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SOUTH AFRICA'S COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH



BUILT ENVIRONMENT
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Science, engineering and technology for
the built environment

CSIR
our future through science

A sound and effective built environment is critical for socio-economic development and economic growth in the country. Expanding and improving infrastructure such as roads, rail networks, bridges, ports, airports, buildings and other facilities is a national priority and must be achieved without forfeiting environmental sustainability. In addition, the effective operation of the infrastructure through proper management of these components is crucial for economic welfare.

The provision of infrastructure and associated operations is not only an enabler of economic growth, but also stimulates growth by increasing the productive capacity of the economy. Social development, which is fundamental for any country, can only take place with proper provision of basic amenities such as hospitals, schools and housing together with infrastructure for electricity supply, water and sanitation.

The CSIR conducts relevant research and development to find key solutions to facilitate socio-economic development and improve the quality of life of South Africans. Specific focus areas include:

- Energy-efficient buildings;
- Updating the national housing atlas to facilitate the establishment of sustainable human settlements;
- Designing appropriate tuberculosis (TB) facilities to assist in combating cross-patient drug-resistant TB;
- Publication of the 6th State of Logistics™ survey to quantify and provide trends of important logistics indicators;
- Physical modelling of an off-shore iron-ore loading wharf to facilitate construction of ports;
- Progress on the interdisciplinary research platform to investigate models of sustainable and integrated municipal service delivery.

The CSIR has implemented and successfully transferred the technology for the built environment in the areas highlighted but also in other instances. Many of these are used extensively locally and in a number of specific cases internationally.

This issue of *ScienceScope* showcases some of the work done in the CSIR's built environment research impact area, focusing in particular on human settlements, building construction, roads and transport logistics, and service delivery.



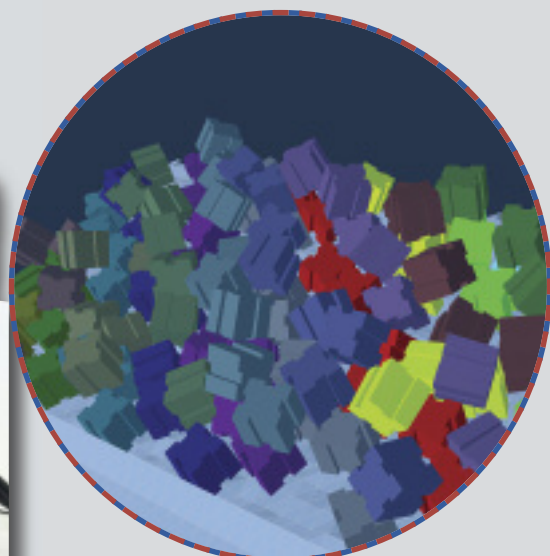
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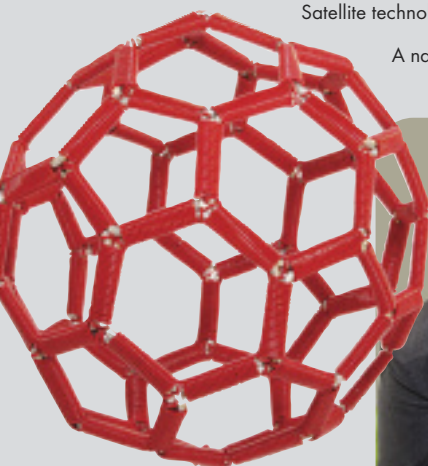
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TOTAL COSTS OF LOGISTICS IN SOUTH AFRICA NEED TO BE REDUCED

BY HANS W ITTMANN

Worldwide, the logistics sector suffered from the effects of the economic downturn the past year or two. This forced those involved to reconsider the entire way in which supply chains are designed and managed.

Almost everything we use these days has been moved by a freight operator – be it the food on our plate, the pen with which we write or the clothes we wear. Logistics – or supply chain management – is the term used widely to describe the transport, storage and handling of these products as they move along the chain from the raw material source, through the production system to their final point of sale or consumption. Effective, efficient and predictable movement of goods are important and contribute to economic growth.

Supply chains include all the activities, linkages, information exchanges and relationships formed by all those who choose to work together in these chains; some chains being very complex.

CSIR research in supply chain management is aimed at improving the overriding goal and objective of every chain – to transport, distribute and move products and services ever closer to final consumption in a more cost-effective way, adding value in the process. This requires dedication, creativity and innovation by all parties involved.

Some years ago, the Foundation for the Malcolm Baldrige National Quality Award conducted a survey in the USA among chief executive officers, which revealed an almost unanimous agreement that globalisation was becoming a major challenge. Furthermore, reducing costs and improving global supply chain performance were a top priority.

The logistics fraternity in South Africa needs to serve consumers inside the country while an increasing number of local companies also operate in the global market place. In both instances, it is critical to operate supply chains as efficiently and effectively as possible, keeping logistics costs as low as possible while also providing quality service.

Given the long distances in the country and the fact that the main economic activity in South Africa is concentrated in the centre of the country (in Gauteng), the reality is that internal logistics costs are higher. Our geographical location also disadvantages South Africa when competing in the global market place. The pressure is therefore even more severe on logistics efficiencies and costs.





It is accepted today that a competitive network of global logistics is the backbone of international trade. Many countries have not benefitted from this. The recently-published World Bank Report on the topic of trade logistics competitiveness emphasises this: *"Improving logistics performance has become an important development policy objective in recent years because logistics have a major impact on economic activity."* Furthermore, *"The importance of efficient logistics for trade and growth is now widely acknowledged. Analysis based on the 2007 LPI or similar information has shown that better logistics performance is strongly associated with trade expansion, export diversification, ability to attract foreign direct investments, and economic growth."*

The South African government's policies are geared towards the country becoming a player in the global marketplace. What holds true for international trade is also valid, to a large extent, for internal trade within a country. The World Bank Report shows that South Africa is ranked 28th out of 155 countries on the world logistics performance index with a score of 3.46. The actual score has decreased from 3.53 and South Africa is down from 24th in 2007. This trend is obviously a concern.



Our country is by far rated the highest in Africa and – excluding high-income countries such as Germany and the USA – it is among the 10 most significant over-performers. Based on the income of the country, South Africa is actually over-performing from a logistics point of view. Other over-performing countries include China and India. This is very encouraging.

The 'in-country' logistics costs as a percentage of gross domestic product (GDP) for South Africa are presented in the most recent 6th State of Logistics™ survey published jointly by the CSIR, Stellenbosch University and IMPERIAL Logistics. The total logistics costs in South Africa for 2008 was R339 billion – an increase of 6.9% on the 2007 amount of R317 billion; the logistics costs as a percentage of the GDP are 14.7%, which is the lowest it has been since the first survey in 2004.

Although these numbers are seemingly moving in the right direction, they need to be analysed carefully in order to understand which factors are driving this percentage down. Compared to other countries, the logistics costs as a percentage of GDP are still high – in the USA, the percentage for 2008 was 9.4% while for 2009, the percentage de-

creased to an all time low of 7.7% of GDP. The local situation with freight is exactly the same as the past number of years. Total freight in 2008 increased slightly with 2% or 32 million tons, with all growth being on road again. This is not ideal; not only is this the main contributor to high transportation costs, but heavy vehicles are damaging our road infrastructure. Various efforts over the past few years have not had the desired effect of getting some freight back onto rail.

Freight also contributes to congestion on our road networks. The recent upgrades of roads in the main metros across the country will alleviate this congestion. However, CSIR research found that the effect of bad roads, mainly the secondary roads in the country, has a substantial effect on increasing maintenance and repair costs of freight trucks and vehicles, adding to higher logistics costs.

Logistics and supply chains are integral parts of the economy of a country. For South Africa to be reckoned as a player in the global marketplace, the logistics and supply chain management environment will have to improve continuously to further reduce costs and stay abreast of new developments to improve our country's competitiveness.

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MULTI-MILLION RAND RESEARCH TO DESIGN BETTER, DURABLE ROADS

Roads contribute to regional cohesion by playing a prominent role in the geographic distribution of economic growth and wealth. Generally, zones with high job densities are located near major road arteries because of the businesses' need for easy access to suppliers, customers and employees.

Dr James Maina was recently awarded the coveted JD Roberts award for 2010. The award is made by Murray & Roberts in collaboration with the CSIR. The award is made annually within the built environment area in recognition of competitive and environmentally-sustainable solutions to human dilemmas. It encourages scientific research into technology that will enhance the quality of life of all South Africans.





Between 2006 and 2020, the South African government will invest more than R63 billion for the development and maintenance of the country's road network. Roads are expensive – to construct 1 km of road can cost as much as R25 million.

"The majority of South Africa's national road network is older than 25 years, which exceeds the design life of the roads, and, although well maintained, the national road network is experiencing unprecedented high traffic volumes. For example, recent data show that the N3 has carried the equivalent of 20 years of traffic in a period of two years," notes Dr James Maina, a CSIR chief researcher.

"Further, over the past 10 years, the provincial and municipal road network has deteriorated dramatically, not only because of maintenance neglect due to insufficient funding, but also because of increases in traffic volumes and axle loads," he says. Maina specialises in pavement engineering, with 'pavement' being the term used for roads that are paved.

Poor conditions of the South African road network – particularly the occurrence of potholes – have led to safety hazards and increased user costs. In addition, saturation of the road network capacity has resulted in unprecedented traffic jams with increased fuel consumption and transportation costs as well as lost production time. According to the Automobile Association of South Africa, these factors have a combined estimated cost of about R200 billion a year to the economy.

The current South African road pavement design method (SAPDM) is based mainly on technologies and material performance models developed by the CSIR and collaborators during the 1970s and 1980s. The SAPDM has formed the backbone of road design methods used in South Africa, as well

as the southern African region, and compared well with the best in the world.

"The outdated and inaccurate models used for calculating materials strength and responses due to loading have rendered important parts of the SAPDM obsolete and in dire need of serious revision and updating," explains Maina. The depletion of appropriate virgin road construction materials as well as public opposition to aggregate mining and to land-filling have also led to problems in the use of materials not catered for by the current SAPDM and guideline documents.

"We need an advanced system that will enable national, provincial and municipal governments to properly design and effectively maintain and protect the road systems that are put in place at a very high cost to tax-payers." The South African National Roads Agency Ltd (SANRAL) has started a comprehensive study aimed at evaluating and updating the current SAPDM. "In view of increased premature road failures and associated traffic congestion, the benefit-cost ratio of the project is expected to be significant," says Maina, the main project leader. The research, development and implementation will require a substantial financial investment, with SANRAL committing more than R50 million and the CSIR providing more than R10 million.

"An additional complication is a plethora of different road design methods and test protocols currently being used to cater for deficiencies in the current SAPDM. The use of some of these methods may lead to costly designs and/or failures, and with increasing entry of consultants from abroad to the market, the situation is likely to worsen," notes Maina.

SAPDM guideline documents, test protocols and equipment for new design and rehabilitation investigation will be modified in light of new information generated by this project.



"Recent data show that the N3 has carried the equivalent of 20 years of traffic in a period of two years."



R1 047 trillion	=	value of SA's road network
R100 billion	=	SA road maintenance backlog
R32 billion	=	annual road maintenance need
R9.2 billion	=	current maintenance expenditure

The new SAPDM will protect the multi-billion rand investment in the South African transport infrastructure through improvement of the quality of road pavement design by the local road industry. Pavement behaviour is a complex research field, as roads consist of a number of layers with distinct material properties. "Resilient responses and damage models of individual layers are very difficult to assess within the holistic response of the road. The key to proper design of roads and their subsequent maintenance is the ability to understand the macroscopic behaviour of materials when subjected to traffic loading under varying environmental conditions," Maina comments.

The updated SAPDM will facilitate the analysis of the current road network condition as a preventative maintenance process. Roads approaching the end of their design lives will be identified timeously, allowing early light rehabilitation instead of total (and more costly) reconstruction.

The SAPDM will cater for different levels of expertise and design complexity, covering a broad spectrum of roads ranging from national roads to light structures for rural access and urban mobility.

"We are confident that, once finalised, the updated and refined SAPDM will be adopted across the board as the primary national tool for road pavement design. User requirements have been obtained from national, provincial and municipal road authorities, the local consulting industry as well as research and academic institutions. This project will address user needs, wants and preferences directly. Due to the inclusive manner in which the new

SAPDM framework had been prepared and made available for input, all parties involved in teaching, designing, construction, managing and maintaining road pavements have a stake in the revision of the SAPDM."

Users concur that the new SAPDM should have the following characteristics:

- It should be a single, innovative, affordable and accessible South African national design tool;
- It must promote a uniform, risk-based analysis and design method;
- It will replace all other outdated design tools and methods;
- It will combine deterministic (mechanistic-empirical) and performance-based (empirical) approaches;
- It will cater for both novice and expert users;
- It will be applicable to all types of roads, from low-volume roads in rural areas to high-volume urban roads and freeways; and
- It will enable the optimum use of scarce, natural non-renewable resources, while also accelerating the use of waste material and renewable resources.

"The SAPDM will be a web-based software application available to the industry through membership registration, managed by SANRAL with technical support from the CSIR. At the core of the new SAPDM will be advanced constitutive models for road construction materials, and software for numerical modelling to simulate responses of roads when subjected to various environmental and traffic loading conditions."

The project will draw from a large body of current expertise while also creating new knowledge. The CSIR's international research collaborators in this project include the universities of California Davis, California Berkeley, Illinois and Calgary. "The collaboration will provide the opportunity to calibrate and verify the accuracy, reliability and validity of laboratory models using actual field data," Maina notes.

The procedure for applying the new SAPDM will entail the following:

- A designer will select a road pavement type, develop a trial design and provide traffic load, system geometry, material parameters and climate data.
- The SAPDM software will estimate the damage using mechanistic analysis tools and predict key failures over the road design-life using field-calibrated performance models.
- The road design will then be verified against the performance criteria and may be modified as needed to meet performance and reliability requirements.

"Our aim is to package the solution into a user-friendly format by 2011/12, with technology transfer to local industry being part of the project. The major vehicle for disseminating research results will be the Road Pavement Forum, a biannual meeting of leaders in the road delivery industry in South Africa. Training, together with the adoption of the new SAPDM as a standard road pavement design method, will start in South Africa and may be extended to the Southern African Development Community and the African continent," Maina concludes. - Hilda van Rooyen

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BAD ROADS

IMPACT ON CONSUMERS AND HAMPER ECONOMY

The increase in internal logistics costs due to inadequate road conditions is experienced by most, if not all transportation companies. This figure can potentially add up to a massive increase in the logistics costs of a country. As the logistics costs increase, the costs of products in the global marketplace increase, placing an added burden on the consumer and having devastating effects on the global competitiveness of that country.

Increased maintenance and repair costs lead to increased vehicle operating costs for transport operators. Worsening road conditions could also result in increased vehicle vibrations, which could translate into increased damages to transported cargo. "When transporting goods on roads with deteriorating riding quality, the transport operator has to increase transport tariffs due to the higher operating costs. Consequently, the price of products may increase – the increased transportation costs are either absorbed by the seller or, by us, the consumer," comments the CSIR's Wilna Bean. She undertook a case study with former CSIR colleague and now professor in civil engineering at the University of Pretoria, Wynand Steyn.



Wilna Bean, an industrial engineer at the CSIR

The researchers looked at three ways of trying to overcome increased product prices:

- Improved packaging of transported products. This will increase the total packaging costs of the manufacturer, again resulting in costs to the consumer. It could also lead to an increase in non-renewable packaging material used, with a resultant negative effect on the environment.
- Improved vehicles for transporting products will decrease damages to transported cargo and vehicles that could withstand conditions of bad roads. This will have to be applied to all vehicles used for transporting cargo, having massive cost implications for transport operators.
- The obvious option is to improve and maintain the condition of roads in South Africa. This would provide the best long-term solution, addressing the root of the problem. The costs of road maintenance are high, so one will have to investigate the economic feasibility of this option.

Table 1: Summary of vehicle maintenance and repair costs for routes with different IRIs

Company	Route information	Average IRI (m/km)	Road condition rating	Average maintenance and repair costs (R/km)
A	Gauteng to Durban (N3)	2.7	Good	1.01
	Gauteng to Cape Town (N1)	3.6	Fair	1.30
B	Gauteng to Durban (N3)	2.7	Good	0.90
	Gauteng to Nelspruit (N4)	2.9	Fair	0.82
	Gauteng to Witbank (N12)	3.4	Fair	1.27
	Gauteng to Rustenburg (N4)	3.3	Fair	1.04
	Gauteng to Richardsbay (N17 and N2)	3.6	Fair	1.31
	Johannesburg to Vereeniging (R82)	3.6	Fair	1.57
	Gauteng to Cape Town (N12 and N1)	3.6	Fair	1.29
	Gauteng to Botswana (N4)	3.9	Fair	1.35
	Newcastle to Gauteng (N11 and N17)	4.2	Bad	2.09
Gauteng to construction sites	4.3	Bad	2.13	

Case study

“To oversimplify, our case study indicated a potential percentage increase in maintenance and repair costs of up to 120% per year for a truck travelling on a good road compared to a bad one!” Bean says.

Bean and Steyn conducted a case study at two operating companies of a large logistics service provider in South Africa. Company A transports cargo mainly on national roads, whereas company B transports cargo on both primary and secondary roads. Data were used to compare the effects of good and bad roads on vehicle maintenance and repair costs, with Company A’s data also used to look at the effect of increased vehicle maintenance and repair costs on the total logistics costs of the company.

“Our analysis provides an indication of the potential effects of bad roads – the results and findings are not absolutes, since limited data were available. Other factors could also influence logistics costs, such as the increase in vehicle operating costs and cargo damages due to road works and congestion,” stresses Bean.

‘Roughness indices’ are single values used to quantify the roughness level of a specific road. These indices are calculated using mathematical equations and measured road profiles. The International Roughness Index (IRI) is a widely-used, standardised measurement of the roughness qualities that impact vehicle response. The IRI of a good road should be below 2.7.

“We compared the IRI of roads, as well as the repair and maintenance costs of vehicles of the two companies travelling on those specific routes. Company A identified 10 trucks from its fleet, travelling mostly on the same route

Table 2: Summary of potential increases due to worsening road conditions

Road condition	Average maintenance and repair costs (R/km)	Average % increase in truck maintenance and repair costs	Average % increase in company logistics costs
Good	R0.96	-	-
Fair	R1.24	30.24%	2.49%
Bad	R2.11	120.94%	9.97%

and provided a database of actual maintenance and repair costs for a specific period. Company B provided a database of its actual maintenance and repair costs for a fleet of 577 trucks over a comparable period, operating on a range of roads in South Africa. Both companies used similar trucks to ensure that the route and the IRI are the only significant difference in the analysis.”

“The results show that a truck travelling from Newcastle to Gauteng (300 km) has maintenance and repair costs of R627 per trip. A similar truck from the same company travelling on a stretch of the N3 between Gauteng and Durban (also 300 km) will have maintenance and repair costs of only R270 per trip. The total maintenance and repair costs of the first truck amount to R125 400 per year, while it will be R54 000 for the second truck.”

Impact on total logistics costs

“We did another analysis to investigate the potential impact of the increase in vehicle maintenance and repair costs on the total logistics costs of a company. Additional data were obtained from company A for two periods between January and June 2008 and 2009. The particular data for this analysis were the total vehicle maintenance and repair costs and the logistics costs of the company for the two time periods. We used the estimated maintenance costs as a percentage of

total logistics costs, as well as the average percentage increase in truck maintenance and repair costs to derive the average percentage increase in company logistics costs. The estimated maintenance costs of company A varied between 7.48 and 9.01% of total logistics costs, during the specified time periods.

“The increase in truck repair and maintenance costs due to deteriorating road conditions could lead to an increase of around 10% in the total logistics costs of a company,” says Bean.

Other costs that could be linked to deteriorating road quality are increased vehicle operating costs, increased fuel consumption, increased cargo damages and increased vehicle design and manufacturing costs.

Results obtained from the analyses indicate that the potential effect of deteriorating road quality on vehicle maintenance and repair costs and the total logistics costs of a company, is significant. “It is therefore vital that stakeholders become aware of the potential negative impacts of bad roads to ensure that sufficient attention is given to timely and proper maintenance of roads,” Bean concludes. – Hilda van Rooyen

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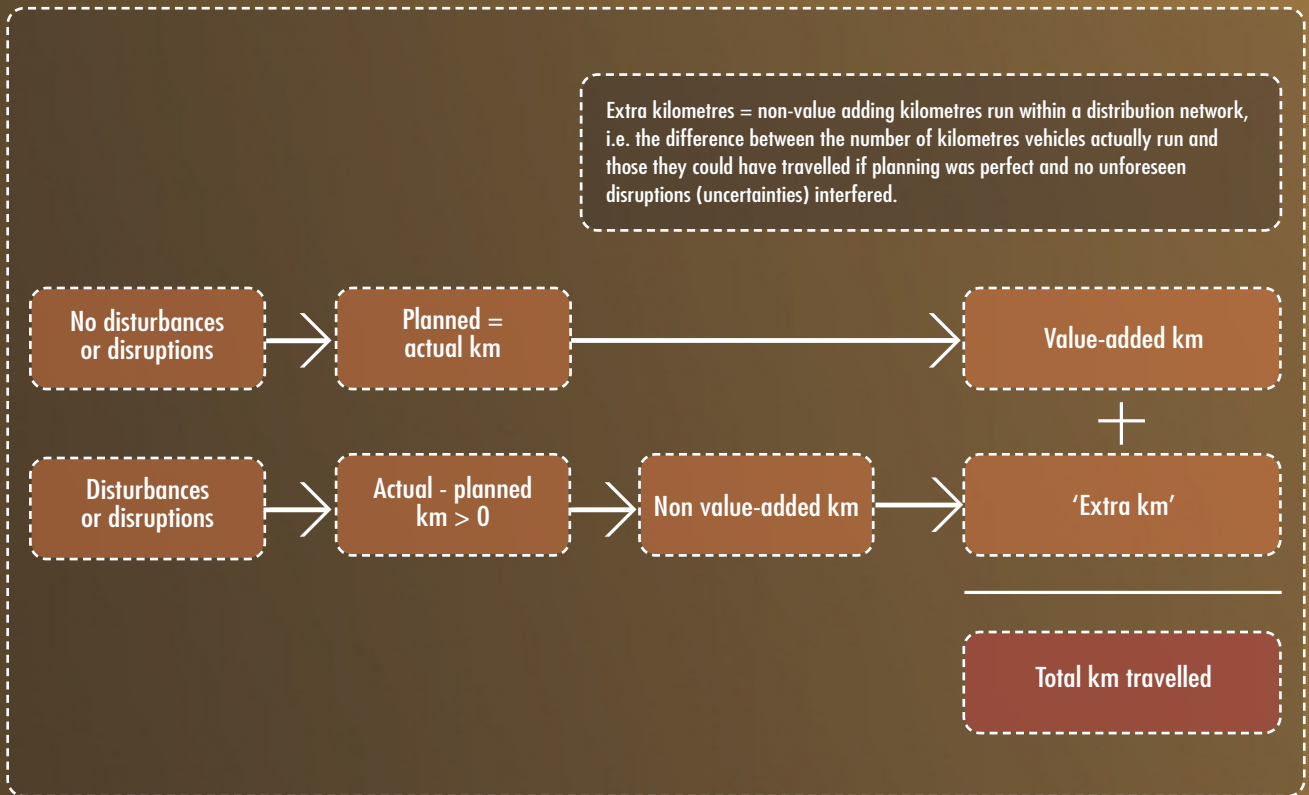


Chanel Schoeman

Eliminating extra kilometres results in extra cost savings

Due to the competitive nature of the fast-moving consumer industry, companies actively pursue continuous improvement opportunities. The drive towards environmental preservation makes it imperative for such improvement opportunities to be eco-friendly. In this context, the CSIR, Cardiff University and IMPERIAL Logistics undertook a case study to assess the causes and impact of extra kilometres on the supply chain.

Figure 1: Total kilometres travelled as the sum of value-added and extra kilometres



The study analysed the uncertainties that caused extra kilometres and investigated the environment (green) as well as the bottom-line (gold) effects of these extra kilometres, with the aim of informing better supply-chain decisions.

With transport being a substantial contributor to green house gases, supply chains can have a significant effect on sustainability by analysing the causes and measuring the impact of variables (such as extra kilometres) that influence resource usage (e.g. fuel) and emissions.

The perception persists that transforming to a sustainable, green supply chain results in reduced profit margins by increasing the cost burden faced with new eco-friendly equipment and technologies, and additional process measures.

"The drive towards green supply chains shouldn't be seen as a financial burden – optimally managed resources, energy and waste reduction have decreasing cost implications which speak directly to the bottom-line. Green strategies can also provide a competi-

tive advantage as consumers and regulation start demanding greener products and manufacturing practices," explains CSIR researcher Chanel Schoeman, who specialises in supply-chain analysis.

"When transport planning is based on accurate and timely information on the volumes to be moved, and no operational failures disrupt the delivery process, one can cut down on the 'extra kilometres' aspect," notes Schoeman.

"We can describe the economic impact of these extra kilometres in terms of additional fuel needed to complete a delivery, and the environmental impact in terms of more CO₂ emissions produced. From previous research by Cardiff University in the United Kingdom (UK), we realised that the difference between the ideal and the actual kilometres run was caused by various uncertainties that impact on the sustainable performance of the supply chain. The main causes of transport uncertainty in the UK studies were identified as delays within the supply chain; variable demand and inaccurate forecasting; lack of supply chain coordination; and delivery restrictions."

SA case study

Following the UK study, the CSIR and Cardiff University set out to identify the causes of uncertainties and to quantify the consequences of these in terms of resulting extra kilometres in the supply chain of a major food chain company in South Africa.

"We applied the concept of extra kilometres to the company's distribution centres (DCs) servicing over 200 stores throughout the country. We gathered the extra kilometre data from distance-based archival data and focused on the two major DCs in Johannesburg and Cape Town. A week in January 2009 was selected, which represented a typical or average week and a fair sample of what happens over a period of one year," says Schoeman.

Detailed information was captured on trips that contained extra kilometre incidents. This included store location; kilometres run; extra kilometre source; and visible cause. Incidents were categorised according to their causes and quantified. The week's extra kilometre data were extrapolated to annual estimates, and used to perform risk assessments.



Table 1: Impact of extra kilometres on two secondary DCs in a typical week

	Johannesburg	Cape Town	Overall
Total kilometres run	172 000 km	35 000 km	207 000 km
Extra kilometres	11 538 km	1 605 km	13 143 km
% Extra kilometres	6.71%	4.59%	6.35%
Costs of extra kilometres	R149 994	R20 865	R170 859
Kg of CO ₂ due to extra kilometres	18 100 kg	2 500 kg	20 600 kg

Impact of extra kilometres

The overall impact of extra kilometres on the two secondary DCs in a typical week is summarised in Table 1.

“Based on these findings, we estimated that the extra, non-value adding kilometres account for more than R8.88 million additional costs and 1 071 additional tons of CO₂ pollution in one year,” notes Schoeman.

The study found the two main causes of extra kilometres to be DC failures (any event that causes the shipment not to be ready at the DC according to the transport schedule) and short-notice volume increases from clients (last minute, additional stock requests by grocery retail stores). Together these account for more than 90% of the extra kilometres.

The extra kilometres resulting from the two main causes are:

- DC failures were the largest source of extra kilometres (345 696 extra kilometres annually) and therefore additional CO₂ pollution (10 415 kg). According to the staff involved, this is caused by delays due to a shortage of staff to pick the products.
- Short-notice volume increases (mostly in long-life products) were the second major

source of extra kilometres found and the most frequent source. It was responsible for 287 560 extra kilometres annually, resulting in 8 663 kg of CO₂ pollution. According to the staff involved, this occurs primarily due to inaccurate demand forecasting of volumes to be moved, which is managed by the client.

“We measured risk in terms of outcome and probability – if the frequency of an event was low but its outcome could have a highly-detrimental impact on the supply chain, the occurrence of such an event represented a considerable risk to the supply chain. Due to the high impact and medium probability of occurrence, both these sources of extra kilometres constituted a high risk and needed to be monitored and controlled closely,” Schoeman warns.

- One DC failure incident generates on average 185 extra kilometres and occurs about five times a day. The picking process in the DC should therefore be evaluated and re-engineered to reduce this extra kilometre source.
- One short-notice increase in volume incident originates on average 142 kilometres and also happens some five times a day. As this

extra kilometre source is caused by inaccurate volume forecasts, the product demand forecast process needs to be revised.

Following the study’s recommendations, the client has taken steps to ensure routing and scheduling processes remain dynamic and optimised. They implemented new software that enables them to measure – on a continuous basis – the actual kilometres undertaken against those planned.

“Our extra kilometre assessment can be used as a diagnostic tool in other transport operations to increase transport efficiency within distribution networks in terms of extra kilometres or unnecessary vehicle usages. It can also be used to determine the causes of unnecessary kilometres and estimate the risk that these represent. In this way, a more explicit link can be made between supply chain uncertainty and deviations in transport performance,” Schoeman concludes. – Hilda van Rooyen

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ULTRA-THIN CONCRETE

– strong, affordable roads of the future?

Traditionally, the costs of using concrete instead of conventional material like asphalt in road construction are prohibitive. Concrete is, however, far more durable, rendering roads with an expected lifespan of up to 40 years compared to 25 years for conventional roads. With increasing oil and bitumen prices, concrete has also become a more competitive road building material.

The CSIR has been involved with the development of specialised, ultra-thin concrete technology ideally suited for labour-based construction. Stringent testing and field trial evaluation resulted in the development of two different types for different applications, one for low-volume roads (typically residential streets) and the other for high-volume highway applications.

Low-volume roads

After seeing the research results, the Gauteng Provincial Department of Roads and Transport (GPDRT) decided to use this concrete technology during its Expanded Public Works Programme for the upgrading of unsealed residential streets. "The ultra-thin (50 mm thick), reinforced concrete technology with a steel mesh inside has been piloted in roads in Mamelodi, Atteridgeville and Soshanguve. Authorities in KwaZulu-Natal have subsequently also expressed their interest in piloting this concrete road technology. For roads carrying low volumes of traffic this is an ideal technology," explains Rafeek Louw of the CSIR.

Rafeek Louw at an ultra-thin concrete road constructed in Mamelodi



"The ultra-thin concrete road construction method is labour-intensive and requires only light equipment, thus providing meaningful employment to local communities and small contractors. Based on current experience, about 14 times more jobs are created than during conventional asphalt road construction," he says.

On urban and low-volume roads the existing material could be used depending on the test results. A stabilising agent may be needed to modify the material before the new concrete technology is applied on top. This leads to much shorter construction times, as well as no damage to underground services such as sewerage and water infrastructure. Using the *in situ* material, you don't have the additional transportation costs of bringing in other construction materials and carting away excavated material."

Such roads provide an all-weather surface and improve the lives of communities along the roads by curbing dust, providing direct access to residential areas and reducing damage to vehicles. "The research we conducted in collaboration with the University of Pretoria and the GPDRT established that these ultra-thin concrete roads will require minimal maintenance, resulting in reduced life-cycle costs and less disruption to road users," comments Louw.

He says that the ultra-thin concrete technology has application beyond roads. "The community can use it on side-walks or for paving around their homes." The CSIR is currently testing the technology in a low-income housing project as a single, continuous foundation slab to eliminate cracked walls resulting from sub-standard foundations (see article on page 50).

High-volume roads

Simultaneously, CSIR engineers investigated the use of ultra-thin concrete technology for application in high-volume roads. "We used the CSIR-developed heavy vehicle simulator (HVS) to test the technology for use in both low and high-volume roads," explains Louw du Plessis, who is regarded internationally as an expert in accelerated pavement (road) testing.

The original road design idea was imported by the South African National Roads Agency Ltd (SANRAL) from Denmark. In conjunction with the University of Pretoria, the Cement and Concrete Institute, local consultants and the CSIR, the technology was adapted for local conditions. The HVS played an instrumental part in testing the final design and fast tracking the implementation of this technology.

"For application in high-volume roads, we reinforce the ultra-thin concrete considerably – seven times more steel is used than ordinary continuously-reinforced concrete.



Louw du Plessis with a heavy vehicle simulator



"The ultra-high strength cement consists of Portland cement mixed with steel and polypropylene fibres, and an ultra-fine filler, giving the cement paste a packing density similar to ceramic and glass. Compressive strengths are up to four times higher than normal concrete paste," Du Plessis notes.

Construction of high-volume roads with a high labour content is possible using this technology where no special tools or machinery is required other than a mixer and ordinary concrete compaction tools. "Due to a high rate of strength gain, roads can be opened to traffic within one day – conventional concrete roads need a minimum of seven days. In addition, ultra-thin concrete roads meet all requirements to ensure a safe road surface under all conditions and have a life expectancy in excess of 30 years."

"During road rehabilitation, minimum bridge clearance standards must be maintained. Traditionally, deep dig-outs under bridges are required but with the 50 mm ultra-thin concrete technology, this poses no problem. Looking at total life-cycle costs, this technology also offers a cheaper alternative to conventional road maintenance," Du Plessis says.

After intensive research, development and testing, the adapted concrete technology is being implemented by SANRAL. Current rehabilitation projects using ultra-thin concrete include a section of the N12 near the Gilloolys interchange and an apron at Oliver Tambo International Airport. In the Western Cape, the technology has been used on the N1 freeway between the Klip River Toll Plaza and up to and after the Huguenot Tunnel. "Initial results from these projects are very positive," Du Plessis concludes.

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HEAVY VEHICLE SIMULATOR (HVS)

The HVS machine is used to simulate the damage caused by heavy traffic to road structures. Researchers simulate traffic volumes experienced over 20 years within a short period of up to three months.

This accelerated road-testing facility was developed and upgraded by the CSIR and its technology and commercialisation partner, Dynatest, over the past four decades. The latest model, the HVS Mk VI, has numerous advantages over its predecessor, including reduced costs, weight and complexity, increased wheel speed, test beam length, and improved mobility when towed on public roads.

The HVS is a high-tech field laboratory, using unique instruments to measure and analyse the engineering performance of road structures and material layers.

In South Africa, two HVS machines are in operation – one is owned by the CSIR and the other by the Gauteng Provincial Department of Roads and Transport (GPDRT). In conjunction with supported laboratory testing facilities, the HVS technology development programme has achieved remarkable success to advance pavement engineering and the basic understanding of pavement material behaviour in South Africa. According to GPDRT studies, the quantifiable direct benefits of the HVS programme are significant – at a discount rate of 8%, between R3 and R6 are returned for every R1 invested in the HVS programme.

The HVS has found its way to countries including the USA, Sweden, China and India. Research using the HVS has also been conducted in Sweden, Slovenia and Poland. Ten of these machines are now in operation worldwide, with another MkVI on order for a client in the USA.

The international HVS programme has generated foreign income for South Africa of more than R200 million over the past 18 years. It is a proudly home-grown success story of quality research, technology development and sound commercial decision-making.

– Hilda van Rooyen



IMPROVED PERFORMANCE OF HEAVY VEHICLES ON OUR ROADS

CSIR research has shown that road wear and costs associated with heavy vehicles can be reduced, while increasing safety and productivity, and lowering vehicle emissions.

Paul Nordengen, who leads CSIR research in network asset management systems in the roads and transport sectors

"Typical challenges of heavy vehicle operations in South Africa include the high rate of crashes; vehicle overloading, which accelerates the deterioration of our roads; congestion; and high logistics costs," says Paul Nordengen of the CSIR. "The past 10 years saw a 32% increase in freight vehicles on our national and provincial roads. About 15-20% of heavy vehicles currently operating on our roads are overloaded - 60% of the road wear (or damage) caused by all heavy vehicles to our roads can be ascribed to these."

The traditional approach of law enforcement in the road freight sector is not sufficiently effective. Amendments have been made to the National Road Traffic Act to strengthen the legislation. Other approaches include using the road transport management system (RTMS) and performance-based standards (PBS) approach to heavy vehicle design.

Key elements in the heavy vehicle industry are the design, construction and maintenance of the road infrastructure; the design, maintenance and operation of vehicles; and driver wellness.

"The RTMS is a voluntary, self-regulation scheme that encourages consignees, consignors and road transport operators to implement a management system to contribute to preserving road infrastructure, improving road safety and increasing productivity. It is an industry-led, government-supported initiative that focuses on load optimisation, driver wellness, vehicle maintenance and productivity," explains Nordengen. He serves on the national steering committee of the RTMS and leads CSIR research in network asset management systems in the roads and transport sectors.

In the sugar industry, applying the RTMS resulted in a 71% reduction in the extent of overloading and a 53% reduction in the degree of overloading within a period of three years. "This industry harvests 21 million tons of sugar cane annually that are transported by about 1 500 trucks," comments Nordengen.

Performance-based standards

"Most countries control heavy vehicle use on the road network through prescriptive regulations, which does not seem effective in many cases, particularly in developing countries. PBS uses a different approach, specifying the performance required from the operation of a vehicle on a road network, thus what a vehicle can do," explains Nordengen.

Following successful results obtained through PBS in Australia, New Zealand and Canada, the CSIR started a research programme in South Africa. In collaboration with the forestry industry, a number of PBS demonstration vehicles were designed, manufactured and operated to obtain practical experience and

Table 1: Summary of performance outcomes of two PBS demonstration vehicles in forestry compared with baseline heavy vehicles

PERFORMANCE INDICATOR	MEASURED RESULT OF PBS VEHICLES
Tons transported per month	Average increase of 19.3%
Fuel consumption	Average savings of 12.7%
Fleet size	Reduced by 17%
Incident and accidents	Reduction from 3.1 to 1.1 per month
CO ₂ emissions	Reduction of 1 280 tons of CO ₂ per year based on a freight task of 700 000 tons per year
Road wear	Reduction varies from 2 to 23%

quantify and evaluate the potential infrastructure preservation, safety and productivity benefits for road freight transport.

PBS allows more flexibility for vehicle designers to use innovative solutions and the latest technology to meet the required performance standards, resulting in improved safety outcomes and more effective use of the road infrastructure. As vehicles operated under a PBS framework are usually longer and carry heavier payloads, they are limited to travel on a subset of the network to ensure protection of the road infrastructure and acceptable safety levels. "It is important to match vehicles to specific routes. The standard of the road infrastructure varies, with national and provincial roads being most appropriate for PBS vehicles."

Monitoring and evaluation

"A scientific comparison was done between three baseline vehicles and the PBS vehicles, using the South African mechanistic-empirical design method. Eight typical road designs were used in both wet and dry conditions. Operators of the PBS vehicles were required to be accredited through the RTMS self-regulation accreditation scheme."

Data were collected and monitored monthly, which has not yet been done elsewhere in countries implementing PBS. Data were obtained on:

- Load per trip
- Average trip speeds
- Kilometres travelled per month
- Average monthly fuel consumption
- Maintenance costs
- Records of incidents and accidents.

"An average wear cost was calculated for the 16 cases (eight pavement types, wet and dry conditions) for each of the baseline and PBS vehicles," explains Nordengen. The effect of increasing the wheel spacing of the dual tyres on the drawbar trailer was also investigated.

"To look at actual cost savings, we calculated the average road-wear costs for each vehicle

type in South African cents. Taking into account the different permissible maximum loads on each vehicle, a road-wear cost per km per ton of load transported (c/ton km) was calculated for each vehicle." The average road-wear costs of the PBS vehicles ranged from 7 to 8.3 c/ton km, while the baseline vehicles ranged between 8.4 and 10.6 c/ton km.

Safety is an important aspect in heavy vehicle operation: baseline vehicles of 22 m long typically carry payloads of up to 35 tons, while the longer PBS vehicles of 24 to 27 m carry up to 46.5 tons. "Safe handling during lane changes, for example, is critical when livestock wanders onto a road in front of a heavy vehicle moving at speed. The PBS heavy vehicles showed a far better performance during high speed transient off-tracking, one of the PBS standards," says Nordengen. "However, to do a validated scientific assessment of safety performance, we need a minimum of 5 million km of travel data."

"We are very excited about the initial results. The use of PBS vehicles shows improved productivity and fuel consumption, improved safety performance and a reduction in CO₂ emissions," he notes. "We anticipate that other vehicle and tyre modifications could also be implemented that result in more road-friendly vehicles, without a negative effect on productivity."

The positive performance of the PBS demonstration project has resulted in the approval of 30 additional permits for such vehicles in the forestry industry, thus expanding the pilot projects specifically for conducting more research on safety aspects.

"Due to the successful pilot in the forestry industry, discussions are underway with the sugar cane, coal mining and general freight sectors," Nordengen concludes.

- Hilda van Rooyen

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CSIR system contributes to WELL-MAINTAINED BRIDGES

Roads and bridges usually compete for the same 'pot' of government funding in terms of maintenance. While road damage is more visible, bridge failures due to delays in repair may have catastrophic results when users are involved.

"Roads deteriorate far quicker than bridges – the majority of roads have a design life of 20 years, while well-maintained bridges should last more than 120 years," comments Paul Nordengen, the research leader of infrastructure asset management systems at the CSIR.

South Africa has about 100 000 bridges, including rail bridges. The construction of bridges requires a substantial financial investment. The average cost of constructing a bridge is currently about R15 000 per m² – the replacement value of a typical 100 m long, 20 m wide bridge is thus in the order of R30 million.

The causes of bridge deterioration could include:

- The location of structures
- Traffic intensity, including the percentage of heavy vehicles passing over the bridge
- The material quality
- Design and construction defects
- Harsh climatic conditions
- Pollution.

To assist with bridge management and maintenance, the CSIR developed the Struman bridge management system (BMS) in collaboration with local consulting engineering firm Stewart Scott International in the 1990s. The CSIR Struman system comprises customised and regularly updated software, manuals and training programmes for clients, ensuring that qualified engineers who act as bridge inspectors have a consistent approach in rating the condition of bridges.

Bridges are a major asset that needs to be maintained on a regular basis – the CSIR recommends inspections every five years so that maintenance strategies of road authorities in South Africa can be planned over a five-year period, based on a priority list of bridges in need of repair. "Structures can thus be maintained at acceptable levels of service, and defects identified timeously and repaired economically. The accessibility of information also ensures that funds can be channelled to repair urgent and important defects," explains Nordengen.

Implementing the Struman BMS, authorities inspect and evaluate 21 basic bridge elements, using the 'DER' rating system –

- D** - degree or severity of the defect
- E** - extent of the defect, that is, how commonly the defect occurs on the specific item
- R** - relevancy of the defect, taking into consideration the consequences of defects in terms of user safety and the structural integrity of the bridge.

The urgency of the need to carry out remedial work is also assessed, which provides a way of applying recommended time limits on the repair requirements.

The advantages of the CSIR's Struman BMS for road authorities include that the system focuses on actual defects rather than trying to determine the overall condition of all bridge elements; and that the system is able to prioritise bridges in need of repair in order of importance. "It is critical that people who operate the BMS must believe in the results and that the repair of the bridge stock is not based on perceived needs, but rather on a systematic approach," comments Nordengen.





Paul Nordengen

Most of South Africa's bridges are 'short', less than 20 m in length, with the five largest bridges being situated on the Garden Route. Some very large bridges are also found on the proposed Wild Coast section of the N2. "The Bloukrans arch bridge near Nature's Valley in the Western Cape is by far our biggest bridge. It stands at a height of 216 m above the Bloukrans River, making it the highest single span arch bridge in the world. Its central span is 272 m and the bridge is 451 m in length. As a matter of interest, it is believed to host the world's highest commercially-operated bungee jump activity," says Nordengen.

Worldwide, BMSs rely on inventory data and inspection data. Most BMSs in the world rely on visual inspections as their primary data source to determine the condition of a bridge. Diagnostic testing is generally used only for detailed inspections once bridges possibly in need of maintenance are identified.

Locally, the South African National Roads Agency Ltd has implemented the Struman BMS, with all three toll operators using this

BMS. The system is used in Mpumalanga, KwaZulu-Natal, the Western Cape and the Eastern Cape. "The Taiwan Area National Freeway Bureau was our first major international client, while Namibia, Botswana and Swaziland have also implemented our BMS," says Nordengen.

Namibia is quite advanced in the Southern African Development Community regarding its road infrastructure maintenance programme. "Our most recent project was to assist Namibia with evaluations and analyses for that country's bridge maintenance strategy. We also trained their bridge inspectors to ensure quality control and calibration of results. Following our recommendations presented to the Namibian roads authorities at the end of 2009, they compiled a priority list for bridge maintenance, on which their budget motivations can be based," concludes Nordengen.

– Hilda van Rooyen

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WORLD-FIRST SYSTEM PREVENTS DERAILMENTS CAUSED BY RAIL BREAKS

An SA-developed system that can effectively monitor the world's ageing railway infrastructure is drawing international attention. The system has demonstrated the ability to detect breaks in continuously-welded railway tracks and thereby avoid expensive and life-threatening derailments. But can it be made more cost-effective and applied internationally?

Railway operators commonly inspect rails by using conventional ultrasonic inspection techniques. These require ultrasonic probes to be drawn along the length of the rail. It is a labour-intensive process that can only be conducted periodically and can interfere with the normal schedule of trains.

When South African rail operator Spoornet required an alternate method for continuously monitoring its heavy duty iron-ore line between Sishen and Saldanha, it contracted the Institute of Maritime Technology (IMT) to develop an acoustic broken rail detector system. This particular welded line suffers from fatigue cracks, which lead to complete breaks in the rail. These breaks have caused derailments costing around R50 million per event.

From underwater sonar to guided wave ultrasound

IMT was familiar with the CSIR's expertise in underwater sonar transducers and contacted the CSIR to conduct the ultrasonic transducer development task. Project leader Dr Philip Loveday tells the story: "The project required us to develop piezoelectric ultrasonic transducers that could be permanently installed on the rail at intervals of between one and two kilometres apart. We had nine months in which to develop the transducers and deliver 200 of them."

The system operates according to the following concept: Ultrasonic waves are transmitted along the rail between transmit and receive 'stations' that are placed alternately along the length of the rail. If the required ultrasonic signals are not received, an alarm is activated indicating a broken rail. This means that the entire 850 km of rail can be monitored continuously and also allows the railway operators to know in which section the rail break has occurred.

He continues: "Because we had no understanding of how ultrasound waves travel in rails, the transducer was developed purely by trial and error with various versions tested on the rail near Saldanha. Ten years on, we have produced approximately 1 500 transducers that perform adequately over a distance of 1.5 km."

Since the completion of the original development project, various changes have been made to the original design to ensure that the transducers survive in the extremely hostile environment in which they operate. While these transducers work well, it is expected that the intervals at which they are placed along the rails could be substantially increased. This would lower the cost of the system, making it a more attractive solution to railway operators.

Performing on an international stage

The solution's uniqueness and effectiveness have attracted considerable attention from the international railway community. The system has been tested at the Transport Technology Centre in Colorado, USA; on a test section in Kingston, Canada; on the subways of New York City and Hong Kong; and is currently being tested in Japan.

"These tests have had varying levels of success, most probably because different rail cross-sections are used on these lines for which our transducer may not be suitable," explains Loveday. While welded lines are not common in South Africa, they are standard abroad. "We believe we now have the expertise to not only extend the system's range to substantially more than just 1.5 km, but also make it successfully applicable to different rail profiles that are used abroad."

Improving the system

After internal changes, the opportunity arose to initiate research at the CSIR aimed at understanding the physics of wave generation and propagation in rails with a view to improving the system. Research in the area of guided wave ultrasound has established unique capabilities for modelling and measuring the transduction and propagation of elastic waves in rails. These new capabilities are currently being applied to the development of a transducer that can transmit energy over greater distances and thereby improve the competitiveness of its Rail Break Alarm System.

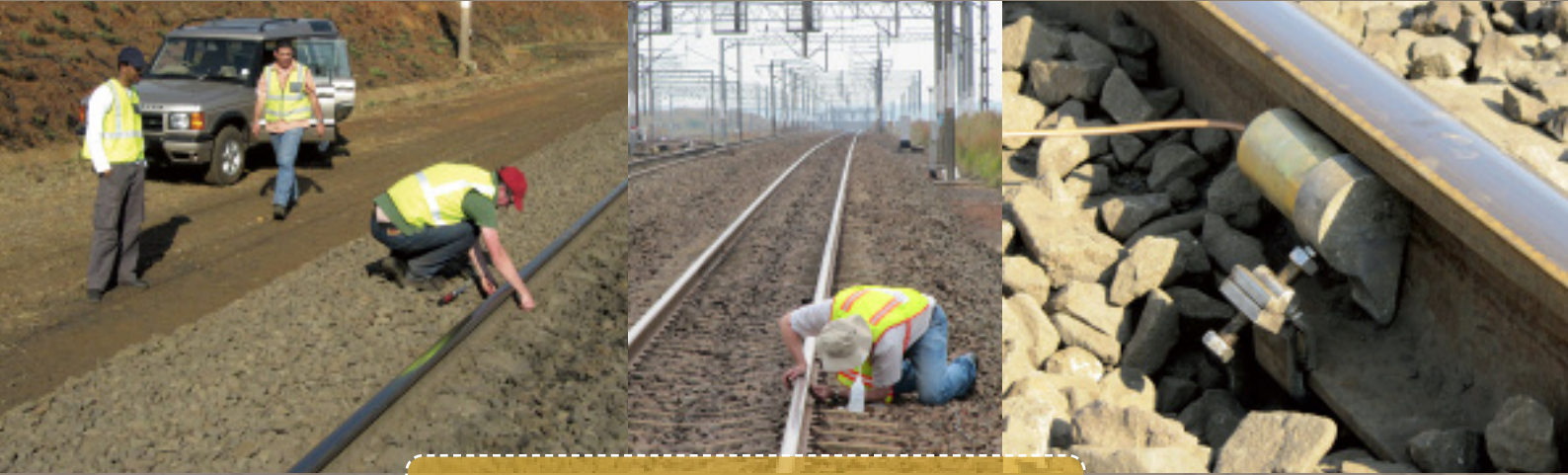
"Our work is now focused on developing a technology demonstrator transducer for long-range guided wave transmission and detection," says Loveday. "The transducer will be developed to operate on two welded rail lines in South Africa. In addition, the numerical models used will be coded in software and the development procedure will be documented so that transducers for other rail profiles, used internationally, can be easily developed in future."

He continues: "It should be noted that this is the first such system to have been implemented in the world. We need to move now to take the system to the next level so that the first international business in this domain originates from South Africa."

Loveday believes that the transducer development capability being established will later support research into the detection of cracks in the rails before complete breakage occurs.

– Petro Lowies

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Field tests of the Rail Break Alarm System are being conducted by the project team


What is a piezoelectric ultrasonic transducer?

A device that converts an electrical signal into ultrasonic sound waves and *vice versa*.

Piezoelectric materials have the property of changing size when a voltage is applied. Applying an alternating current across them can cause them to oscillate at very high frequencies, thus producing very high frequency (ultrasonic) sound waves.



Dr Philip Loveday, leader of the CSIR's rail transducer project



WEIGHBRIDGES

REDUCE OVERLOADING OF HEAVY VEHICLES

Overloading does not only cause considerable damage to South Africa's road network, but it also contributes to serious road safety risks. It is a safety hazard that leads to the rapid deterioration of roads, resulting in increased maintenance and transportation costs.

To address the recurring problem of overloading, the Department of Transport identified a need for overload control statistics to be available centrally. The CSIR was subsequently commissioned to analyse available heavy vehicle weighing data for a period preceding 2010.

Vehicle-weighing data from 1995 to 2009, obtained from various authorities responsible for overload control in South Africa, were analysed by a team of specialists. The CSIR team comprised Michael Roux, Ismail Sallie, Mauritz Kemp, Volanda de Franca, Kay Muronga and Paul Nordengen. According to Roux, a senior civil engineer at the CSIR, weigh data from 118 static weighbridges were analysed. Of these weighbridges, 70 are currently operational. Approximately 70% of the

current operational weighbridges are situated on or in close proximity of a national route, while the rest are situated on provincial roads or in municipal areas.

Weighing statistics

Statistics showed that the number of vehicles weighed increased significantly during the period 1995 to 2008. Since 2005, more than 1 million vehicles were weighed per annum, with a maximum of approximately 1.7 million in 2008. In 2009, approximately 1.6 million vehicles were weighed. The provinces of the Western Cape, KwaZulu-Natal, Mpumalanga, Limpopo, Gauteng and the Free State have been the most active in terms of overload control during the past 15 years.

"There has been a significant downward trend in the percentage of heavy vehicles overloaded and chargeable during the period 1995 to 2007. Since 2007, the percentage of vehicles overloaded has stabilised at approximately 18%, while the percentage of vehicles chargeable has continued to decline, being less than 4% in 2009. The majority of heavy vehicle weighing takes place on the national routes. In 2009, for example, 92% of vehicles weighed were travelling on national routes," says Roux.

Over the past 15 years, statistics showed that the average overload per vehicle declined from more than 3 000 kg in 1995 to 1 500 kg in 2001 and to approximately 600 kg in 2009. The average overloads prior to 2001/2002 cannot be reasonably com-

pared with those since 2002 due to the relatively small sample sizes prior to 2002 (less than 50 000 vehicles in 1995 increasing to almost 300 000 in 2001). From 1995 to 2009, the number of overloaded vehicles in the 0 to 1 000 kg range increased significantly from approximately 24% to 84%, while the number of overloaded vehicles in the greater than 2 000 kg range showed a marked decrease, from approximately 54% to 4%. This is an indication that the degree of overloading is decreasing.

All the weighbridges for which data are available are summarised per province and current status in the table on this page.

Weighbridges with a status of 'operational' are weighbridges currently being used. Those with a status of 'non-operational' are weighbridges currently not being used, but that can be made operational through maintenance or upgrading. Weighbridges with a status of 'in disuse' are sites that have been abandoned. Most of these sites were equipped with single axle scales. These types of scales are no longer being used due to potential problems with accuracy.

"The available analyses based on data supplied to the CSIR show that overload control activities have increased considerably over the past 15 years, with approximately 1.4 million vehicles currently being weighed per year. The increase in vehicle weighing activities has resulted in a continued improvement in the heavy vehicle overloading situation in South Africa, both in terms of the extent of overloading and the degree of overloading, on those routes monitored with static weighbridges, which are mostly national routes. There are, however, indications that overloading on routes not monitored with static weighbridges is significantly higher. These are mostly the primary provincial roads, and cost-effective ways should be found to carry out overload control on such routes," concludes Roux. - Josephine Mailoa



Michael Roux at a weighbridge station in Gauteng

SUMMARY OF WEIGHBRIDGES PER PROVINCE AND CURRENT STATUS

PROVINCE	CURRENT STATUS			TOTAL
	Operational	Non-operational	In disuse	
Eastern Cape	3			3
Free State	2	1		3
Gauteng	13	6	1	20
KwaZulu-Natal	16		4	20
Limpopo	7		5	12
Mpumalanga	19		17	36
Northern Cape	3			3
North West	6	3	3	12
Western Cape	9			9
South Africa	78	10	30	118

* The Northern Cape has a fourth operational weighbridge on the N14 at Upington, but no data were received for this weighbridge

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South Africa's traffic-related fatalities exceed 14 000 per year; for each person killed, 17 are seriously injured. Monetary cost is calculated at R80 billion per year; the cost in terms of loss of human life and resulting trauma to much larger numbers cannot be calculated.

"Our goal is to teach people to measure and help them to manage road traffic."

AN INTELLIGENT PLATFORM FOR SAFE AND EFFICIENT ROAD TRANSPORT

It is widely recognised that an efficient transport system forms the cornerstone of a successful modern economy; in South Africa, the bulk of this transport occurs by road. A group of CSIR researchers has pooled skills to start working on fundamental technology to develop an intelligent transport solution for South Africa, which takes cognisance of the unique mix of practical challenges that our country faces.

Kobus Labuschagne, a traffic engineer at the CSIR, highlights the imperatives for pursuing this solution. "Firstly, we must improve road safety for users of our roads, and those affected by road use. The loss of human life on South Africa's roads is a cause of great concern. Of the fatalities cited, 40% are pedestrians. Secondly, energy efficiency on our roads can significantly reduce the cost of transport for our country. Traffic congestion is costly in terms of wastage of fuel and loss of productivity."

The 6th State of Logistics™ survey released by the CSIR and its associates – IMPERIAL Logistics and Stellenbosch University – gives

2008 transport costs as R339 billion or 14.7% of gross domestic product (GDP), which is significantly higher than international benchmarks.

Labuschagne raises the need to use existing assets and infrastructure to best advantage as the third imperative. "In short, we must optimise what we have," he concludes.

What is an intelligent transport system?

The term intelligent transport system or ITS is well known and refers to collective technologies that are harnessed for the management of transport. An ITS moves information through

a platform to manage specific transport situations.

Labuschagne gives a simplified explanation of how the ITS works, "The ITS collects data from a variety of sources, for example, sensors, postings of traffic movements or data on people movement. It also collects data on the condition of or reports on incidents on free-ways." Data are relayed to the back office where these are integrated to generate information and intelligence for decision-making. "This means that information on road conditions and road usage can be used as the basis for decisions to reroute traffic via alternative routes," he says.



Members of the CSIR ITS team:
Karien Venter, Ally Mahlangu,
Kobus Labuschagne and Semira
Mohammed

It follows that an ITS comprises different elements, with a common thread of information and communications technology (ICT) to tie them together. Labuschagne warns, "South Africa has fallen behind in the harnessing of ICT in the effective management of our road infrastructure and traffic systems." The South African National Roads Agency Ltd is currently in the process of procuring an ITS, which is a step in the right direction.

Progress to date

South Africa's use of ICT-based systems has been confined to managing isolated aspects of transport and traffic systems. However, these have limited value to the integrated planning of the overall transport system, due to lack of interoperability, the existence of non-uniform data and technology standards, and lack of captured data integrity.

It is encouraging that despite these obstacles, several proofs of concept have been developed by way of building blocks and training initiatives for a South African ITS.

Based on the sensor web concept, the CSIR's NyendaWeb project aimed to boost collaborative research and development (R&D) in ITS, transport engineering and traffic management; the latter includes road safety and other

social and environmental aspects. Its other aim was to support people in this field with a mentoring and internship programme.

A multiyear research project, it set out to explore ways to boost the performance of South Africa's transport system by developing a number of advanced systems for improved traffic management. Systems investigated were hardware, sensors, software systems and data management systems. "We have developed good technology," confirms Labuschagne. "These resources are now available for improved traffic management, to mention a pertinent application."

As a web-based system built on open source software, the NyendaWeb prototype demonstrated the feasibility of the system for analysis and as a platform for municipalities to manage transport systems locally.

As a data-rich environment, NyendaWeb also confirmed its feasibility as a neutral platform from which different role-players can draw information as and when needed. "We envisage it as a resource base to which individuals could also add data – by means of global positioning system-enabled mobile devices," comments Labuschagne.

The sensor web is a network of sensors located in different places and with different functions, which interact and communicate with one another. Data collected *via* the sensor web are integrated using middleware; this makes it possible to extract information for decision-making for different purposes, such as traffic management.

Aquila, a software tool developed by a multi-disciplinary research team from the CSIR for the South African National Energy Research Institute, demonstrated the feasibility of a health risk assessment tool for measuring air quality impact relating to traffic emissions. Aspects taken into account are traffic congestion, air pollution, green house gas emissions and the relative health risk of these to susceptible communities. Labuschagne notes, "The Aquila software is a real-time tool able to give an emission and health risk index at a given time, at a specific location." As part of the project, the research team also developed a sensor controller that is GPS-coded and transfers data wirelessly from the location to any defined server.

A third project, on the Moloto Road north of Tshwane, sought to provide video-captured data for analysis in terms of safety implications by an ITS. The volume (in numbers) and speed of vehicles were logged; this information still has to be integrated with spatial planning and transport network data.

The way forward

Much has been achieved in terms of feasibility studies regarding an ITS for South Africa. Some fundamental research questions that remain to be addressed in the quest for an ITS for South Africa include: What are the unique differentiating qualities of the transport and traffic domains in developing countries with diverse cultures? How should such factors be incorporated in the design, deployment and operation of ITS systems? What are the parameters of 'road stress', which links road capacity with environmental, roadside, vehicle, road users and socio-economic factors?

Labuschagne is confident that this R&D will take off in the near future to ensure that South Africa has its own, customised ITS.

– Biffy van Rooyen

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The words 'precision engineering' are not usually associated with 300 000 tonne bulk carriers, being loaded with iron ore along a 2 km-long off-shore wharf. Let alone with so-called 'long waves' which are not easy to detect on a sunny Australian afternoon.



The CSIR's coastal engineering and port infrastructure team conducted 24 ship motion tests and 16 wave propagation tests for the Port Hedland-project – making it the largest and most precision-built project they've ever worked on. From the left (in front) is research group leader Dave Phelps, Luther Terblanche, Kishan Tulsi and Johan Kieviet. In the back row are Marius Rossouw, Dr Wim van der Molen, Padhraic O' Connor and Pierre Swiegers

CSIR DEVELOPS LARGE, PRECISION-BUILT MODEL OF OFF-SHORE IRON-ORE LOADING WHARF

The CSIR recently completed one of the world's largest 1:100 scale models of an off-shore wharf at Port Hedland on the north-west coast of Australia. The model was precision built to 2 mm in the vessel response wave basin at the CSIR's Hydraulics Laboratory in Stellenbosch. "The modelling will ensure that the actual harbour being constructed will provide for the safe and easy movement of large ships," says Dave Phelps, research leader of the CSIR's coastal engineering and port infrastructure group.

With more than 30 years of experience in this area of research, the CSIR was approached by international consultants Baird & Associates to undertake the physical and numerical model studies for the Port Hedland project.

"Because of the scale of our modelling hall, and the fact that we can include ship motion in the equation, we are one of the few companies in the world that could achieve a precision-built modelling scale where both waves and ship motions could be measured to an accuracy of smaller than 1 mm," explains Phelps.

This is not only the largest model yet built by the CSIR, but also the most exact, precision-built model constructed by the group, under the leadership of Dr Wim van der Molen.

"The project has now been extended to include modelling and testing of the appropriate distance between passing carriers and the influence on vessels moored at the wharf. This could have huge implications for the amount of dredg-

ing the client will have to do," Phelps notes. What made this specific model more intricate and complex than any other they have ever built, is that they had to be able to imitate the effect of long or large-period waves and measure the effect of these on the movement of various sizes of bulk carriers.

Phelps says: "The challenge starts when 'long waves' are generated deep in the ocean. You could have a sunny, windless day at the harbour, with a forecast of stormy conditions in perhaps a day or two. These storms develop deep in the ocean, and build up long waves as they move towards the shore, which can sometimes be felt long before the storm arrives at the coast line. You will notice a long wave only when you analyse the wave energy spec-



The three-dimensional Port Hedland model is 54 m long, 32 m wide and 1 m deep. Six two-tonne wave generators were used to generate so-called 'long waves' together with the normal short-period waves. Wave measurement systems were placed at particular locations inside and outside the port basin. The motion of the bulk carriers under different conditions and different port layouts were measured using the CSIR's keoship video monitoring system. Four model carriers imitated bulk carriers of 150, 205, 250 and 312 thousand dead weight tonne (kdwt), respectively. The model carriers were tested both fully laden and in ballast

Kishan Tuli loading a model bulk carrier with the right tonnage, at exactly the right spot

trum. We had to make provision for long waves with a peak period somewhere between 100 and 200 seconds on the prototype scale."

"The long waves influence the surge and sway movements of the bulk carriers, affecting the efficiency of the loading operation. In some cases a long wave can even cause a bulk carrier to break its mooring lines and possibly damage the vessel," he says.

The modelling hall in Stellenbosch is currently filled to capacity. The hydraulics team recently completed two other model studies for Port Dampier and Barrow Island, also in Australia. Phelp adds that they have had to expand the already large modelling hall last year to make room for all the projects. The Port Hedland model has not even been completed, and they are already working on another massive project: modelling the newly-planned Doha harbour will require an 80 m-long channel – another 1:100 scale model already overtaking the size of the basin constructed for the Port Hedland model. – *Wida Basson*



The vessel's movements and reaction to the long waves are monitored closely and recorded by a variety of capacitance probes and keofloats. The keofloat system consists of polystyrene floating blocks monitored with video cameras – these are especially suitable for measuring small and long waves

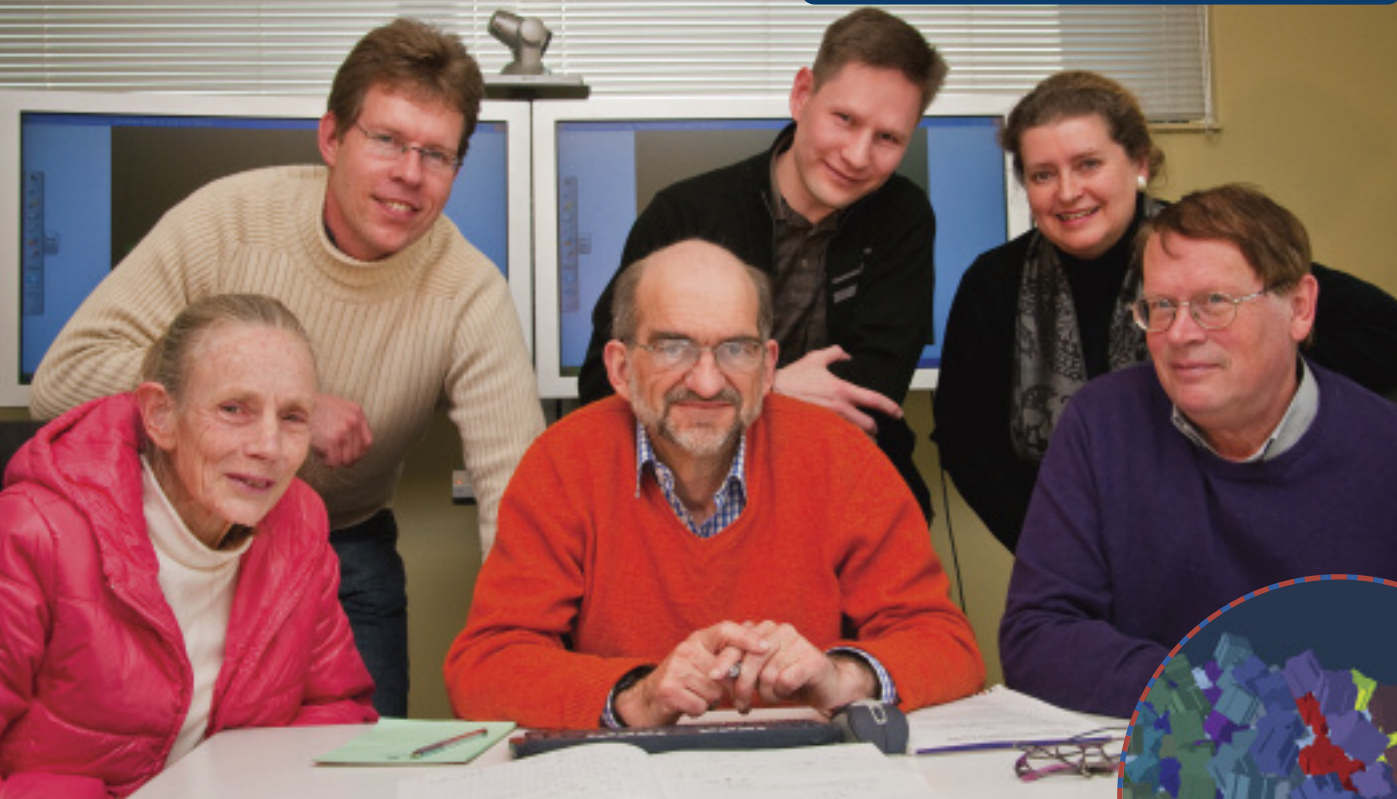
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NUMERICAL MODELLING TO SHED NEW LIGHT ON PROTECTION OF COASTAL STRUCTURES

Breakwater armour, such as dolosse, is essential for the protection of harbours, piers and other coastal infrastructures, absorbing the impact of violent waves.

The performance of complex breakwater structures and their interaction with waves, tides, currents and storms have a direct impact on the durability and safety of coastal structures.





Members of the multidisciplinary research team who are based at the CSIR in Pretoria: (from the left) Rosalie de Villiers, Jan Hendrik Grobler, Antony Cooper, Dr Frans van den Bergh, Dr Igle Gledhill and Dr Jan Greben

A consortium of CSIR researchers from many disciplines is combining their expertise in a multiyear project aimed at the numerical modelling of the armour units (such as dolosse) that protect breakwaters and harbours, and their interaction with waves. The project brings together expertise from fields such as coastal engineering, fluid dynamics, physics, computer science, photogrammetry and road engineering.

"In the process, we are creating new knowledge, using a combination of physics and computational fluid dynamics (CFD) in a novel application to simulate the behaviour of armour units," says Antony Cooper, the project leader of the team.

"To model the rigid physical structures – such as the armour units – we use PhysX™, a physics engine developed originally for computer games. We can model the fluids around the armour – such as air and water – with CFD, for which we are using STAR CCM+™. Researchers simulate and place the armour units into a virtual harbour structure. "Based on previous work, we can now place over 5 000 armour units in such a structure, which enables us to simulate complex conditions. The main purpose of such studies is to analyse the stability of different packings of armour units, thereby determining possible damage to structures under the exposure of waves or storms."

Armour units are generally made from un-reinforced concrete and weigh from as 'little' as 5 tons to over 30 tons, depending on their design and the environmental conditions. Over 30 different designs for armour units are in common use, such as the dolos, Antifer cube and Core-loc™.

The numerical modelling by CSIR researchers is aimed at supplementing the physical modelling done by the organisation's coastal engineering group in Stellenbosch. There, they build three-dimensional physical scale models of actual or planned harbours in a model hall to study dynamic processes. Physical scale models offer the best way for researching set structures, such as a specific harbour.

"Physical scale models are expensive and time consuming to construct. We aim to complement them with numerical modelling of the placement, stability and damage done to armour units. The intention is to synthesise packed arrays of armour units on a large scale. However, one of the disadvantages of numerical modelling is that various simplifying assumptions are needed to make the calculations feasible. Hence, numerical models are not intended to replace physical models – they are aimed at supplementing the understanding of the dynamics in physical models. An advantage of numerical modelling is that we can 'see' around and underneath the individual armour units, which should tell us what

is happening at all levels to the breakwater units and even to the rubble underneath them," Cooper explains.

Numerical calculations are tested against specific experiments conducted in the CSIR's model hall. If researchers can obtain reliable predictions with the numerical toolset, the software can be used for assisting with breakwater studies for current or future harbours.

The CSIR team collaborates with international experts in the field, including Dr Jentsje van der Meer, a leading coastal engineering consultant from the Netherlands. Locally, the CSIR has strong research alliances with Dr Kessie Govender and his team at the University of KwaZulu-Natal.

"In the long term, it may be possible to use our technology for developing an armour unit packing simulator or trainer, which could be used for training crane operators to pack armour units in the field, and for training staff of a model hall to pack model armour units in a harbour model. This could enhance the CSIR's capabilities to remain one of the top physical and numerical modelling facilities and expertise, locally and internationally," Cooper concludes. – Hilda van Rooyen

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LOGISTICS BROKERING SYSTEM EASES ACCESS TO TRANSPORTATION IN RURAL AREAS

Constraints in rural environments include high transport costs and irregular service demand and supply. Displaced rural communities are those who are removed from services and facilities (and subsequently also employment).

The CSIR has initiated a project, using information and communications technology (ICT) and involving the community, to address rural accessibility challenges. "The project focused on the development of a logistics brokering system for better transportation services for residents. The system uses a session-oriented service technology known as unstructured supplementary services data (USSD) to enable services between users, service brokers or facilitators and the end users," says CSIR researcher Johan Maritz.

"ICTs have proven extremely valuable in the developed world and have had a revolutionary impact on the way we do business, live and learn. In many respects it has replaced the need for travel to access some services or facilities. Previously, a large percentage of applications or systems developed for rural communities failed, either through improper design methods or insufficient involvement of the affected communities," Maritz notes.

Logistics brokering

Kgautswane, located east in the Sekhukhune district, comprises a series of villages located in a valley with an approximate population of more than 100 000 residents. Almost no

formal and substantial economic activities are found within the valley, and main employment and service centres are located outside Kgautswane. The villages are served by both bus and taxi transport services, which mainly operate during morning and evening peaks when transport demand is high and more 'predictable'.

Surveys conducted and interactions with local groups confirmed that there was a real need for transport during the late morning and early afternoon periods. A further review of available technologies revealed that cell phones were used widely in the communities.

Maritz explains, "The aim of the proposed service system was to mitigate the disparity between the demand and supply of the public transport market. In essence, taxi operators did not know the extent of demand during off-peak periods and ended up over or under-providing services."

Easy-to-use solution

The intended logistics brokering system had to be simple to use, affordable, and based largely on existing ways and familiar technology. It had to coordinate local logistics service processes to capture and manage

travel demand to schedule viable trips cost-effectively within Kgautswane's geographically-dispersed settlements.

During the technology review, it became clear that cell phones were the preferred communication medium. Although the short message service (SMS) is a widely-used data application in South Africa, it has cost implications and was not seen as an affordable system to use within the impoverished communities.

Several other communication options were considered, including the use of human language technologies and USSD. The latter was selected as the most suitable, given the kind of cell phones used. It is also an established technology with several local service providers to support and assist in development.

USSD allows for the transmission of information via a global system for a mobile communication network and, in contrast to SMS, offers real-time and cost-effective connection. Messages are simple to compose and easy to send. The user can enter the USSD string directly and press 'call' to send the message.

Community members in Kgautswane, located east in the Sekhukhune district, can use the ICT service system for transport needs - indicating their required destination, date and time of a future trip, along with the number of possible passengers





"Users access the USSD service through a service number and proceed to indicate the destination, date and time of a future trip required, along with the number of possible passengers. Requested trips are aggregated and grouped, where possible, by a local service broker on an online database. Confirmation of a finalised trip is sent to both the requestor and the taxi association. The local taxi association then delivers the scheduled trip on the relevant trip date. The intention is to reduce long waiting periods (and no-shows) and trip uncertainties through better matching of the demand for public transport with the public transport supply," says Maritz.

"Using this technology means that community members can schedule their trips and thereby achieve their own access to services. The scale of the project is small to make it manageable from a research perspective, but we believe that more attention should be given to systems such as these to address accessibility and mobility challenges. Ultimately, it will improve livelihoods if implemented more widely. We would like to complete implementation and possibly replicate the project in other areas too," Maritz concludes.

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Johan Maritz has worked on a project, using information and communications technology and involving the community, to address rural accessibility challenges in Kgautswane



Comprehensive, sustainable rural development is a challenge facing countries worldwide. Development programmes are aimed at creating a vibrant economic and social cohesion in rural areas, enabling people to take equitable control of their destiny.

The CSIR's Dr Charles Nhemachena (right) and former colleague James Chakwizira assisted the Department of Roads and Transport in Mpumalanga to pilot a rural accessibility project for the community

EMPOWERING RURAL COMMUNITIES THROUGH IMPROVED ACCESSIBILITY AND MOBILITY

Achieving rural prosperity is a multidimensional and multidisciplinary activity, requiring approaches that address the whole spectrum of the poverty domain. "One of the big challenges in this area is the development of a critical mass of infrastructure and services that would link communities to one another in the process of transforming rural spaces, places, people and cultures," comments Dr Charles Nhemachena of the CSIR.

A CSIR study focused on integrated mobility and access as key elements for improving socio-economic conditions and spatial livelihoods in rural areas. "Affordable and reliable transport is critical for people to access basic services and resources. Geographical isolation, long distances, poverty levels, poor infrastructure and limited transport services in rural and peri-urban areas inhibit such access," he says.

"We followed an integrated rural mobility and access (IRMA) approach to look at sustainable solutions relating to rural transportation infrastructure and services," he explains.

Nhemachena and James Chakwizira, a former CSIR colleague, worked on practical, affordable technology in the form of outcomes-based interventions. The CSIR teamed up with the Department of Roads and Trans-



“Circuitous routes of up to 8 km, for example, have been reduced to 3 km through the provision of footbridges.”



Access for rural communities in the Albert Luthuli Municipality in Mpumalanga before (left), during (centre) and after (right) infrastructure interventions

port in Mpumalanga, with this provincial government department intervening proactively. Together, these two entities piloted infrastructure-related elements as part of the broader IRMA approach in the Albert Luthuli Municipality in Mpumalanga.

“We conducted a feasibility study to unpack the access and mobility issues in that specific municipal area. Together, the department and we then considered integrated infrastructure interventions and generated strategies for implementing affordable access and mobility interventions,” says Nhemachena. These included options such as all-weather roads, footpaths, pedestrian bridges and low-level crossings, all providing access to socio-economic facilities such as schools, clinics, shops and government offices.

Local companies from Mpumalanga were selected for construction, under the supervision of the CSIR. Making use of a local resource-based approach in developing local rural roads and assets proved to be beneficial to the community – this included using local labour and skills, and local resources such as timber, stones and bricks or blocks.

After the completion of the pilot project at different sites in the area, more than 90% of

respondents said there was an improvement in terms of movement and accessibility to services. For example, hawkers’ reach, and by extension their profitability, had increased as they were able to cart their wares to a much wider market.

Commenting on how much such interventions had alleviated daily access challenges as well as reduced transport burdens, a businessman at Mayflower Multipurpose Centre commented: “Circuitous routes of up to 8 km, for example, have been reduced to 3 km through the provision of footbridges. Socio-economic opportunities such as schools and hospitals are now accessible in all-weather conditions. The local level travel and transport burden for the learners, youth, elderly and to some extent, persons with disabilities, have been reduced significantly, thanks to the collaborative efforts of the CSIR and the Mpumalanga Department of Transport and Albert Luthuli Municipality.”

“The pilot project benefited deprived resource-poor rural communities by building local-level intra and intermobility and access infrastructure essential for livelihood sustenance. This laid the foundation for uplifting the standards of living for that rural community and their level of development,” comments

Nhemachena. “We believe such infrastructure interventions will assist the Department of Rural Development and Land Reform within the broader ambit of rural development initiatives.”

In conclusion, Nhemachena notes: “One has to consider that rural transport and development challenges should be addressed from two perspectives. We concentrated on the mobility aspect in this project, which favours the deployment and provision of local-level infrastructure and services. Such approaches make movement and circulation easier and more convenient. The other is a location approach, considering that the placement and provision of facilities and services could be responsible for trip generation. In addition to providing more infrastructure, longer-term development planning should aim to locate facilities closer to the people, leading to self-contained rural neighbourhoods and communities.”

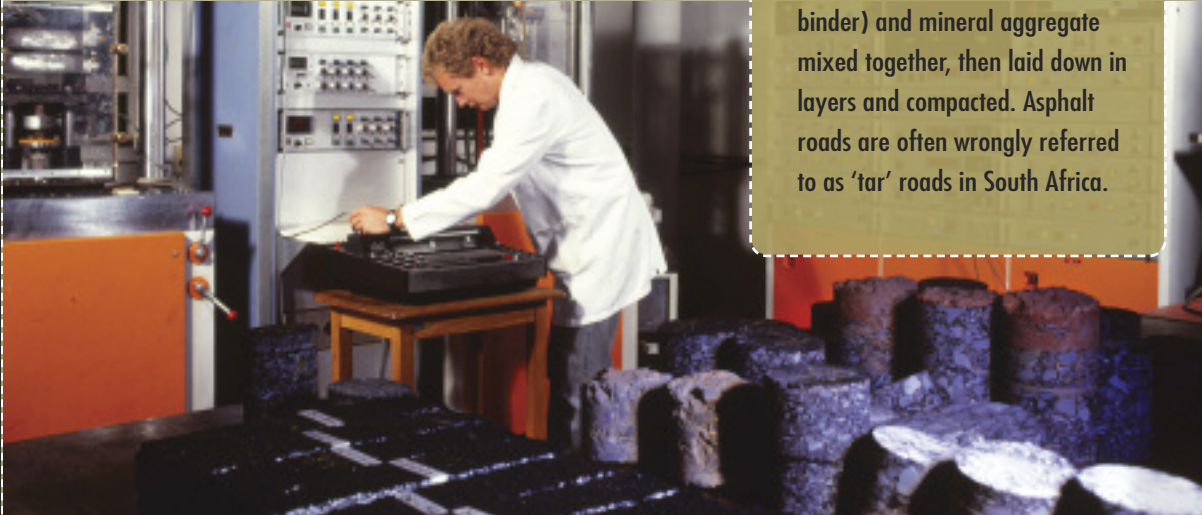
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LONG-LIFE PAVEMENTS POSSIBLE WITH HIGH-MODULUS ASPHALT



Conducting research to increase the design life of heavy-trafficked road sections – the CSIR's Erik Denneman (right) and Tso Nkgapele

Asphalt samples being tested in a CSIR laboratory



WHAT IS ASPHALT?

Asphalt is a composite material, commonly used in the construction of road surfaces, airport pavements and parking lots. It consists of bitumen (used as a binder) and mineral aggregate mixed together, then laid down in layers and compacted. Asphalt roads are often wrongly referred to as 'tar' roads in South Africa.

Transport Minister Sibusiso Ndebele recently announced that the condition of 40% of the country's provincial road network has reached crisis proportions. South Africa's continued economic growth has seen large increases in volumes of heavy vehicles on the country's roads. Road design methodologies and pavement material technology have to keep pace with the increase in demand placed on the infrastructure.

One of the initiatives aimed at increasing the design life of heavy-trafficked road sections is the high-modulus asphalt (HiMA) project undertaken by the CSIR in collaboration with the Southern African Bitumen Association (Sabita). As a non-profit organisation, Sabita represents producers and applicators of bituminous products, consulting engineers and educational institutions.

HiMA was developed in France in the early 1990s where it is now used extensively on main routes, airports as well as urban roads. The technology combines superior permanent deformation resistance with high structural strength and good endurance.

"The key characteristic that distinguishes HiMA from other asphalt types is the hard binder. HiMA has a greatly improved resistance against permanent deformation compared to conventional asphalt mixes," says Erik Denneman.

Denneman explains that because HiMA is stiffer, it can be constructed in thinner layers while achieving the same structural capacity, saving on non-renewable material usage and costs. The long-term aims of the project are to reduce road user costs by creating pavements with a longer service life, high riding quality and a decreased need for maintenance and therefore road user delays.

"Before HiMA technology can become an accepted practice in South Africa, we need to prove to road authorities its higher cost effectiveness compared to that of local conventional pavement material types and structures. It is a material that can render longer pavement life with improved performance," adds Denneman.

In addition, a longer-life pavement ensures improved whole life-cycle costing by, for example, reducing user delays on heavily-

trafficked roads. To demonstrate this benefit, the CSIR will construct a trial section with HiMA as a base layer, surfaced with a thin asphalt wearing course, and subject it to accelerated pavement testing (APT). The results obtained from the performance of this pavement structure and materials can then be compared with historical data.

Denneman concludes, "The CSIR's tests on HiMA mixes also feed into the larger revision of the South African pavement design method by the South African National Roads Agency Ltd (SANRAL). As part of the project, tentative performance criteria have been set for the South African equivalents of the French test methods. A preliminary guideline for the design of HiMA mixes and pavement structures containing HiMA layers has been completed. In the next phase, locally designed HiMA mixes will be tested under APT to validate the design methods and gain further local experience in this technology."

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ROAD STRUCTURES TO BENEFIT FROM **SLOPE MANAGEMENT SYSTEM**

In South Africa, the structural capacity of road pavements receives significant attention but little consideration is given to the road environment and associated structures. These include *cuts* (where earth is removed from a road over elevated or mountainous land to level the road) and *fills* (where earth is deposited to level a road in, for example, a valley). Cuts and fills are expensive structures with severe consequences in terms of mobility and access when failures occur and even the potential for loss of life and damage to property.

“When a rockfall or landslide occurs, three potential impacts ensue: safety risks to motorists on that section of road, the economic impact associated with the traffic diversions during clearing and reopening of the road, and possible damage to adjacent land and infrastructure.”

Researchers at the CSIR set out to develop a road hazard rating system to assist road management authorities with mitigating the effects of rockfalls and landslides on our transport infrastructure. The slope management system will identify the risk of strategic transportation routes being adversely affected by slope instability.

Potential landslides on the increase

According to CSIR researcher Robert Leyland, "Recent international research shows that the increasing incidence of slope failures is linked to global climate change, and landslides are becoming more frequent and more severe. This international trend appears to be occurring in South Africa as well; a number of serious landslides have occurred in South Africa over the past few years, leading to long and costly road closures and lengthy deviations of traffic.

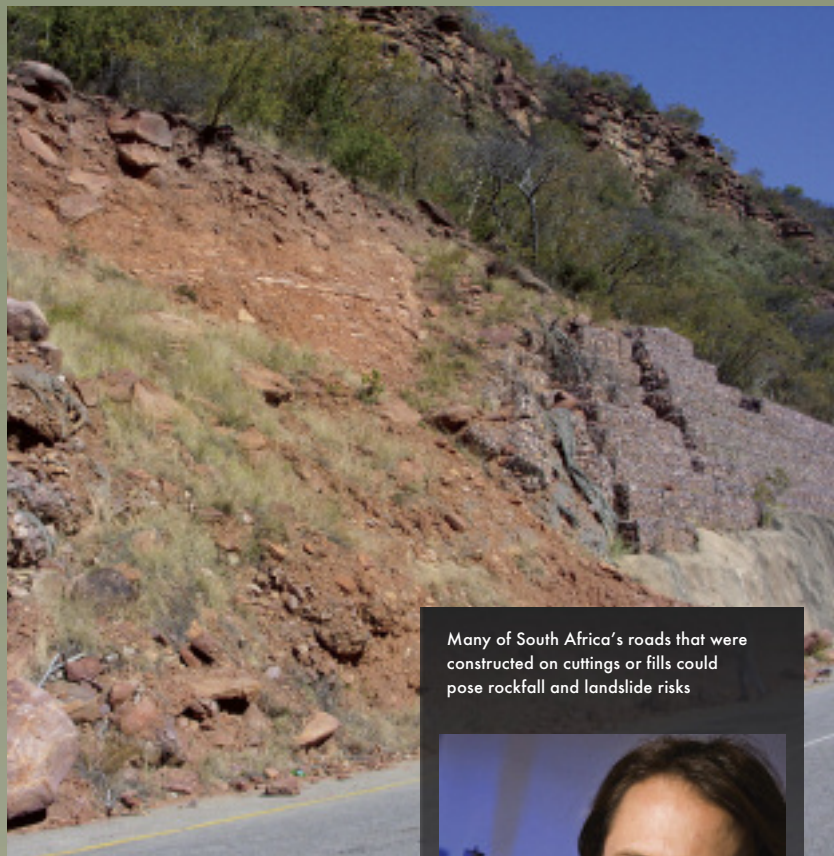
He continues, "A number of our road cuts and fills were designed some time ago and, in some cases, with budget constraints and in line with old regulations. Over time, the geological and geomorphological conditions of such cuttings can change and create potentially hazardous conditions."

"When a rockfall or landslide occurs, three potential impacts ensue: safety risks to motorists on that section of road, the economic impact associated with the traffic diversions during clearing and reopening of the road, and possible damage to adjacent land and infrastructure."

Improved, proactive management

The CSIR slope management system will allow road management authorities to monitor the road cuttings within their jurisdiction. All cuttings can be ranked and potentially unstable areas that pose the greatest risk can be identified. The high risk areas must be modified or mitigation measures should be implemented.

"The system, therefore, assists in the effective management of one of the aspects required in a comprehensive pavement management system," Leyland adds. Currently, no formal requirements exist relating to the monitoring and maintenance of road cuts after construction. The last formal publication on road cut-



Many of South Africa's roads that were constructed on cuttings or fills could pose rockfall and landslide risks



Robert Leyland works on a slope management system that will enable the proactive management of road cuttings

ting management in South Africa was *Investigation, design, construction and maintenance of road cuttings* published by the CSIR in 1987 and slightly revised by the Department of Transport in 1995. This document only states that monitoring should, in its simplest form, consist of regular visual inspection during which staff should be able to identify potentially unstable features such as tension cracks or unexpected water flows. The current practice is therefore aimed mostly at landslides and rockfalls on a reactive rather than proactive basis.

Leyland points out that the CSIR is working towards a system that will afford road authorities an opportunity to be more proactive and prioritise potential rockfalls and landslides before these occur. The systems for this project are being modified and a test application is almost complete. Development of a database system and user GIS interface is underway.

"The informal consultations that have occurred with potential users have been positive. The objective is to use this preliminary work as a pilot study before consulting with the relevant road authorities to extend the work country-wide," concludes Leyland.

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APPROPRIATE SANITATION INFRASTRUCTURE AT SCHOOLS IMPROVES ACCESS TO EDUCATION

Good physical infrastructure at schools enhances access to education, while inadequate and poorly maintained infrastructure excludes learners.

In the Butterworth education district in the Eastern Cape, some 400 schools are benefiting from clean sanitation facilities due to a pilot intervention by the CSIR.

The CSIR's Dr Kevin Wall

Every day – directly because of lack of maintenance of the physical infrastructure especially the water and sanitation facilities – countless learners at many rural schools are deprived of learning contact hours. “Girl learners are most affected by this as they often have to go home to find a clean toilet. And due to the long distances they have to walk to school, they then don’t return to school for the rest of the day,” explains CSIR civil engineer and town planner, Dr Kevin Wall. “Girls who are menstruating would often rather not go to school than having to deal with the lack of privacy,” he adds.

The great majority of the 6 500 schools in the Eastern Cape are located in rural areas, and nearly all of these schools have pit latrines. “Very few of these toilets have ever been properly maintained – many of them are full, and are therefore no longer usable,” Wall comments.

An innovative programme whereby emergent micro-entrepreneurs are trained and mentored to provide routine cleaning and maintenance services of sanitation facilities at schools is being tested and evaluated at the Butterworth district schools.

“The programme, using concepts formulated by the CSIR and developed by the CSIR in collaboration with the Water Research Commission (WRC), is based on partnerships. These involve skills development and incentive principles similar to those of franchising,” says Wall, who specialises in policy and strategy formulation to assist government in delivering and managing infrastructure services.

“We set out to facilitate the creation of emergent micro-businesses to undertake cleaning and maintenance services of small-scale water and sanitation facilities – facilities such as those owned by schools, clinics and municipalities. The franchising concept was not entirely foreign to the people with whom we engaged – they have all patronised franchises such as food outlets and petrol stations.”

The franchisor in this instance – Amanz’abantu Services (Pty) Ltd – is an East London-based service provider with many years’ experience of working alongside rural and developing communities. “Under the guidance of the franchisor, trainee franchisees were equipped to start cleaning and maintenance of the sanitation facilities at the schools,” says Wall.

The programme establishes and supports local franchisee micro-businesses, thus creating entrepreneurial and employment opportunities – mostly for women, as it turns out. “The franchisees first received appropriate training from Amanz’abantu and assistance with setting up their businesses. The company thereafter continues to provide structured learning in the form of on-the-job mentoring, and also further training as required,” notes Wall.

The cleaning and maintenance services provided by the franchisees at schools are being paid for by the schools from their budgets annually allocated for operation and maintenance of infrastructure.

Irish Aid, Ireland’s government department that assists developing countries, has committed to providing substantial research and development funding for the pilot for three years.

This is in line with an agreement reached between Irish Aid, the CSIR, the WRC, the Eastern Cape Department of Education and Amanz’abantu. “We provide policy, management, technical and other assistance necessary to facilitate the pilot programme. This includes drafting the terms of reference, formulating contractual documentation, monitoring progress, and disseminating results with a view to replicating such projects in other areas,” says Wall.

“The franchising concept ensures quality control and reliability while offering first-time entrepreneurs the chance to set up profitable businesses. A maintenance job could be a job for life, so these employment opportunities are sustainable.”

Using franchisees to maintain small-scale infrastructure will overcome many current operation and maintenance challenges, also beyond schools. “Equipped with the skills to maintain infrastructure, the franchisees could expand into routine maintenance of infrastructure owned by others, such as health authorities and municipalities.”

Wall concludes: “The project in the Butterworth district is proving so successful in cleaning the sanitation facilities, and thereby enhancing learners’ access to education, that the provincial Department of Education is keen to roll out the sanitation maintenance programme to about 1 000 more schools within the province.” – Hilda van Rooyen

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Cleaning of sanitation facilities using franchising principles



CSIR industrial engineer, Elias Willemse

DEVELOPING OPTIMISATION MODELS AND ALGORITHMS FOR **MUNICIPAL RESIDENTIAL WASTE COLLECTION**

Waste management is an important basic service provided by local municipalities. Recently, various initiatives aimed at improving waste service delivery have been formulated and implemented by the South African government.

A total of 2.2 million households are without adequate waste management services.

The CSIR aims to assist service delivery through transportation scheduling of household waste. Some waste management initiatives include the draft White Paper on integrated pollution and waste management for South Africa, the action plan for general waste collection and the national waste management strategy. These initiatives are a step in the right direction but fail to address one of the key and integral operational areas of waste management: the collection and transportation of municipal solid waste.

CSIR researcher Elias Willemse explains, "As industrial engineers, we strive to make an impact to improve municipalities' service delivery through transportation scheduling of household waste. One of our main objectives is to improve systems and processes. Local government has systems and processes that can, and should, be improved using scientific and engineering principles. Industrial engineering has the potential to help government better utilise resources, and in so doing reduce unnecessary expenditures and increase service delivery."

Municipal solid waste can be classified in three major categories. The first is commercial waste found at small businesses, restaurants and apartments. The waste is usually placed in large containers and collection involves point-to-point visitation and emptying of the containers. The waste is then transported to a land-fill site.

The second category is roll-on-roll of waste collection. It involves the pickup, transportation, unloading and drop-off of large containers that are typically found at construction sites, industrial areas and other locations that generate high volumes of waste. With both these categories collection points are usually scattered throughout a geographical area, and collection is, hence, performed on a point-to-point basis.

The third waste category is residential waste. In developed areas the state of practice of residential waste collection is through curbside collection. Municipalities have to collect the waste of each household at least once a week. Households place their generated waste, which are stored in either bins or refuse bags, on the designated days in front

of their properties, where waste collection vehicles can then collect the waste. Here, the emphasis is not on point-to-point collection, but on street-to-street collection.

Undeveloped and rural areas require a direct collection strategy, mainly due to poor road access and long collection distances. One approach is to subcontract the door-to-door waste collection to local entrepreneurs who then transport household waste to a container, called a transfer station, in or near the service area. The municipality then empties the container once a week. Residential waste forms the biggest percentage to be collected by municipalities. It is highly repetitive with each household's waste being collected weekly throughout the year. Therefore, even a small improvement in the waste collection and transfer operations can lead to significant savings in costs.

The research being conducted by Willemse and colleagues is based on using optimisation models and algorithms to provide decision support to local municipalities. Similar studies have been successfully conducted in Europe and the United States, and resulted in improved service delivery and savings of millions of euros and US dollars. "Our aim is not to try to apply the techniques developed for first world countries, but to adapt and test the techniques in the South African environment," adds Willemse.

To help municipalities reduce their operational costs and deliver a sustainable waste collection service, the optimisation studies in waste collection routing need to be complemented and integrated with similar studies into tactical and strategic waste collection decisions. Accordingly, the aim of this project is to develop and integrate optimisation models and algorithms to help municipalities make better strategic and tactical waste collection decisions. The studies will revolve around three key areas impacting on vehicle routing: determining the type and number of collection vehicles required; sectoring a service area into balanced collection days and vehicle areas; and determining the location of transfer stations within a collection area.

"Recent findings show that there is a need for decision-support systems in municipal waste

management. Preliminary tests show that the transportation routing algorithms that we've developed are capable of providing quantitative decision support. Our algorithms are capable of generating collection routes that minimise vehicle fleet size and total time required to service a given area. We've tested our algorithms on networks consisting of thousands of roads and the algorithms produce routes for the whole area within seconds."

Statistics show that in South Africa's six major metros, approximately 90% of households have access to a weekly refuse removal service. In small to medium-sized municipalities, approximately 60% have access to refuse removal. In rural towns, only 20% of households have access to weekly refuse removal. A total of 2.2 million households are without adequate waste management services.

Some of the key challenges faced by municipalities include budget constraints, insufficient skills development and lack of in-house capacity. "Our algorithms can alleviate budget constraints by optimising the use of municipalities' existing waste collection and transportation resources. The algorithms can then be used by the CSIR to provide decision support to municipalities, and in so doing, provide municipalities with some of the critical skills and capacity desperately needed to run the service in an efficient and effective manner."

Willemse believes that the value of their work lies in the fact that it is an investment for the future. "We are in the final phase of algorithm modelling and refinement. Importantly, we know what the limitations of our models and algorithms are, and we know how to apply them to provide decision support to municipalities. The next phase of the project is the most critical. We have to demonstrate proof of concept through a case study. Once we have proved that our algorithms are capable of providing effective decision support to municipalities, we want to implement the algorithms at as many municipalities as possible. The more the better..."

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SMALL TOWN SERVICE DELIVERY: EASING THE INFRASTRUCTURE BURDEN

In the June 2009 edition of *ScienceScope* (focusing on energy), an article by Dr Louis Waldeck outlined the CSIR's plan to aid small town municipal service delivery.

This plan, which forms part of the CSIR's Integrated Renewable Infrastructure Project (IRIP), is aimed at using renewable energy as a catalyst for creating sustainable jobs; assisting rural municipalities with the management of their wastewater treatment plants; and combating the negative effects of climate change on the food and water security of rural towns.

The plan involves several technology solutions. "Renewable energy solutions such as concentrating solar thermal power and algal biodiesel are harnessed and integrated to establish enterprises that combine independent power producers, food production and agri-processing industries into a viable business concern, while easing the burden of municipal waste water treatment on the local municipality," explains Dr Chrisna du Plessis.

"Ultimately, this technology system could be a franchised enterprise in at least 40, if not more, rural towns in South Africa. It could also

be expanded to include equivalent towns in neighbouring countries," she says.

More than 80 suitable rural towns have already been identified according to their size and the availability of sunshine where they are located. However, the project's implementation may not realise for some years because the different technologies used within the integrated solution are at different stages of development.

Du Plessis explains: "The plan is based on five main technology subsystems, each with between one to six different technology areas. These have to be developed up to at least a technology readiness level where an integrated system prototype can be demonstrated within the true environment. This may take some years to achieve."

She is, however, very optimistic about its eventual implementation. "Getting this plan right

will be a world first. Its successful implementation will relieve small town municipalities from much of the burden of wastewater treatment by sharing the responsibility with the private sector."

"The potential income from producing electricity from biogas, as well as the downstream agricultural activities, will provide the private sector with a direct interest in the staffing, operation and maintenance of the plant. The savings associated with the reduced responsibility for treating wastewater by the municipality can then be spent on other aspects of service delivery." – Petro Lowies

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Demonstrating the usefulness of sensors in everyday life: Dr Anwar Vahed, Adnan AbuMahfouz and John Isaac of the CSIR with Dr Gerhard Hancke of the University of Pretoria. Pictured right is Dr Barend Taute of the CSIR

SENSORS TAKE THE HEAT

FINDING DECISION SUPPORT SOLUTIONS FOR THE BUILT ENVIRONMENT

Distributed sensor networks are central to effective decision-making for demand management in the built environment. This is the opinion of researchers John Isaac and Dr Barend Taute of the CSIR Meraka Institute; both are involved in discussions regarding the establishment of a joint research group with the University of Pretoria to focus on the potential applications for and impact of distributed sensor networks in South Africa.

Taute explains, "Sensors in themselves are useful devices, and when connected via a communications system, form a distributed sensor network. The nodes where sensors come together can be used to monitor and control electricity and water supply and usage as well as telecommunications services."

What are sensors?

Sensors are similar to the senses that people use every day. Just like our senses that detect stimuli to provide inputs for perception, a sensor measures a physical quantity and converts it into a signal that can be read by an observer or by an instrument.

Sensors can be classified according to type; this list includes acoustic, mechanical, chemical, electrical, optical, thermal, motion, radiation and presence sensors.

Distributed sensor networks or DSNs comprise autonomous sensors and actuators distributed at various points, which monitor physical or environmental conditions. Sensor nodes can be connected via a wired or wireless network. The cost and size of nodes vary depending on the requirements for energy, memory, computational speed and bandwidth.

The value of distributed sensor networks

The value of a DSN should be seen in the context of current thinking on the 'Internet of Things'. In an address at the 2nd Annual Internet of Things Conference, held in Brussels in June 2010, European Commissioner for Digital Agenda, Neelie Kroes, stated, "Beyond the technical and physical reality, the 'Internet of Things' is an aspiration. It is an ecosystem of applications which will be key to a truly IT-enabled world. These applications will help us navigate, and open our eyes to new possibilities in our work and leisure." The 'Internet of Things' is becoming a reality as sensors in cell phones are tools for interacting and managing the environment.

At a practical level, the value of a DSN can be seen in its potential to create smart spaces and save costs. John Isaac elaborates, "Examples of smart spaces are homes with devices to assist owners to manage their utilities and enjoy enhanced security. Wireless metre reading is another example of how these networks can be used." He speaks of high-rise buildings with self-detecting structural sensors to help correct faults, thereby enhancing safety.

Taute concurs, "Sensors help measure, monitor and control. Having a sensor network allows us to collect data that can be used to create information systems for decision-making and control." Peak demand for electricity can be managed, for example, through what is called a 'smart grid' that optimises the use of renewable energy, re-directs transmission flow in case of a failure, and chooses optimal timing for heating geysers. It also becomes possible to map trends and create models to

introduce artificial intelligence into the system to enable automatic decision-making, for example, in cases where electricity supply becomes unstable.

Planning and monitoring of water, electricity and telecommunications can be centralised for cost-effective utilisation through accurate identification of problem areas and usage levels. This would in turn empower national utilities.

Another application is management of distributed assets and services. "If we combine a DSN with a geographic information system, it becomes possible to keep tabs on moving assets and assets in transit. Services located remotely can be monitored and managed remotely."

The way forward

Given its existing competence in sensor technology, wireless communication networks and other areas pertinent to DSN, the CSIR is exploring the establishment of a joint research group with Professor Gerhard Hancke of the Department of Electrical, Electronic and Computer Engineering of the University of Pretoria (UP). Through this agreement, UP and the CSIR will work *inter alia* with the Georgia Institute of Technology's international expert, Professor Ian Akyildiz, on a feasibility study to identify niche areas where DSN research and development can have maximum impact in South Africa.

- Biffy van Rooyen

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CSIR PROVIDES SUPPORT IN GUIDING HOUSING AND HUMAN SETTLEMENT INVESTMENT

Limited resources are available for South Africa's housing needs, while housing development pressures emerge in diverse locations. Human settlement authorities need to make well-informed and justifiable investment choices that will promote the sustainable development of and also redress historical spatial imbalances.

The Department of Human Settlements (DHS) commissioned the CSIR to update the Human Settlements Atlas 2009 published by the department this year. It is the third edition in the atlas series, which is aimed at guiding the locality of investments in housing and settlements by various stakeholders, from a very dysfunctional, inequitable space economy towards more sustainable human settlements.

"The main spatial challenge in South Africa is still the spatial exclusion of low-income families from the main socio-economic facilities of cities and regions. Locations close to employment areas, opportunities and services are not accessible to all people because of issues such as high land costs, limited availability of space, limits to planning and financial instruments, and lack of infrastructure in appropriate places," explains the CSIR's Helga Goss.

The Investment Atlas includes a conceptual framework, spatial analyses and recommendations for investment in housing and supportive services. The atlas features a comprehensive set of maps of the country as part of the analysis, showing different circumstances and potentials of provinces and regions. Individual spatial maps are provided on various aspects, such as access to job opportunities, population trends, social issues such as grant dependencies and health, and environmental suitability.



Team members Tsepang Leuta, Helga Goss and Alize le Roux with a copy of the Human Settlements Atlas 2009

"It is not merely spatial information and maps for the purpose of data dissemination. CSIR research on economic and demographic data and also data supplied by the department are converted into detailed, interpreted analyses to support decision-making. Many of our analyses go right down to spatial areas of 7 x 7 km, which are very useful for districts," Goss says.

The three main outcomes of the atlas are:

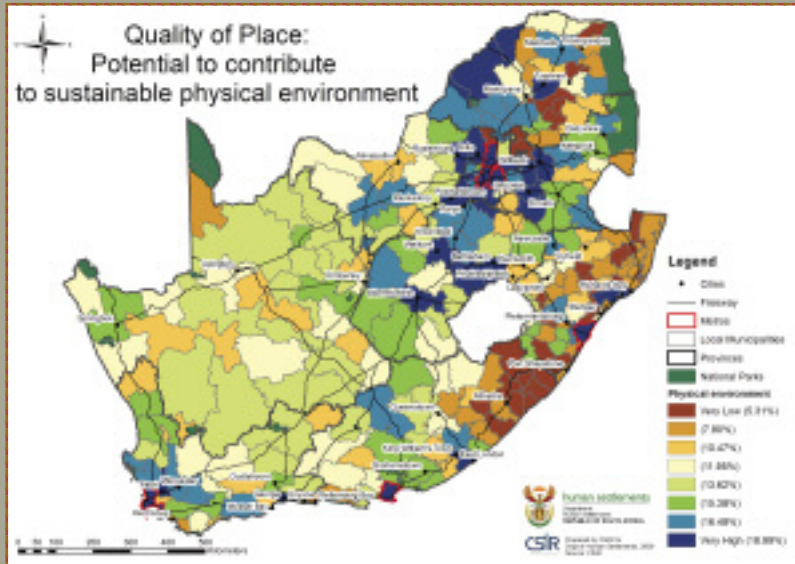
- A spatial quality of life index (productive life; shelter; safety; health)
- A spatial quality of place index (viability; diversity; accessibility; efficiency and protection of resource use)
- A differentiated settlement investment potential profile based on the quality of life and of place index of areas, linked to recommended types of housing and supportive service investments for each type of area.

"The quality of governance is an additional index, but is not included in the atlas due to it not being a spatial phenomenon. It refers to the ability of government to provide and maintain an acceptable quality of life and place within the economic and ecological constraints. This implies supporting policy frameworks and effective regulatory measures, based on the principles of justice, equity and protection," explains Goss.

The CSIR's recommended housing investment choices are based on five broad categories, taking into account the dwelling types, density, housing delivery models and levels of formality. The five different densities and types of housing units are:

- Very low density: Single, detached units, which include government-subsidised or privately-funded dwellings;
- Low density: Single, detached units with backyard shacks, semi-detached units such as duet houses, and detached duplexes;
- Medium density: Cluster housing such as townhouse complexes, detached triplexes, and low-rise apartments (three to four storeys high), as well as developments with a range of dwelling and tenure types;
- High density: Medium-rise stacked units (five to 10 storeys) and high-rise apartments (10 to 20 storeys);
- Very high density: High-rise, point block apartments (more than 20 storeys).

Based on investment potential, appropriate investment responses are indicated for different places. "We developed an investment potential profile that indicates what types of housing units and supportive services should be built where, in the most suitable location that is likely to have the highest potential to support sustainable human settlements."



CSIR researchers linked the different housing investment choices to the spatial profile of different combinations of quality of life and quality of place. The main concentration of areas with a high quality of life as well as a high quality of place includes most of Gauteng, Cape Town and surroundings, eThekweni, and Nelson Mandela Bay. A selection of secondary cities and major towns also falls within this category, including Middelburg (in Mpumalanga), Secunda, Nelspruit, Sasolburg, Bloemfontein, Welkom, Polokwane, Makhado, Potchefstroom, East London, Richards Bay and George. Other broad areas with a high quality of life and of place include areas surrounding Phalaborwa, Albertinia, Riversdale and Howick.

"Low quality of life and low quality of place were found predominantly in areas located on the eastern side of South Africa, and a few isolated areas in the remainder of the country. These include mostly former 'homeland' areas, characterised by low levels of economic activity and high population concentrations," comments Goss.

"It stands to reason that areas with a 'high quality of place' also have a high physical potential to support sustainable human settlements and a higher probability that people can support sustainable livelihoods, than in a locality with a 'low quality of place'. If one

looks from a purely 'return-on-physical-investment' point of view, it would make sense to prioritise the areas for physical housing investment. Interestingly, high quality of place does not automatically translate into a high quality of life. A place could be economically viable if viewed from the perspective of GDP per capita, but households can still lack the means to access the livelihood opportunities presented by the area due to factors such as lack of physical access, poor health or lack of appropriate skills."

"People have a constitutional right to adequate shelter, regardless of whether they live in a low quality of place and low quality of life area. In this context, decision-makers have to look at appropriate investment packages for every type of locality, consisting of suitable housing types as well as supporting services to increase quality of life," concludes Goss.

The Human Settlements Atlas 2009 is distributed by the DHS in printed format and as an electronic map viewer product on CD.

- Hilda van Rooyen

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South African cities are characterised by urban sprawl. The predominant typology is one house unit per family per plot, which results in South African cities being among the least dense cities in the world. CSIR researchers set out to identify the benefits of medium-density, mixed housing as an alternative housing solution.



Gerty Matsebe, Sizo Sebake and Dr Amira Osman

MEDIUM-DENSITY MIXED HOUSING TO SUPPORT SUSTAINABLE HUMAN SETTLEMENTS

The two extreme poles in the housing sector are government-subsidised housing (the so-called RDP houses) and very upmarket developments. Both ends of this spectrum are based on a detached house in the middle of a plot.

"It is the market between these two extremes that can perhaps offer opportunities for innovative housing solutions and multi-family typologies such as medium-density, mixed housing," says Dr Amira Osman, an architect at the CSIR. This approach is advocated by 'Breaking New Ground', a comprehensive plan for the development of sustainable

human settlements approved by Cabinet. CSIR-initiated research has thus focused on medium-density mixed housing in a multiyear study.

"We are looking specifically at the 'gap' market for the development of medium-density mixed housing (MDMH). That involves people in the lower to middle income groups, typically with a monthly salary of R3 500 to R7 500. Their salaries are 'too high' to qualify for government-subsidised housing, yet 'too low' to access home loans through financial institutions," comments Osman.

MEDIUM-DENSITY MIXED HOUSING

This is defined in the CSIR research project as having a minimum of 50 dwelling units per hectare (du/ha) and a maximum of 125 du/ha. The case studies selected were generally a maximum of four storeys with private external spaces.

These developments are also characterised by a mix of building/unit types, tenure forms (ownership, rent-to-buy or rental units), income groups (affordable and market-rate housing) and mix of land uses (residential, commercial, public open space, business).



MDMH is defined as a minimum of 50 dwelling units per hectare (du/ha) and a maximum of 125 du/ha. "These various densities have different spatial and physical manifestations, and the definition is relative to the locality of housing, as inner-city contexts may require significantly higher densities," explains Osman. This type of housing is generally characterised by ground-level entry, private external space for each dwelling unit, and close proximity to secure parking and ground related, thus these developments are rarely over three to four storeys above ground.

Case studies

CSIR researchers initiated and conducted seven different case studies. "The research premise was that MDMH has the potential to solve problems regarding spatial restructuring, integration, optimum infrastructure development and increasing access of lower income groups to housing in urban contexts. MDMH has a direct influence on the economy (more support for small-scale entrepreneurs) and the environment (less pressure on natural resources)," Osman notes.

The CSIR team looked at spatial and social factors, as well as the viewpoints of different groups of stakeholders. Table 1 provides the distribution of selected case study areas.

Some of the key findings of the CSIR MDMH project (2007-09) are listed below:

- MDMH may offer more opportunities with regard to deconcentrating poverty, revitalising neighbourhoods, enabling greater social mix and contributing to opportunities for improved safety.
- Case studies indicate that people are willing to consider alternative housing typologies for the benefit of being closer to job opportunities and/or more security.

TABLE 1: CASE STUDY AREAS

PLACES	PROVINCE	MUNICIPALITY	SIZE (IN UNITS)
Amalinda	Eastern Cape	Buffalo City	598
Brickfields	Gauteng	Johannesburg	345
Carr Gardens	Gauteng	Johannesburg	211
Cosmo City	Gauteng	Johannesburg	12 400
Hull Street	Northern Cape	Sol Plaatje	2 200
Pennyville	Gauteng	Johannesburg	2 800
Sakhasonke	Eastern Cape	Nelson Mandela Metro	337

- MDMH has the potential to add to the viability of a project by promoting affordable housing options and the opportunity to include low(er)-cost housing in mixed developments. It is found, within certain limits, that developers may use cross-subsidisation to achieve a better social mix and a degree of integration.
- There is a willingness from investors to spend on developments that have a mix of tenure options and income groups. This is therefore seen as a financially-viable approach to housing.

It was also found that it is possible to use subsidies to achieve medium-density 'RDP' developments.

SUSTAINABLE SETTLEMENTS

Well-managed entities where economic growth and social development are in balance with the carrying capacity of natural systems, resulting in development, wealth creation, poverty alleviation and equity.

Such settlements are environmentally, economically and socially sustainable. They support people's livelihoods through diverse opportunities and also put less pressure on the environment. Developments of this nature build communities and provide environments of learning, safety and stability through good planning and design principles.

The CSIR also attempted to objectively describe and rate the characteristics of the residential built environment in an urban setting. A tool was developed that facilitates a qualitative and quantitative (mixed) approach to assessment. This may allow for better informed design decision-making based on empirical research. By assessing proposals for new developments, the gap between policy-makers, designers, developers and end-users could be closed. - Hilda van Rooyen

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CSIR EXPERTISE AND TECHNOLOGY TO IMPACT ON LOW-INCOME, SUBSIDISED HOUSING

The huge backlog in government-subsidised housing provision is a harsh reality facing South Africa. The Ministry of Human Settlements has also declared publically that shoddily-built, sub-standard low-income houses are unacceptable.

Communities who depend on subsidised, low-income houses in South Africa could benefit greatly from technology developed and tested by the CSIR. Having determined the shortcomings of a default 40 m² low-income house scientifically, researchers set out to develop a demonstration house that would be thermally more comfortable, more durable, faster to build, easily extendible and less dependent on municipal services.

With sustainable, quality low-income housing a national priority, the Department of Science and Technology (DST) commissioned the CSIR to investigate technology possibilities for improved low-income housing.

"We used innovative design and construction technology for developing a demonstration house with significantly improved performance and sustainability," says the CSIR's Llewellyn van Wyk, the project leader. "To design for sustainability, you have to move from the idea of 'transforming nature' towards 'transforming society' by improving the quality of and relationships between all living beings, communities and the natural and built environments."

Two other houses were also built on the CSIR campus in Pretoria – both are the standard

40 m² size and design of subsidised low-income houses. One is a replica of a standard subsidy unit, while the interior and exterior finishing of the second house is as per typical suburban standards, illustrating the difference in appearance and experience when inside the house.

"Our experimental house is the standard size, but has an optimised design with the added advantage that it can be extended easily by home owners. The proposed starter unit can be developed into a fully-fledged three-bedroom home without any demolition of the existing structure," explains Van Wyk.

Certification

The complete CSIR demonstration house has been certified by Agrément South Africa, the internationally-acknowledged body that provides assurance through technical approvals of non-standardised or unconventional construction products and processes. The house also adheres to the National Building Regulations and the requirements of the National Home Builders Registration Council. If built according to CSIR specifications, and on large scale, such houses would be constructed faster and at slightly higher costs than when using conventional construction methods.

Features

"We used innovative technology in the roof assembly, construction of the super-structure and sub-structure, the wall finishing and the service structures," Van Wyk says.

The CSIR used a modular, design-to-fit approach – similar to a Lego set – where pieces have to fit together correctly to form the bigger unit, which also ensured zero waste in construction material. One big difference to current low-income houses is the design of the bathroom and kitchen area, and the use of a waste outlet manifold that is prefabricated, quality-tested and installed on site. This reduces the extent of the plumbing installation substantially while ensuring that the installation is done to the required standard.

To eliminate cracked walls resulting from sub-standard foundations, a CSIR technology developed for roads was adapted to form a single, continuous foundation slab instead of conventional foundations. Local labour can be used to construct such a foundation slab, which is based on ultra-thin, continuously-reinforced concrete technology developed and tested for low-volume roads. "This contributed greatly to us being able to reduce the amount of concrete used during construction of the house by about one ton, which, in turn, will

lead to an estimated reduction of CO₂ emissions of about one ton per house," says Van Wyk.

Standard low-income houses have no ceilings and thus no insulation, which results in huge variations in indoor temperatures. "We improved the thermal performance of the house's roof significantly by adding an insulation material that doubles up as a ceiling. In addition, the orientation of the house also provides optimum natural thermal performance and comfort. The house is orientated for maximising the winter sun, ensuring bedrooms can benefit from sunlight, while the living room faces north."

Additions

"For improved energy efficiency and less dependence on municipal services, we decided to include some additions. These are a standard, commercial solar water heater on top of the roof for providing home owners with hot water. A photo-voltaic panel above the front door furthermore powers five LED lights and a cell phone charger inside the house," says Van Wyk.

As part of an integrated approach, a water tank was installed next to the house for harvesting rainwater off the roof.

Pilot study

The CSIR's low-income housing initiative is a research project-in-progress. Researchers are currently undertaking performance analyses of the demonstration house, doing initial life-cycle assessments and energy simulations.

To put the advances achieved in this project in perspective, the following statistics hold true for households in South Africa:

- 20% of households do not use electricity for lighting
- 42% of homes do not use electricity for heating
- 34% of units do not use electricity for cooking
- 53% of households have no access to piped water inside the unit
- 45% of households have no access to flush toilets connected to sewerage facilities

The local authority of the Overstrand Municipality in the Western Cape is collaborating with the CSIR and the DST in a pilot study within the local community in Kleinmond. Incorporating many features of the CSIR-developed low-income demonstration house, 441 pilot units are being built in an existing housing development. The local authorities are responsible for the occupancy waiting list, along with a community liaison officer deployed to interface with the community regarding expectations.

"We are expecting that the first pilot houses will be ready for occupation by December 2010, with the last houses set for completion by March 2011. The DST has commissioned us to monitor and evaluate the pilot houses in Kleinmond after one year's occupation to determine the performance improvements

achieved throughout the four seasons. If one looks at the data obtained for the CSIR demonstration house from preliminary performance assessments and simulations, we are very excited about the possible extrapolated data and performance that could be associated with the 411 houses under construction," concludes Van Wyk.

- Hilda van Rooyen

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Geoff Abbott (second from right) on the construction site of the MDR-TB ward at Catherine Booth Hospital in KwaZulu-Natal

DEDICATED WARDS FOR TB PATIENTS CONSTRUCTED AT NINE HOSPITALS

South Africa has insufficient infrastructure to cope with the growing tuberculosis (TB) epidemic, with extensively drug-resistant TB (XDR-TB) now adding to increasing numbers of multi-drug resistant TB (MDR-TB) patients. The CSIR has set out to address the lack of appropriate hospital infrastructure to prevent cross-infection – a key constraint in the effective treatment and rehabilitation of patients.

Infrastructure constraints in existing hospital buildings for TB patients remain an obstacle to safe health service delivery. “The spatial layout in many buildings impedes the implementation of airborne infection control of diseases such as TB. In South Africa, very few facilities exist that are able to manage suspected or confirmed TB patients adequately,” notes Geoff Abbott of the CSIR.

“The CSIR is assisting seven provincial Departments of Health with the roll-out of special ac-

commodation for M(X)DR-TB patients at existing hospitals. More than R92 million of international donor funding was sourced by the national Department of Health (DoH) from The Global Fund for this project as part of its drive to strengthen national and provincial capacity in South Africa for the prevention, care and treatment of drug resistant TB patients. The provinces where such facilities are being constructed have committed to contributing an additional R115 million towards the project,” says Abbott.

In discussions with the national DoH, facilities were identified where the establishment of new patient accommodation for M(X)DR-TB was crucial. Construction at the first hospital site started in 2009, with most of the other projects getting off the ground from April 2010.

The whole drive is aimed at providing additional ‘beds’ for TB patients, usually at existing drug-resistant TB hospitals. In total, 460 beds will be added at nine hospitals in seven provinces.



Geoff Abbott

R92 million+
International donor funding sourced from The Global Fund for this project

R115 million+ Additional funding commitment from provinces where such facilities are being constructed

R207 million+
Total project capital investment

"The lack of appropriate hospital infrastructure for treating drug-resistant TB is a key constraint against the effective and safe treatment and rehabilitation of patients. Unfortunately, many cases have occurred where both patients and staff have been infected with drug-resistant TB in existing facilities because the buildings are not appropriately designed or have not been remodelled to reduce the risk of cross infection," explains Abbott.

The CSIR is using the research on The Global Fund and other drug-resistant TB projects to review existing international guidelines for the planning, design and operation of drug-resistant TB facilities and to develop and adapt these to local requirements in South Africa. Key local issues include the sheer numbers involved in the epidemic – South Africa has the highest incidence rate for the disease in the world, this links to HIV where over 70% of TB cases are co-infected with HIV, funding and staffing constraints and a wide range of climatic zones.

A focus of the CSIR research is on providing low-cost yet fully-functional units. "The use of natural ventilation is key to providing low-cost, low-maintenance facilities. However, one still needs to ensure that the required number of air changes and effective dilution of the air are achieved. Various window, fixed opening and roof configurations were developed and tested in the CSIR's building performance laboratory. We used primarily computational fluid dynamics software to model building options and to adjust and refine designs. By careful management of airflow, even in very light wind conditions, acceptable air change rates can be achieved. After construction, we will evaluate the buildings in use to validate our research results," says Abbott.

As drug-resistant TB patients have to stay in health facilities for up to a year, health authorities involved in this new roll-out are trying to make their stay as comfortable as possible.

New CSIR designs generally provide for patients to be accommodated in single rooms, which not only reduces the opportunity for cross infection, but also provides for greater patient dignity. Research has shown that patients in multi-bed units are often cross-infected with different strains of TB, increasing treatment costs and a considerable increase in the length of stay. New national policies also consider the spread of facilities, looking to accommodate patients as close to their families as possible.

"The different phases in TB treatment require differing types of accommodation. Acute patients need a high level of nursing care and need to be located close to the nursing support base and a higher level of technological support. Post-acute patients spend most of their rehabilitation time outside the building. Here, one has to provide recreational spaces for supporting activities such as sports, visitor areas, physiotherapy facilities, as well as a business hub for people to continue with running their businesses from the unit. Even classrooms for schooling of the younger patients are taken into account. These extra facilities are generally funded from the provincial budgets," explains Abbott.

Along with the FIFA 2010 fever, one enterprising contractor decided to use excess soil from levelling the construction site to improve a school soccer field near a new TB ward. "This linked well with the national 'Kick TB' public awareness campaign with presentations at schools and soccer balls with appropriate messaging for learners."

Construction of the new 40-bed MDR-TB unit at Manguzi Hospital in KwaZulu-Natal has been completed. "In this instance, a new comprehensive service unit for MDR-TB has been built at the community hospital. It comprises male and female wards, along with an administration and out-patient service block." In Welkom in the Free State, the decommis-

sioned maternity unit at Kopano Hospital has been completely remodelled to provide a similar 45-bed comprehensive service unit for MDR-TB, with construction due to be finished within the next three months.

Other locations for new or improved TB wards include:

- Catherine Booth Hospital in KwaZulu-Natal
- Modimolle Hospital in Limpopo
- Bongani Hospital in Mpumalanga
- West End Hospital in the Northern Cape
- Tshepong Hospital in North West
- Jose Pearson Hospital in the Eastern Cape.

A ninth project, the conversion of existing wards into an MDR-TB unit, was added late in the process at Nkqubela Hospital in the Eastern Cape. "This project will be run as part of a skills capacity-building programme involving staff from the provincial health and works departments and local architects and engineers. It is intended to provide a model for other similar conversions elsewhere in the province."

"We anticipate that seven of the nine sub-projects will be completed and ready for occupation by the end of 2010, with the remaining two scheduled for completion early in the new year."

The two provinces that currently do not form part of the project are Gauteng and the Western Cape, based on earlier funding from The Global Fund. "Due to the work undertaken so far in other provinces, the Western Cape has approached us for assistance in a major new XDR-TB project at its main provincial TB centre in Cape Town. The intention is to draw on this project for developing guidelines for use in other provincial projects," Abbott concludes.

The CSIR recognises that continued research, development and implementation to improve health infrastructure for patient safety along with capacity development for healthcare professionals are crucial in the fight against diseases like TB. – Hilda van Rooyen

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BUILDING PERFORMANCE LAB LOOKS AT SCIENCE BEHIND DESIGNING FUTURE BUILDINGS

The South African architecture sector could be in for an innovative and scientific overhauling following the establishment of a building performance laboratory (BPL) at the CSIR. The aim of the BPL is to assist the professional design and building sectors to generate new concepts and to prototype and test new integrated assemblies to support long-term performance of buildings.

According to CSIR senior researcher and project leader Dr Dirk Conradie, the intention with such a lab is to make future buildings *inter alia* more efficient and environmentally friendly. "Moreover, we have established the BPL both to deepen the analytical simulation capabilities in the design of buildings for research purposes as well as to provide a service for building design professionals in South Africa," he says. "By means of prediction and simulation, we would be able to determine how a new building will perform, in terms of natural ventilation, lighting and other performance aspects," he says.

He adds that the CSIR group intends to use the team's skills and range of software to model buildings including offices, lecture venues and healthcare facilities such as clinics to avoid cross-infection of tuberculosis and other communicable diseases.

Recently, Conradie and his CSIR colleagues Dr Sidney Parsons, Geoff Abbott, Sheldon Bole, Peta de Jager, Faatiema Salie, Luke Osburn and Lorato Motsatsi performed their first advanced predictive simulation when they conducted a pilot project in a proposed new lecture building in East London for the University of Fort Hare (UFH).

Dr Dirk Conradie



"The client opted for a naturally-ventilated building that combines aerofoil-driven ventilation with a Trombe hot-air buoyancy-driven system. A Trombe wall is a sun-facing wall patented in 1881 by its inventor, Edward Morse, and popularised in 1964 by French engineer Félix Trombe and architect Jacques Michel. It is a massive wall separated from the outdoors by glazing and an air space, which absorbs solar energy and releases it selectively towards the interior. In the case of the UFH project, two modifications to the traditional Trombe wall were made.

An exhaust vent at the top was introduced that opens in the venturi suction area of the roof aerofoil. Such venting makes the Trombe wall act as a solar chimney pumping fresh air through the building during the day. The simulations indicated that it works well when there is no wind to ventilate the building. It continues to perform with moderate strength breezes. In the case of strong wind, the Trombe is cooled down by the amount of air entering the building. In the latter case the Trombe action is not necessary because the building is adequately ventilated with wind action.

For the UFH project, the Trombe wall was interrupted with windows. This lowers the efficiency but was done for natural lighting and aesthetic reasons. If the outer glazing has high ultraviolet transmittance, and the window in the Trombe wall is normal glass; this allows efficient use of the ultraviolet light for heating. At the same time, it protects people and furnishings from ultraviolet radiation more than windows with high ultraviolet transmittance do.

"The complex interaction between the two ventilation systems makes it very difficult to quantify performance," he says. "The wind strength and direction are highly variable even though the predominant wind directions are well known. However, the UFH wanted to quantify the percentage of time the building would perform well with regard to air changes per hour. This necessitated the extensive and in-depth analysis of the weather data, combined with a large number of

computational fluid dynamics (CFD) simulations (± 300) to accurately derive at the building ventilation performance under different conditions."

The lab seeks to deepen the analytical simulation capabilities in the upstream design (feasibility studies and design) of buildings for research purposes as well as to provide a service for building design professionals in South Africa. The UFH project provided a unique opportunity and case study for the CSIR team to obtain predictive performance data during the development of the design, to demonstrate a range of techniques for virtual building modelling and performance assessment and to validate performance in the actual building over time. An AutoDesk Revit building information model (BIM) was used as primary input.

BIM is rapidly becoming the preferred method for architects to design and document their designs, as the architect essentially builds a virtual, electronic model. All projected documentation such as plans, sections, elevations and details are automatically coordinated and consistent, because they are all derived from a single model. The interface between building analysis tools and BIM models is gradually improving, which will make the technical analysis process increasingly viable.

Conradie says the UFH had asked the CSIR to quantify the expected daily and annual ventilation performance of the building during its operational hours.

"We," continues Conradie, "studied the East London climate and weather patterns very intensely and even erected our own mini weather station to verify the South African Weather Service's information that was available only for the airport in East London. We did an analysis of the wind strength, direction and the number of hours for a particular direction and strength combination," says Conradie. "We modelled the building in three dimensions with our analysis software using the 3D BIM model supplied by the architect as a basis."

Conradie and his group also used CFD to study airflows and quantify the effectiveness of natural ventilation inside the building. He says that the debut pilot project was eventually a resounding success. "In this particular case ventilation is driven by both heat and wind and it's a complicated interaction," he says.

While some of the technology has been available at the CSIR previously, the results and the capability of this project are new. He adds that this lab's performance capability, aimed at assisting designers or architects, is new. The lab was established two years ago.

"The synthesis and capability are entirely new and we want to combine the information brought by engineers and designers to predict performance of new or planned buildings, as buildings have a long life cycle."

This capability at the CSIR is extremely useful, as designers are unlikely to have CFD equipment, because it is very costly in terms of the initial acquisition cost, and also in configuration and processing time.

"From their [designers] side, there is a high awareness of what needs to be done but there's a lack of capabilities to quantify these designs effectively," he says. "A lab such as this one can help to predict the performance upstream and avoid expensive mistakes downstream with regard to ventilation, natural light and other performance aspects."

"The lab enables us to gain research experience when doing projects such as the one for the UFH. Knowledge generated and applied in real-life buildings will have a profound impact on the long-term performance of a building." The phenomenal computer hardware and software capabilities are now such that advanced desktop-based predictive building simulation processes can be undertaken using digital 3D virtual models. "This was impossible 20 years ago!" Conradie concludes.

- Mzimasi Gcukumana

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"A lab such as this one can help to predict the performance upstream and avoid expensive mistakes downstream with regard to ventilation, natural light and acoustics."

SMALL CLAY NANOPARTICLES

SHOW BIG POTENTIAL IN THE BUILT ENVIRONMENT

Due to their potential fire hazard, polymer-based building materials, other than paints, are traditionally not commonplace on a building site. If researchers at the CSIR have it their way, that is bound to change through the inclusion of clay nanoparticles.

"The addition of a relatively small amount of clay significantly improves the mechanical and material properties of polymers," says Professor Suprakas Sinha Ray, chief researcher, polymer nanocomposites and leader of the CSIR-hosted National Centre for Nanostructured Materials (NCNSM), one of the Department of Science and Technology's nanotech innovation centres. "The comparison with pure polymer materials or conventional filler-filled composite materials is quite remarkable."

The "relatively small amount" that Sinha Ray is referring to is exactly that. Researchers at the NCNSM have shown that the inclusion of just 2% (in weight) of clay dramatically changed the inherent properties of composites - including paints and coatings. Among others, the paint and coatings become both UV and fire resistant, and it flows better or, as the scientists say, has "improved rheological behaviour".

"The nano centre is currently negotiating the transfer of the technology to a paint producer," he says.



Professor Suprakas Sinha Ray and Manfred Scriba from the National Centre of Nanostructured Materials

Small addition, major impact

According to Sinha Ray, researchers worldwide are giving a great deal of attention to the addition of nanoclay particles into polymer matrices to produce composite materials. He explains: "This is because the nanoclay particles improve the properties of those materials. For instance, nanoclays can act as flame-retardant fillers by moving to the surface of the polymer, forming a coating that acts as a heat shield. In addition, as shown by research at the NCNSM, chemically modified nanoclays may act as a binder (compatibiliser) between otherwise un-mixable polymers."

Manfred Scriba, a senior researcher at the NCNSM, comments on another way that nanoclays may impact on the building industry: through engineered composite materials.

"By manipulating the surface chemistry of nanoclay particles to facilitate proper dispersion and binding, we are able to convert plastic waste into advanced composite materials for housing components such as extruded window and door frames, and possibly even whole wall panels. The particles also act as a fire retardant. Furthermore, by including biomass such as wood or bamboo flour into the composite material, building costs as well as the carbon footprint may be reduced."

The commonly-used clays for the preparation of nanocomposites belong to the same general family of 2:1 layered or phyllosilicates. These layers are about one nanometre thick. "The secret," says Sinha Ray, "lies in the modification of the surface of these nano-layers or nano-platelets so that the nano-properties come to the fore when incorporated in the paint or the plastic."

Upscaling for industry

The NCSNM recently acquired a piece of equipment that will greatly assist scientists' efforts in developing nanomaterials for industry use. This equipment, called a batch extruder, can produce 30 kg of composite per hour.

"This will allow us to upscale laboratory-produced nanocomposites by producing small batches that can be tested in extruders and injection moulding processes in industry," explains Scriba. The first product to follow this route will be bamboo and wood plastic composites intended for housing components.

– Petro Lowies

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Cell phones allow us to explore our physical environment

INTELLIGENT CITIES: A VISION OF THE FUTURE – DREAM OR REALITY?

Versatile applications of existing technologies hold the promise of intelligent cities in the not-too-distant future. This, according to researchers Drs Ennio Macagnano and Quentin Williams of the CSIR, brings the prospect of independence, mobility and empowerment for inhabitants of and visitors to an urban environment, irrespectively of level of education, culture, age, level of physical ability and language.

"Intelligent cities, although in their infancy, are already here. The sky is the limit and we already carry the world in our pocket."

A modern urban environment is characterised by ever-increasing population numbers and density, and vast human features in comparison to areas surrounding it. The resultant dynamic shape or urban morphology in which social forms and activities are expressed in the physical layout, and conversely, physical forms producing or reproducing various social forms and activities, and present challenges and opportunities for all inhabitants or visitors. Mobility, access to services and general information are three of the most important challenges.

By 2050, 75% of the total population of South Africa will be residing in metropolitan areas, and the old-age economic dependency ratio will have risen by 160%. Significant challenges and socio-economic requirements for social inclusion, continued active participation to national economic growth and full access to public services represent key challenges.



Drs Ennio Macagnano and Quentin Williams

“South Africa has embraced these new realities and the future looks bright. The CSIR is ready to help, assist and guide our country into the future.”

Simultaneously, the complexity and lack of accessibility and usability of many ICT-based products and services presented a barrier for many people.

Intelligent environments for independent living: the ICT project

A three-year project titled *Intelligent environments for independent living (IE4IL)*, which Macagnano and Williams championed and coordinated, considered the different barriers to independent living, both in the virtual ‘on-line’ world and in the physical environment, faced by persons with physical disabilities, including blindness and deafness, and mental and intellectual disabilities, and the aged. Overcoming these barriers was deemed the key to independence and active participation in society and in the home, and for integrated care and rehabilitation.

With regards to the aged, people over the age of 65 are currently the fastest growing group worldwide; given the constantly shrinking younger, ‘tax-paying’ population, this is causing serious financial burdens on national budgets worldwide.

An effective extension of working life, increased mobility and better access to information through innovative ICT, would alleviate such problems and reinstate human dignity and better reintegration in society among the disabled and the aged. The IE4IL project aimed to address such problems and recommended technology solutions which are now already available.

The IE4IL project used a multidisciplinary research approach to address disability and the needs of the aged in a holistic manner. Findings were also captured in a technology demonstrator, accompanied by an illustrative

video. This film illustrates clearly and poignantly the difficulties faced by a blind person, a paraplegic, a deaf person and an aged person in terms of communication, access to information, ease of movement (mobility) and access to services in an urban environment. The centre of Pretoria was used as a test-bed. New technological ICT solutions were illustrated and a not-too-distant ‘technologically convergent’ future was explored.

“Our research findings at the time highlighted the urgency and relevance of research into how people, future technologies and the urban environment ought to be integrated by means of a complex information and communications technology-interactive system,” says Macagnano.

“Current technological advances in ICT and related technologies such as augmented reality, portable and ubiquitous computing,

communications, GPS and 3D tracking and nanotechnology already offer effective solutions and open up opportunities for the 'emarginated' strata – the disabled and the aged – of our society."

Putting research findings into practice: the Meraka building upgrade

This study direction was taken one step further when the findings from the IE4IL project were translated into an actual and real 'proof-of-concept' in service of CSIR Meraka Institute's disabled staff members and visitors.

The upgrade of the building housing this unit on the CSIR's Pretoria campus provided an ideal opportunity to implement stylish, yet fully functional, practical and fully accessible interventions. These modifications, completed in 2010, reflect the commitment to provide a fresh, agile and effective environment for all staff members, clients and visitors, including persons with disabilities and the aged.

Macagnano, supported by a wider team, championed the overall design, technical systems, interiors, equipment and interiors to meet the needs of vulnerable members of society by bringing the accessibility of the building up to the latest international technical specifications.

These changes are immediately visible on arrival at the main entrance to the building. A ramp with a gradient of 1:20, intermediate landings and suitable hand-railings for wheelchair users, leads up from the accessible disabled parking bays, giving independent access to the building through 'hands-free' motion-activated glass sliding doors. This allows direct access to/from the reception area and the rest of the building, to disabled workers and visitors. The access via a second entrance was also upgraded and made accessible to include automatic glass doors, disabled parking and a ramp.

Another significant modification was the design and equipping of special toilets for use

by people in wheelchairs in direct proximity of an accessible auditorium, used for lectures and presentations. Meeting rooms and the new cafeteria on the top floor of the building are reachable via accessible lifts, soon to be assisted by Braille indicators and audio automatic floors announcements.

Throughout the building, all internal doors are double-panelled and wide enough to allow independent wheelchair access. As part of the main specialist features, adjustable 'transformer' tables and chairs are on wheels, artificial lighting levels can be adjusted, and a spotlight function and a platform for sign-language interpreters are available in the main auditorium. Grey-blue carpets throughout have a repeat rectangular pattern which changes to a square pattern to indicate a change in direction for partially sighted persons.

A truly intelligent environment – what does it take?

Macagnano summarises, "Through our understanding of technological discoveries and special devices, and by seizing technology advances and applications coming our way, we have the opportunity to fully use our urban 'intelligent' environments, to become fully integrated in a socio-economic context, and citizens of the world."

Research into intelligent cities has yielded new insights for the future. "Our changing world requires that the physical structure and infrastructure of buildings and cities become intelligent, interconnected and able to respond to ever-changing human psycho-physical and social needs. Finding ways to leverage existing and developing technologies to assist a variety of citizens in an urban environment is now our focus."

Macagnano is actively spearheading the new U-City (Ubiquitous City) project, in collaboration with local government departments and international partners. This project represents a natural practical and technological evolution of the research carried out so far on intel-

ligent environments. Recent international technological advances are making the U-City project possible and relevant for South Africa in particular in terms of service delivery.

Pivotal in much of the current technology regarding intelligent cities, is the cell phone, now a technologically fully convergent and very powerful device. "Through a cell phone, it is already possible to download applications that allow one to perceive, examine and question in real-time the physical environment which surrounds us and which we use in our daily activities, through augmented reality," Macagnano explains. It becomes an effective delivery mechanism of useful and up-to-date information for recreational, travel, work, education and socio-economic integration, to the benefit of all.

Applications relying on GPS information can now also be downloaded onto cell phones. Voice-assisted directions can, for example, allow users (even the blind) to navigate with ease in any unknown urban environment. Google Earth – the virtual globe, map and geographic information program – is another powerful resource that is freely available and can be adapted to specific needs in the intelligent city. 'Street-View' features, allowing 360 degrees interactive 'real-time' views, related to most South African cities, buildings, streets and cultural recreational areas, have now become available to South Africans (coinciding with the recent 2010 Soccer World Cup event). These are interactively related to a large variety of other services such as Wikipedia, YouTube and National Geographic applications.

"South Africa has embraced these new realities and the future looks bright. Intelligent cities, although in their infancy, are already here. The CSIR is ready to help, assist and guide our country into the future," Macagnano concludes. – Biffy van Rooyen

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TECHNOLOGIES TOWARDS A MORE COMPETITIVE CONSTRUCTION INDUSTRY

The South African construction industry faces significant challenges to enhance its role as a catalyst for growth. Among the main pressure areas it faces are depletion of resources, increased competition by international enterprises, and the growing demand for increased efficiency.

CSIR architect, Llewellyn van Wyk

“Globally, construction employs more people than any other industrial sector and 98% of construction enterprises are small, medium and micro enterprises (SMMEs), thus key to economic growth.”

"The challenges that construction faces are also its opportunities. To capitalise on these opportunities, one needs a critical analysis of the construction processes used from the perspectives of designers, contractors and users," explains Llewellyn van Wyk, an architect at the CSIR.

The CSIR has initiated a multiyear research programme to identify and solve the science-based issues that impede the uptake of new technologies in the construction sector. "Our long-term aim is to demonstrate the effectiveness of such technologies for enhanced construction performance."

Construction is one of the largest contributors to South Africa's economy, while its importance also lies in the provision of buildings and infrastructure used by all other industries and public groups. "Globally, construction employs more people than any other industrial sector and 98% of construction enterprises are small, medium and micro enterprises (SMMEs), thus key to economic growth," says Van Wyk.

"We must recognise, however, that the construction industry extracts more raw materials than any other sector. The creation and operation of the built environment – including directly-associated transport and processing materials – accounts for at least 50% of all energy consumption and almost 50% of global warming emissions," notes Van Wyk.

For the multiyear CSIR research programme – the advanced construction technology platform (ACTP) – researchers reviewed the global construction sector, and specifically the South African construction industry and its operating environment, including emerging trends. "We found that the real value added by the construction sector has more than dou-

bled compared to the previous expansion period of 1993-1996. The main contributor to the increased financial performance of this sector was the construction of buildings (33%), of which residential buildings formed the largest part," says Van Wyk.

ACTP construction technologies

In the context of this CSIR research, the construction industry is broadly divided into the construction material manufacturers and suppliers sub-sector; the built environment professions sub-sector; and the contractor sub-sector (including subcontractors and specialist contractors).

The ACTP will focus on five technology pillars for improving the construction industry's performance. "Our research will cover conventional, fringe, hybrid, bio and nano construction technologies. Specific areas include materials science with a focus on renewable materials; construction methods, especially regarding quality and speed; building performance analysis as well as evaluation and verification; and assisting with 'upskilling' people active in the construction industry," explains Van Wyk.

Improved technological capabilities are fundamental to increase the competitiveness of the construction sector. "Due to exceptionally low research and development (R&D) investment and a lack of R&D coordination in the construction industry, most enterprises adapt existing products and do not develop new products," says Van Wyk.

The SMME nature of the construction sector leads to a challenge in terms of the affordability of new technologies. Technologies are generally embedded in machinery and in the

CONSTRUCTION TECHNOLOGIES

Advanced construction technologies for new production methodologies will focus on:

- Innovative production, using product and process lifecycle approaches;
- New safe and sustainable design concepts, with high added-value products, buildings, infrastructure and services;
- Adaptive production that supports agility and anticipation for flexible, small-volume and high-value production;
- Resource-efficient, sustainable production;
- Networked production with dynamic, cooperative and value-added networks;
- Knowledge-based production using science-based engineering and organisational knowledge management; and
- Converging technologies such as next generation, high added-value products and businesses.

organisation of the production line. This requires financial investment in buying and upgrading capital equipment on an ongoing basis. "Over the past 20 years, we have seen low R&D investment rates in general, and low capital investment rates in particular, in the construction sector in South Africa. This results in more enterprises falling behind the pace of technological change. Very few local construction enterprises have acquired the latest technology to improve their production techniques and ultimately, improve productivity and efficiencies."

The ACTP will select projects where R&D will result in the development of new and advanced materials and production methods; the beneficiation of existing raw materials in South Africa; and a coordinated effort in construction R&D for fundamental or applied research in a laboratory, the field, or a research facility to create longer-term opportunities for the country.

A key objective of the CSIR's ACTP is to involve stakeholders in working towards a common vision and approach for the development of the technologies concerned. "Technology platforms can bring about effective public-private partnerships, involving public research organisations, industry, financial institutions, users, regulatory authorities and policy-makers," concludes Van Wyk.

– Hilda van Rooyen

CONSTRUCTION MATERIALS AND METHODS

The ACTP will focus on new and advanced technologies in construction materials and methods. In particular, advanced technologies supporting material development will be aimed at:

- Knowledge-based materials with tailored properties and enhanced processibility;
- Reliable design and simulation for material engineering;
- The process design and control of new nano, bio and hybrid materials;
- Product-led, not process-led, industry transformation;
- Generating new knowledge for new industrial products and processes development, using interdisciplinary materials research expertise;
- Interoperable products to create a comfortable living environment; and
- Products that serve customer needs while minimising environmental impact throughout the entire product lifecycle.

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The CSIR's Dr Rajesh Anandjiwala, under whose leadership the prototype natural fibre based insulated sandwiched panel has been developed

NATURAL FIBRE COMPOSITES FOR CONSTRUCTION APPLICATIONS

DR RAJESH ANANDJIWALA AND DR ANDREW DE VRIES

One of the projects that form part of the new strategic investment areas within the CSIR deals with the use of natural fibres in construction products. This initiative seeks to make a meaningful contribution to the concept of bio-based housing. As part of this project, a prototype natural fibre-based insulated sandwiched panel was recently developed at the CSIR under the leadership of Dr Rajesh Anandjiwala. The project has a strong focus on both materials and application-oriented product development.

The prototype product

The roof panel in question is nothing more than a sandwich-type of structure. The sandwich structure consists of an expanded polystyrene centre and outer layers consisting of a natural fibre polymer composite.

Polystyrene is well-known by both experts and consumers as an effective insulator. A polymer is commonly referred to as a plastic. A composite is the combination of at least two materials, natural fibre (flax) and polymer in this instance, which remain distinguishable after they have been combined. This is done to make stronger, better

materials that can be used in all kinds of applications.

Some benefits of the newly-developed roof panel include lower weight, lower cost and inherent insulation compared to traditional roofing products. It is also environmentally friendly due to use of naturally renewable flax fibres.

An environmentally-aware world

As the world becomes more environmentally aware, the drive towards eco-friendly materials and products has gained momentum.

We thus have to rethink the materials we use on a daily basis for packaging, building and manufacturing, so that when these materials reach the end of their life cycle, they would simply be absorbed back into the earth in a way that would not harm the environment.

In recent years, there has been a growing interest in the use of natural fibres in composite applications, especially in the aerospace and automotive industries. These types of composites present many advantages compared to synthetic fibre-reinforced plastics such as low tool wear, low density, low cost, availability and biodegradability. In addition, the construction sector is under considerable pressure from government and clients to improve the quality of its products, reduce its economical, social and environmental impacts, and increase the rate of delivery to meet the growing demand of its domestic markets, especially for affordable housing.

The development of construction products that utilise renewable resources in an environmentally-sustainable manner will therefore greatly assist the industry in meeting these emerging expectations. Furthermore, developing countries like South Africa suffer a serious backlog of low-income or affordable housing with the figure being put at up to three million for South Africa alone. Technologies that can offer a quick, low-cost delivery of such houses would be most welcome for the middle and low-income sectors of the community.

The current project is well-suited to address, along with other initiatives within the CSIR and nationally, the abovementioned needs.

The challenge: finding a biodegradable polymer composite

Unfortunately, most polymer composites are not biodegradable and therefore environmentally unfriendly. This is especially the case with glass fibre composites, one of the strongest composite materials around.

In our case, the natural fibre polymer composite can be considered as a semi-environmentally friendly composite. The polymer (resin) that is currently used for the composite part of the sandwich panel is not derived from renewable resources, but from petroleum products. Therefore, future research will focus on the development of fully bio-based composites.

A bio-based (natural and biodegradable) matrix reinforced by natural fibres also provides an important additional advantage, as renewable resources are used instead of petroleum-based materials. Already existing

WHO IS INVOLVED?

Dr Rajesh Anandjiwala headed up the project. Other researchers involved include: Drs Babu Guduri, Rakesh Kumar, Maya John and Andrew de Vries.

The built environment expertise and guidance of Llewellyn van Wyk and Dr Joe Mapiravana are an essential part in the product development and design aspects of the project.

International involvement by Professor Richard Wool from the University of Delaware (USA) is of further value to the success of this project.

capabilities in the area of renewable matrices in the CSIR will see the advancement of fully bio-based composites.

Furthermore, the current polystyrene core used in the manufactured roof panel presents further environmental challenges. The challenges are three-fold: developing an alternative to polystyrene that is eco-friendly, low-cost, and with good insulation properties.

Ongoing research at the CSIR on bio-cores proposes to address these in a phased development.

Revolutionising the South African construction industry in the long run

The generation and exploitation of new knowledge, and thus innovation, is at the heart of the National System of Innovation and the Department of Science and Technology's Ten-year Innovation Plan. The transferring of technologies and skilled human resources is another major aim of these programmes.

CSIR researcher Dr Andrew de Vries



A sample of the natural fibre-based insulated sandwiched panel prototype

With this in mind, it is foreseen that this project will contribute to these aims. It is also optimistically predicted that projects of this nature will be a factor in revolutionising the South African construction industry in the long run. A major challenge in this regard is to locally produce the product and generating the uptake by the construction industry.

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NORTH WEST DEPARTMENT OF HUMAN SETTLEMENTS

SATELLITE TECHNOLOGIES
TO ASSIST IN DETERMINING
THE STATUS OF INFORMAL SETTLEMENTS

In a project to support the North West Department of Human Settlements to upgrade informal settlements in the province, the CSIR and urban planning consultancy, SATPLAN, joined forces to provide the first ever satellite-derived baseline information on informal settlements in the province of North West.

Working hand-in-hand with provincial housing sector specialist Kabelo Mpobole, the project forms part of an informal settlement upgrading programme planning initiative of the Department of Human Settlements. Initiated and funded by the department, the North West Informal Settlement Upgrading Programme (ISUP) is indicative of the proactive measures being taken by the province in addressing the housing needs of its informal settlements. "It is extremely difficult to address the housing pressures posed by informal settlements without a spatial information baseline. The dynamic nature of informal settlements requires yearly monitoring in an attempt to understand

the trends behind their growth," says Ilan Guest, urban planner, geographical information systems specialist and owner of Johannesburg-based SATPLAN.

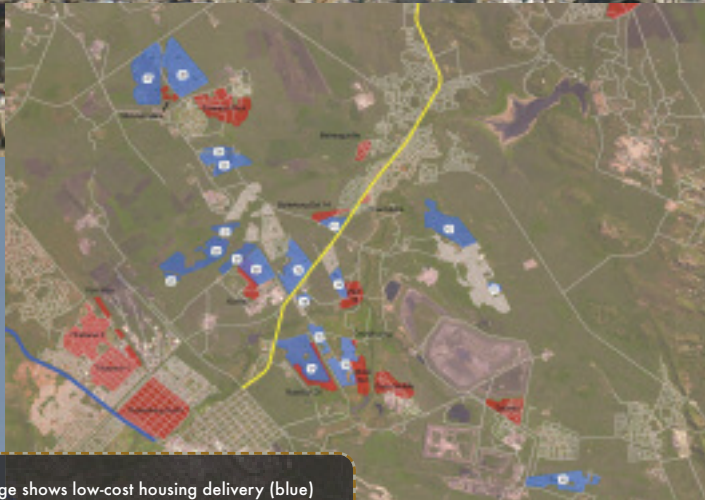
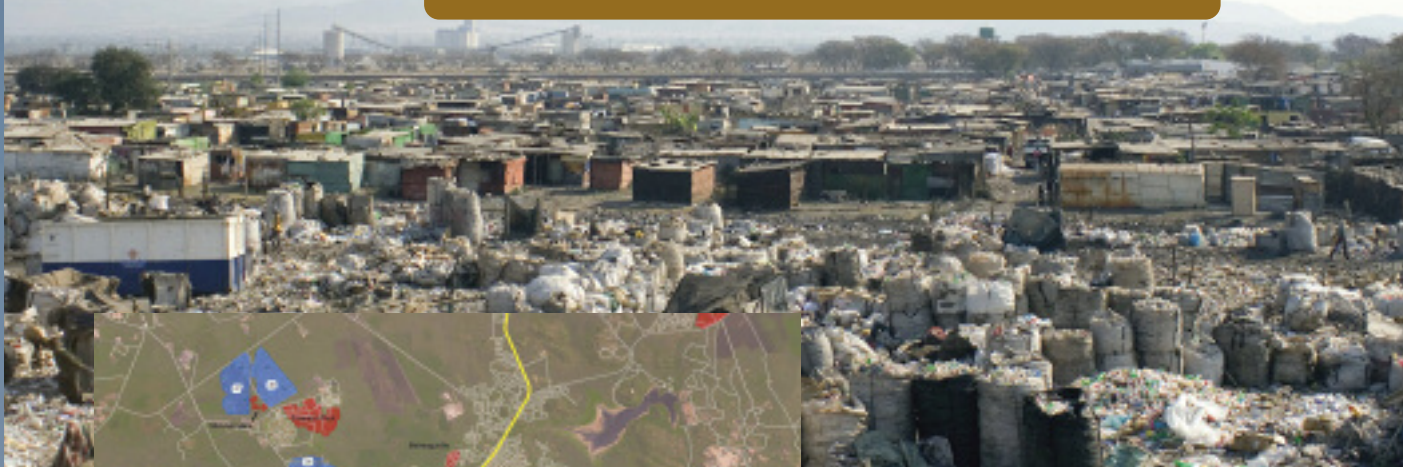
"We have created a multiyear database of informal settlement location and growth dating back to 1994 to compare year-on-year change trends." He says the baseline data created in this study provide uniformity and a common point of reference with regard to information used in the collaborative housing delivery process of the provincial and local government in North West.

The CSIR's Daniel Matsapola says the occurrence of informal settlements in North West exhibits contextual trends. Mining activities along the platinum mining belt stretching between Brits and Rustenburg, for example, correlate strongly with informal settlements in the region.

He adds, "Many informal settlements do not house only local people, but a significant migrant labour force that has come from outside the province to seek employment in the region's platinum mines. In many instances, miners receive a 'live-out allowance' from the mining houses as opposed to being accommodated in hostels, and many opt for the cheap rentals available in informal settlements in order to send as much money as possible back to their families.



Establishing the facts on informal settlements in North West province with the help of satellite data are, from left, Daniel Matsapola of the CSIR, Ilan Guest of SATPLAN and provincial housing sector specialist, Kabelo Mpobole.



This image shows low-cost housing delivery (blue) versus informal settlement location (red) within the city of Rustenburg, in the province of North West

THE CSIR AND EARTH OBSERVATION DATA

The CSIR acquires, archives, processes and distributes remotely-sensed data acquired from earth observation satellites. Satellite imagery used in the project stems from the SPOT satellites as well as some high-resolution commercial colour imagery from the Ikonos satellite.

This is but one factor influencing informal settlements in the province," he says.

The exercise is a five-year project that is currently in its fourth year. The team has captured the baseline data and packaged it into a series of district and local level reports which are shared with municipalities. "Each year a series of workshops was held to individually verify all informal settlements with local municipality housing officials to ensure the highest level of information accuracy possible. At the client's request, we have also extended our analysis to include low-cost housing across the province to understand the relationship between housing delivery and informal settlement growth. In doing so, we are able to compare housing delivery rates against informal settlement growth rates as a means of identifying the delivery gap," says Guest.

The project itself is multi-faceted and provides analytical insight into the nature of informal settlements in the province. "Apart from considering where informal settlements are located and how these have been growing since 1994, we are also concerned with the relationships between informal settlements and factors such as industrial growth and location, proximity to town centres and major infrastructure. We have also sought to count dwellings and estimate population numbers through a high-resolution dwelling inventory," explains Guest.

At the request of the department, SATPLAN also designed and implemented a 'backyard shack' survey in Rustenburg as an enhancement to the project to better understand the phenomenon and guide local policy interventions. Guest explains, "Closer inspection of certain informal settlements in Rustenburg made it clear that there is a high incidence of a particular type of informal settlement within already proclaimed areas of the city. These are referred to as 'backyard shacks'."

A survey questionnaire was designed and implemented with the assistance of the Rustenburg Community Development Workers, whereby backyard shack residents were engaged door-to-door in an attempt to derive a variety of socio-economic and demographic information relating to such residents.

Guest adds, "The post-apartheid settlement landscape in South Africa still shows the impact of apartheid spatial legislation. These spatial legacies were identified and visualised for major cities and towns in the province of North West to assist in the optimal placement of housing projects designed to address informal settlement upgrading. While upgrading informal settlements *in situ* is the preferred approach from a policy point of view – and because it creates less disruption for the communities – it often comes at the expense of proper integrated settlement planning. All of these factors need to be taken into account for informal settlement upgrading."

The project team is committed to ensuring that the output is taken up, with a year of training in the use of the information set aside as part of the project. Guest says the close working relationship between the client – the North West Department of Human Settlements – local municipalities and the project partners is resulting in a beneficial interplay between local, on-the-ground information and the wide-view perspective afforded through satellite imagery. The combination of knowledge ultimately provides a solid understanding that will aid in optimising and stream-lining housing delivery in the province.

Guest explains that the study was undertaken in parallel with the North West informal settlement upgrading strategy. The data derived by the CSIR and SATPLAN formed the primary input data in the strategy development whereby each individual informal settlement was considered in terms of its opportunities and constraints for upgrading. The project itself is a provincial contribution to the ISUP, which forms part of government's sustainable human settlements and improved quality of life strategy. – Alida Britz

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A NATIONAL INVENTORY USING EARTH OBSERVATION AND GIS

BY ANDRÉ BREYTENBACH

Eskom's Spot Building Count (SBC), a geo-referenced dwelling or building frame developed by the CSIR using Spot 5 satellite imagery, has potential benefits not only for stakeholders such as Eskom, but also for other organs of state to assist in the improvement of service delivery strategies and decision-making at district or local municipal level.



André Breytenbach, who works on a geo-referenced project frame that incorporates all classifiable building structures or housing arrangements within the borders of South Africa



**SBC 2008 Evaluation
Sample Site G861
(proclaimed property)**

This figure shows the spatial analysis results of a typical evaluation site located in Gauteng, where all features that either intersected (black dots) officially surveyed land or not (red dots) could be visually inspected and verified

The project

All classifiable building structures or housing arrangements within the borders of South Africa as well as other existing dwelling point layers (where possible) were incorporated into this inventory. The principal data source, from which the SBC layers were derived, was commercial satellite colour imagery.

To arrive at each annual dwelling inventory, the task of capturing and editing the relevant subsets was entrusted to black economic empowerment-accredited sub-contractors. Organising and analysing the data spatially were subject to additional data layers, mainly those obtained from the Chief Directorate: National Geospatial Information, and Eskom. The SBC data were then spatially analysed to extract meaningful information about each feature's relationship to relevant official demarcations and land proclamation patterns, as well as electricity transmission and distribution.

Outcome and results

The total number of dwelling units or buildings at project completion was represented by 11 310 724 point features and 1 016 density polygon features (together 83.9 km²). Results from spatial analysis performed on the SBC layers relate fundamentally to three key geographical information system (GIS) procedures. The first essentially indicated the proportion of electrifiable and non-electrifiable areas. The second routine yielded sufficient insight into the power supply and backlog situation countrywide. The third procedure used a building density and change analysis to highlight certain detectable changes or trends in the data.

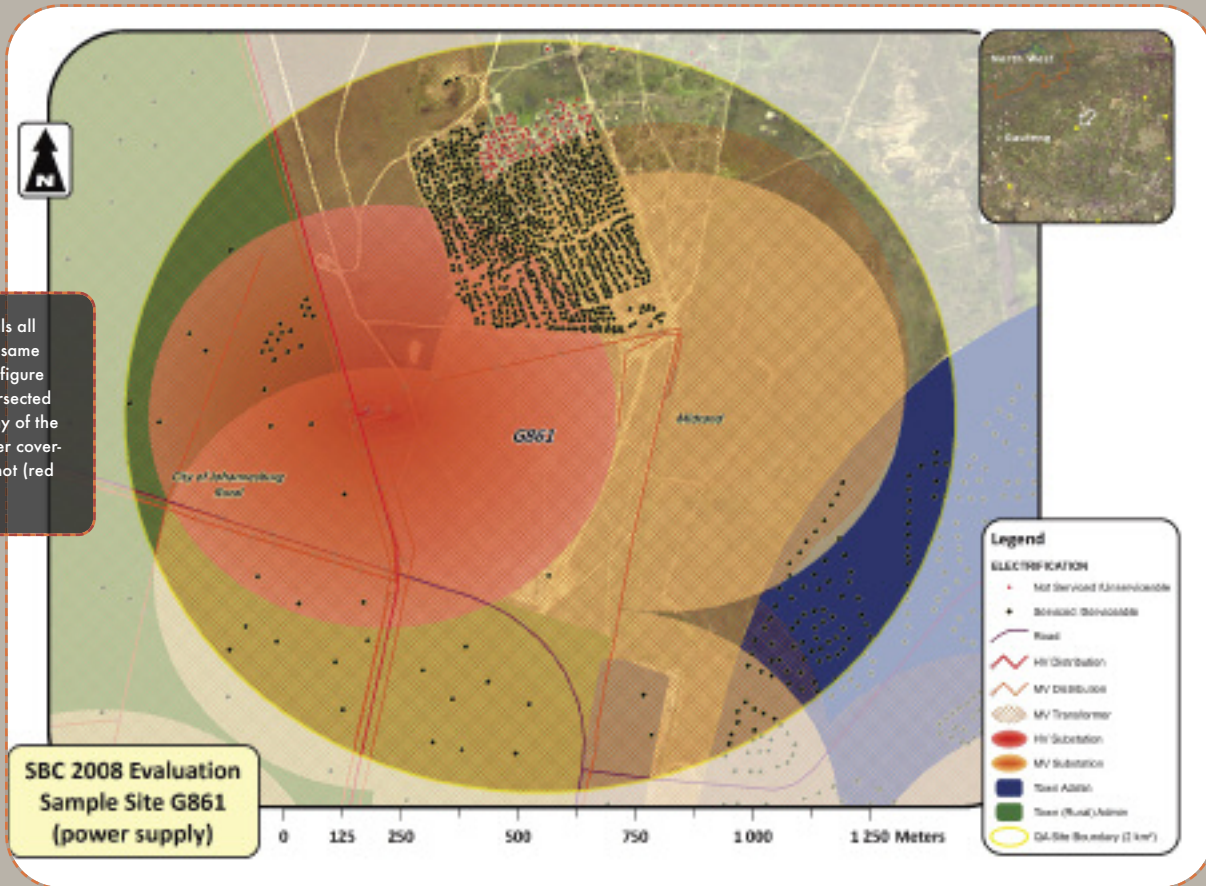
Quality assurance a must

Positional accuracy and data quality as related to the dwelling inventory product were well documented and provided the requisite

evidence to establish confidence among all users. Ultimately, 1 063 sites (12211.2 km²) were sampled and at the completion of this evaluation procedure, around 2% of all captured point features were visited in total. With guidance from the feature status entries made by other operators during updates and edits, CSIR technologists verified and scored all feature types located within each site's perimeter during evaluation. Efforts were also made to record classification inaccuracies and flag duplicate features as far as possible.

The way forward

The automated extraction of buildings from remotely-sensed imagery – by means of accurate stereo-pair autocorrelation and 3D digital surface models, for example – is at an advanced stage. It could largely replace the conventional data accumulation method used here and in doing so comfortably lessen the time between SBC data updates.



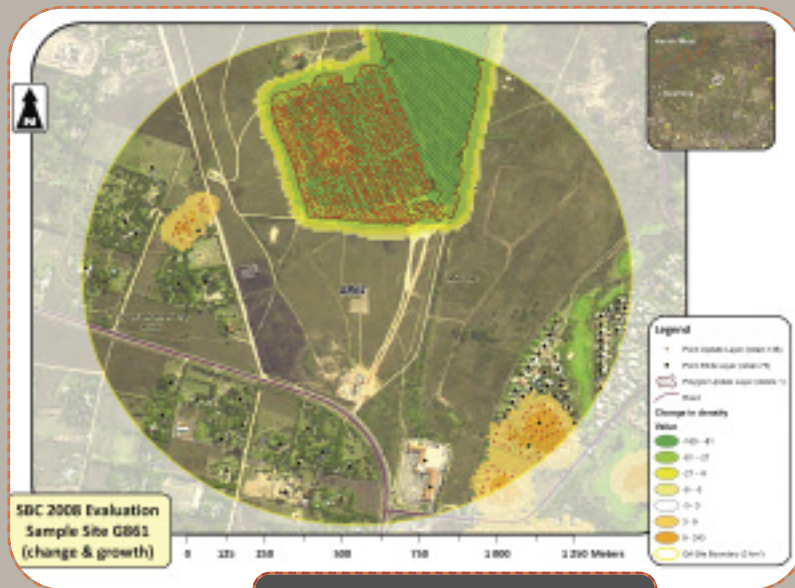
This map reveals all features at the same site as the first figure that either intersected (black dots) any of the prepared power coverage layers or not (red dots)

Data management will also be improved drastically if the vector layers are converted into a geo-database. This is to take full advantage of the available technology for accessing, managing and controlling geospatial data within relational databases.

Many benefits

One could then even link population/census figures to the feature types within their relevant classes by using the features themselves or the density measure. In fact, the uses for this building inventory are numerous, and could include providing addresses for postal delivery by the South African Post Office; developing an authoritative address register for use by departments such as Home Affairs; or supplementing a national crime database or census demarcation work. A long-term funding model will extend and improve the SBC where it is offered at its current level of accuracy and data quality.

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The figure demonstrates the benefit of having another measure, namely buildings/points per hectare, to indicate growth and any changes (or corrections) in the building inventory. The more orange sections indicate the actual positive growth as per the 2008 updated layers, while the corrections (polygon removal and point updates) were demarcated by the greener portions

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