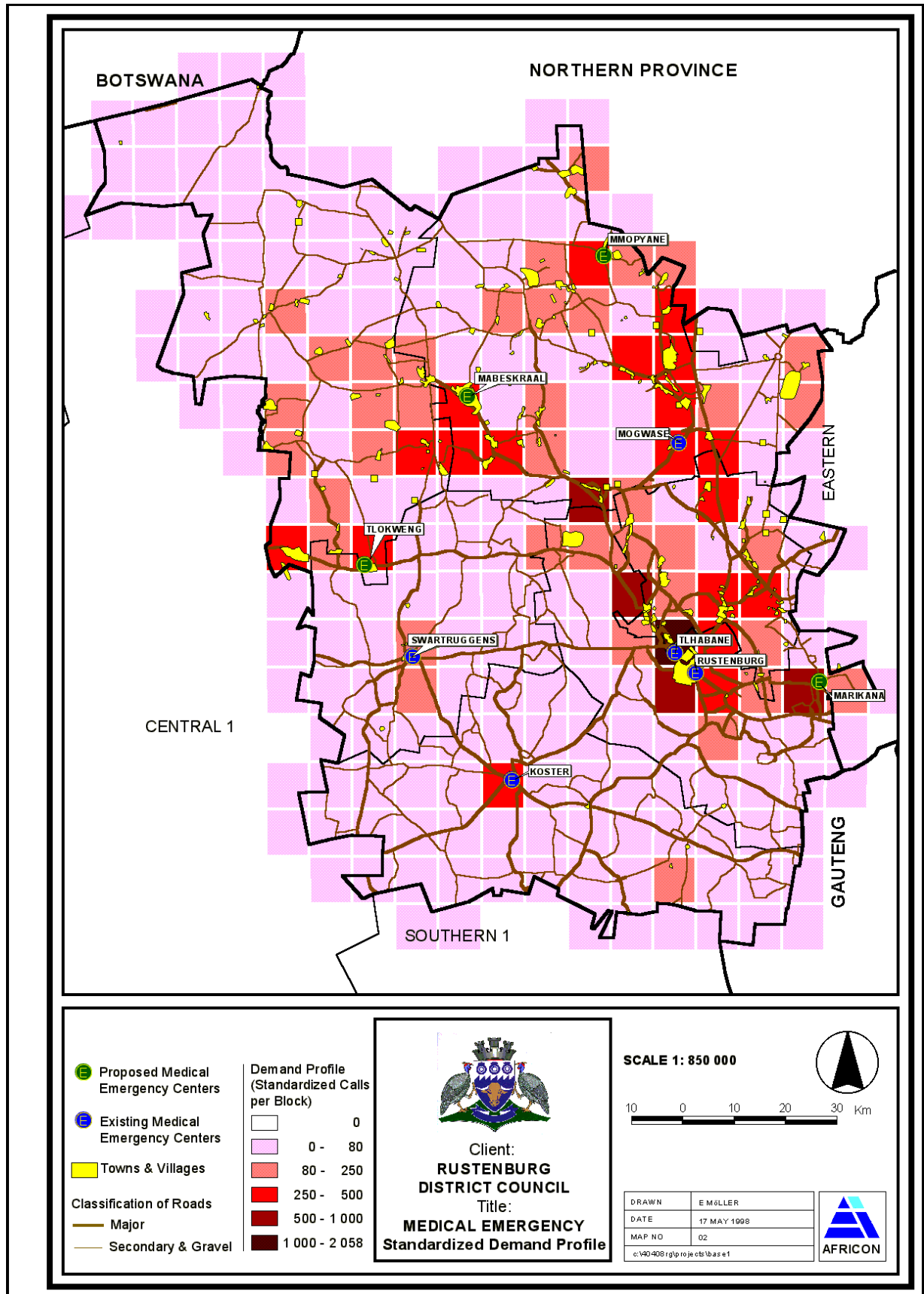
Reaction standards for **fire and rescue services** are contained in SABS 090-1972 [2]. This code specifies the land uses constituting various risk categories, as well as the following reaction times:

- High risk 6 minutes
- Moderate risk 7 minutes
- Low risk 12 minutes

These standards apply predominantly to urban areas, and no clear guidelines could be found on rural areas. It is understood that this is the subject of a more recent code updating effort by the SABS.

Standards for **medical emergency services** could not be found in South African literature. International benchmarks were therefore obtained, mainly from the United Kingdom. An important difference from fire and rescue services standards is that the coverage of demand within a specified time is defined.

Figure 1 Standardised Demand Profile for Medical Emergency Services



It was decided to adopt this approach also for fire and rescue services, in addition to the protection of specified risk profile areas, and to expand these to rural areas, as follows:

Table 1 Adopted emergency reaction standards

Type of service	Urban areas	Rural areas	High risk areas	Medium to low risk areas
Medical emergency services	95% of calls in 15 min	95% of calls in 20 min	Not applicable	Not applicable
Fire and rescue services	95% of calls in 15 min	95% of calls in 20 min	5 min urban and rural	15 min urban 30 min rural

3.4 Determination of coverage contours to establish levels of service

The next step was to define the reaction times from existing facilities. This was obtained by drawing coverage contours from the facilities. Factors such as vehicle speed, the road types and road condition were considered in consultation with emergency services personnel. The following road speed model was therefore used:

Table 2 Emergency Vehicle Road Speed Model (km/h)

Road type	Road condition		
	Poor	Average	Good
Gravel	-	94	-
District	80	105	125*
Provincial	100	120	140*

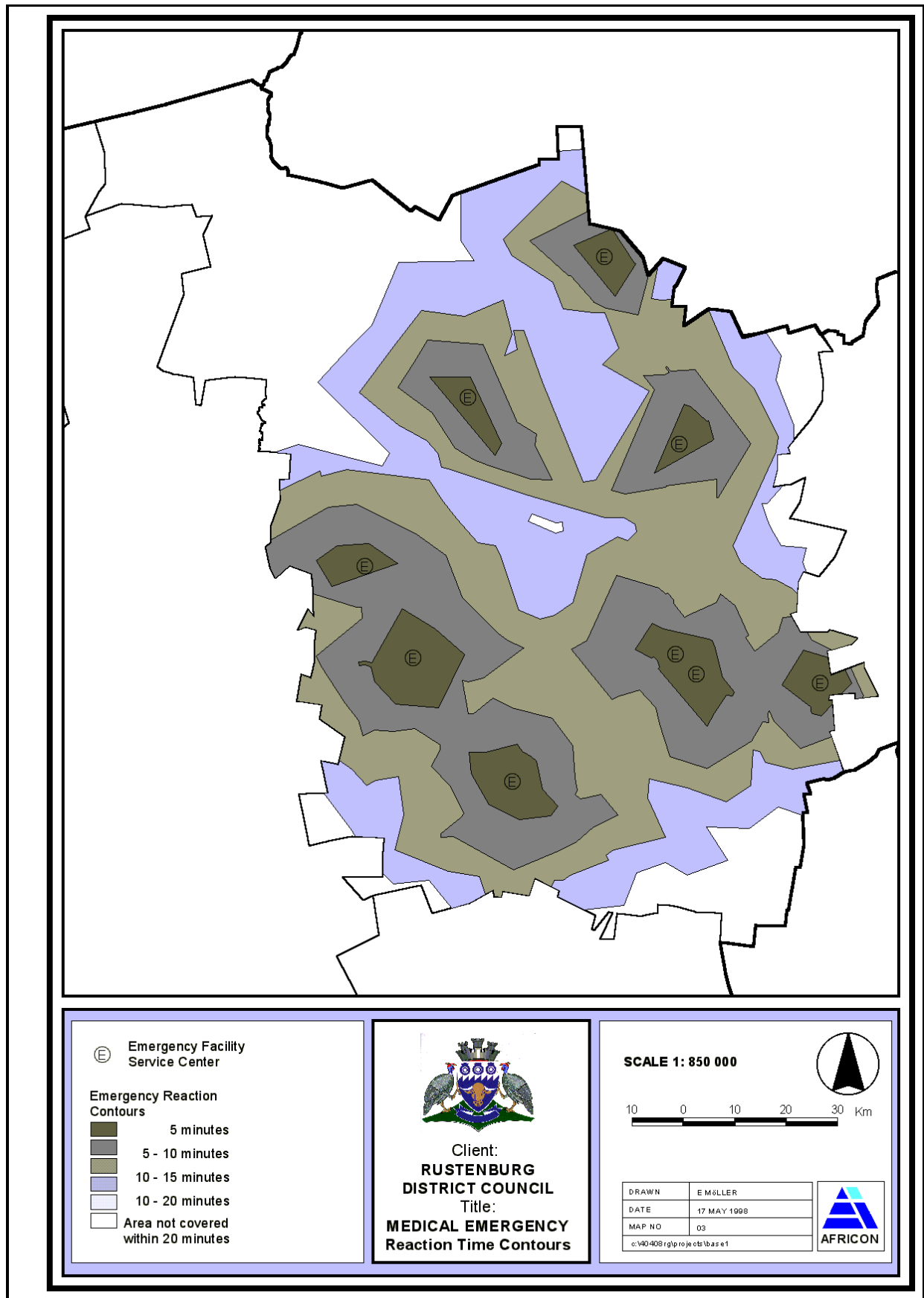
- Note : The maximum speed of fire fighting vehicles was considered to be 120km/h

By using the GIS networking module, reaction time contours could be created and displayed visually, as shown in Figure 2.

3.5 Emergency services demand and supply interface

The demand and Standardised Risk Profile were integrated with the reaction contours to arrive at the current levels of service that are provided in the study area. It is in the development of this aspect that the intrinsic value of the GIS technology came to the fore. For each contour the amount of calls covered within the desired reaction time could be derived, and the areas identified that are not adequately covered could be identified. The location of new stations could also be tested to ensure that the full-required coverage is obtained, while limiting overlaps and ensuring efficiency.

Figure 2 Reaction Time Contours for Medical Emergency Services



4. RESULTS AND INTERPRETATION

In summary, the results from the analysis highlighted the following:

Medical emergency services

The current stations were located in the southern half of the study area, and 56 per cent of calls could be covered within the standard of 15 minutes. A further four stations were proposed in strategic locations, which would result in 95 per cent of all calls covered within the required time.

Rationalisation of existing stations was also possible, due to a significant overlap in the areas covered by the Rustenburg and Thlabane stations, which could be combined in one station, as well as those areas covered by potentially under-utilised private service, such as the mines, Sun City and Pilanesberg Airport.

Fire and rescue services

The results from the analysis showed that 85 per cent of calls are serviced in 15 minutes from existing stations. Although this is a better result than for medical emergency services, four additional stations would be needed to improve coverage to 95 per cent. These stations could be combined with the medical rescue services stations to obtain cost savings in infrastructure investment and staff application.

Again, it was found that the stations at Rustenburg and Thlabane and some private services could be combined due to overlapping coverage.

In addition to the determination of call coverage, the various land use risk categories in terms of SABS 090-1972 were considered to ensure that adequate reaction times are possible, by interfacing coverage contours with risk categories. The semi-rural nature of a significant part of the study area was also taken into consideration, and the finding was that required reaction times could be achieved. In addition, extended basic service coverage from planned rural administrative centres as a first reaction team was also considered and tested.

5. CURRENT INSTITUTIONAL CHANGES AND WIDER APPLICATION OF METHODOLOGY

Recent newly introduced legislation will alter drastically the way that local authorities operate.

The most significant of this legislation is the following:

- The Municipal Demarcation Act of 1998, altering the current local and regional authority boundaries and areas of jurisdiction, and reducing the previous more than 840 bodies to 450
- The Municipal Structures Act of 1998

- The Municipal Systems Bill of 1999 (pending)

In essence this legislation requires local and regional authorities to ensure the integrated, sustainable and equitable social and economic development of its area of jurisdiction. It also needs to "...facilitate universal access to quality services that are affordable to all". Clear management targets are set for local government, and guidelines are provided to achieve these.

To meet the requirements of the new legislation, and in essence the needs of all the inhabitants of a jurisdictional area, the methodology illustrated in this paper can be used to assist decision-making on ensuring that optimal service provision and facilities location are planned in an efficient and equitable way. Changing economic development and demographic patterns can also be accommodated once such a model has been developed.

It should be noted that recent developments in information technology include specific GIS based decision support systems in the fields of Fire, Rescue and Medical Emergency services provision that are currently utilized and that contribute significantly to improved efficiency in service delivery. Relatively new software such as the Transcad package integrates transportation planning techniques and GIS technology, to simplify the solution of planning projects such as the one illustrated in this paper. More complex environments and other aspects can also be dealt with in a similar fashion.

6. CONCLUSION

The purpose of this paper was to illustrate, at the hand of the example of the re-alignment of emergency services provision in the Rustenburg District Council area, how GIS and transportation planning techniques can be combined to ensure that local authority services are correctly provided.

By using these tools planners can assist local authorities in meeting the requirements of new legislation affecting the way in which services are provided in South Africa at the regional and local level, and to ensure that the needs of people are met in an efficient and equitable way.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of their colleagues in compiling the supporting material for this paper, and specifically Mr Andre Heyl. They also wish to express their gratitude to the Rustenburg District Council for permission to use the information presented in the paper.

REFERENCES

1. Rustenburg District Council Location of Emergency Services, Rustenburg District Council, Rustenburg, 1998.
2. Code of Practice for Community Protection Against Fire SABS 090-1972, South African Bureau of Standards, Pretoria, 1972.
3. Rustenburg District Council Settlement Strategy, Rustenburg District Council, Rustenburg, 1997.

THE USE OF SPATIAL PLANNING TECHNIQUES FOR EMERGENCY SERVICES OPTIMAL LOCATION DETERMINATION

Dr P C Lombard and Mr J G C van der Merwe
Africon Engineering International
PO Box 905, Pretoria 0001
Tel: 012-427-2727; Fax: 012-427-2640; e-mail: paul@afriicon.co.za

ABBREVIATED CURRICULUM VITAE: DR PAUL C LOMBARD

Paul Lombard has 14 years' experience in the fields of transportation infrastructure planning, financing as well as restructuring of the roads sector. He was selected as a Fulbright scholar in 1988 and obtained an MSCE in 1989 and a PhD in Urban and Transportation Engineering in 1991 at Purdue University in the USA.

Dr Lombard is fully conversant with privatisation, commercialisation and road tolling issues and the associated economic analyses, also in related fields such as water and landfill services. He has participated either as project leader or as road financing expert in road sector restructuring projects throughout Southern and Eastern Africa, and has extensive experience in development and implementation of road pricing systems in the region. He has worked on projects in South Africa, Namibia, Botswana, Lesotho, Swaziland, Mozambique, Tanzania, Uganda, Ethiopia and Lebanon. This includes several projects funded by agencies such as the World Bank, USAID and the UNCDF. This experience also relates to the transportation planning and feasibility fields.

He has executed several airport feasibility studies, and was the project leader for airport master plan studies, including Johannesburg International Airport, as well as Windhoek International Airport and Eros Aerodrome in Namibia.

He also has lecturing experience. He has co-presented post-graduate courses in transportation planning at the University of Pretoria, the University of Stellenbosch and the Rand Afrikaans University (RAU) in Johannesburg, and has also served as an external examiner for post-graduate students.