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South African infrastructure condition – an opinion survey for the SAICE Infrastructure Report Card

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The South African Institution of Civil Engineering (SAICE) Infrastructure Report Cards of 2006, 2011 and 2017 reported that much of the South African infrastructure is in a poor condition. To augment the recent 2017 Report Card, a survey was, for the first time, conducted amongst SAICE members to obtain their opinion on the condition of infrastructure (in terms of a grading), the trend of the condition over time, as well as the reasons for the individual's grading. The 669 respondents indicated that, apart from a few exceptions such as national airports and the Gautrain, much of the infrastructure is in a poor state, which is very similar to the results obtained from the SAICE Report Card process. The results were also analysed per province and indicated that, in the opinion of respondents, specific provinces in particular are struggling with poor infrastructure. The main reasons given for the poor infrastructure were a lack of maintenance, lack of institutional capability, lack of sufficient funding and over-loading of infrastructure.

INTRODUCTION

Well-functioning infrastructure and an efficient built environment are essential to socio-economic development and poverty alleviation (Perkins 2011). This is emphasised in a number of official government documents, including the Medium Term Expenditure Framework (SA Treasury 2017), the Diagnostic Report (National Planning Commission 2011), the National Development Plan (NDP) (National Planning Commission 2012), and the National Infrastructure Plan (Presidential Infrastructure Coordinating Commission 2012) from which flows the Strategic Infrastructure Projects (SIPs) coordinated by the Presidential Infrastructure Coordinating Committee (PICC). Over the next three-year period more than R900 billion in public funding alone has been budgeted for infrastructure such as roads, energy generation plants, water infrastructure and public buildings.

However, the NDP and the Diagnostic Report, as well as the South African Institution of Civil Engineering (SAICE) Infrastructure Report Cards completed in 2006, 2011 and 2017 (SAICE 2006; 2011; 2017) have all reported that much of the South African infrastructure is in a poor condition, particularly in the areas of health, water, sanitation, and secondary and tertiary roads. These problems are due to a number of factors, including insufficient funding to manage, plan and maintain the infrastructure assets; a shortage of skilled resources leading to problems with institutional capacity; and a lack of appropriate technological solutions for the problems experienced with infrastructure planning, materials, design, construction, maintenance and operation.

In addition to the above, the Fourth Industrial Revolution (Schwab 2017) is currently changing the nature of many industries through the advent of new technologies. This phenomenon is driven by technologies such as autonomous vehicles, 3D printing (additive manufacturing), advanced robotics, new materials, the Internet of Things, sensor technology, etc. All of these drivers will also influence the infrastructure provision and operations spheres. Much infrastructure is designed to last for long periods (20 to 50 years and more), and therefore planners and designers need to take these trends into consideration both in the intrinsic nature of infrastructure (e.g. smart materials and embedded sensors), as well as in providing a conduit for other technologies (e.g. housing fibre-optic cable and sensors). So, in addition to improving the quality of current infrastructure, South Africa will also need to position infrastructure for the challenges of the future.

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This paper describes the survey which was undertaken in parallel to the largely desktop preparation of the SAICE Infrastructure Report Card (IRC) of 2017 (SAICE 2017). This survey was conducted amongst SAICE members to gather their professional view of the condition of infrastructure in a number of sectors. The paper focuses particularly on the results of the survey, and also discusses some of the reasons given for respondents' gradings.

LITERATURE

Management and planning of infrastructure often depend on multiple criteria decision support systems that allow for prioritisation of maintenance and rehabilitation (Scholz *et al* 2015; Šelih *et al* 2008; Woodward *et al* 2019). This requires the measurement of the performance of and the assessment of the condition of the infrastructure (Ahluwalia 2008). These assessments can be categorised as follows:

- Visual inspections
- Non-destructive testing
- Photographic and optical evaluation
- Data recorded from sensors and smart sensors.

Nagarajaiah and Erazo (2016) stated that the majority of civil infrastructure is evaluated through visual assessment using non-destructive methods. However, these traditional approaches are time-consuming and may result in hidden damage not being detected (Ellingwood 2005; Frangopol & Liu 2007). Ahluwalia (2008) found that visual inspections are preferable for the assessment of buildings. Building assets have multiple components with a variety of requirements, and therefore other methods are less effective. Lenett *et al* (1999) evaluated the use of "rapid" multi-reference impact testing for condition assessment of a commissioned steel-string bridge. They concluded that this method is useful to detect existing damage or change in the condition of the bridge, but that visual inspection was still required to determine the nature of the change and which component was affected. In spite of their time-consuming nature and cost, visual inspections remain an integral part of condition assessment of infrastructure.

Non-destructive evaluations include, *inter alia*, ultrasonic and acoustic emissions, eddy currents and X-rays (Nagarajaiah & Erazo 2016) while ground-penetrating radar is used to assess the condition of roads, bridge decks and piers (Maser 1996; Maierhofer 2003). However, non-destructive testing is mainly suitable for identifying faults in the infrastructure such as voids, or to determine pavement thickness for example, rather than for the assessment of the general condition of infrastructure. Several research efforts are focusing on the use of non-traditional methods for condition assessment of infrastructure. These include smart sensors, intelligent infrastructure, machine learning and algorithms. One such example is the use of analytical models that have been calibrated by many assessments to determine the condition of bridges (Aktan *et al* 1996). Marcelino *et al* (2018), however, stressed the cost of data collection and proposed the development of a condition indicator that would use a machine-learning algorithm to predict pavement conditions using less data. The use of algorithms analysing images of corrosion taken by a robotic system was discussed by Jahanshani and Masri (2013). The approach improves reliability of corrosion detection. The surface condition and defects of structures can be assessed by using fuzzy-logic algorithms to analyse images (Pragalath *et al* 2018).

In new infrastructure, the latest technologies in sensors and the Internet of Things (IoT) can be used to ensure rich data collection that can assist in the design and operation of infrastructure, infrastructure condition assessment and the planning of maintenance (Soga 2016; Aktan *et al* 1998; Nagarajaiah & Erazo 2016). A number of cities around the world, for example, use Intelligent Transport Systems (ITS) that has led to cost savings in the management of the road vehicle fleet and the maintenance of road infrastructure. This is done through databases and interactive maps of the road infrastructure condition depicting the type and severity of defects (Staniek *et al* 2017).

Photographic and optical evaluation has been used successfully, and improvements in camera technology and the use of Unmanned Aerial Vehicles (UAVs) such as drones have increased the popularity of this technology. UAVs and drones are increasingly being used to assess the condition of infrastructure, especially in places that are hard to reach (Ham *et al* 2016). UAVs carrying cameras and thermography cameras combined with deep-learning technologies and neural network analysis can be used to determine cracks in concrete and in asphalt (Wu *et al* 2018). Uddin (2011) reviewed the use of remote sensing satellite imagery and Light Detection and Ranging (LIDAR) technologies combined with Geographical Information Systems (GIS) to enhance practices of infrastructure inventory, condition assessment and environmental applications. The study found that accurate assessment of pavement surface distresses, condition and maintenance quantities can be enabled through the use of an airport GIS map and geospatial analysis of LIDAR dense point cloud data and intensity images.

Sewer system inspection is conducted with Closed Circuit Television technology which consists of a camera generally mounted on a crawler or tractor. The inspection is conducted from manhole to manhole, and the analysis of the images provides details of the type and location of defects. These include pipe cracks, joint offsets, leaks, debris, sediment and root intrusions. Caradot *et al* (2018) found that the general condition of the sewer network can be assessed with excellent accuracy with the use of sewer condition evaluations.

The above literature review indicates that infrastructure condition is often assessed at the project (building, road) level. Whilst modern technologies are very useful in collecting infrastructure performance and condition data at this level, there is a need to analyse the condition of the whole portfolio of infrastructure in a cost-effective way to provide input into general policy development and high-level budgeting. In contrast to the use of electronic equipment at a project level, which will be very expensive at a network or portfolio level, this paper describes the use of expert opinion to assess the condition of the portfolio of infrastructure in South Africa. This was achieved through the Infrastructure Report Cards and the opinion survey as discussed below.

SAICE INFRASTRUCTURE REPORT CARD SERIES

The grading of the condition of infrastructure and its presentation in a "report card" is practised in a few countries, including in the United States of America by the American Society of Civil Engineers (ASCE 2017), Canada (Canadian Infrastructure Report Card (CIRC 2016)), Australia (Kaspura 2017) and the United Kingdom (Living with Environmental Change initiative (LWEC 2015)) and the Institution of Civil Engineers (ICE 2017).

To date, SAICE has published three Infrastructure Report Cards (IRCs) – in

2006, 2011 and 2017. The research work for these was primarily conducted by the South African Council for Scientific and Industrial Research (CSIR), with the gradings determined by the SAICE technical panels. The purpose of the IRC series has been to point out to government, decision-makers and the public at large, the importance of maintenance of infrastructure and to factors underlying its condition. Since the first free elections in South Africa in 1994, significant progress has been made in correcting imbalances in infrastructure provision – with more focus on infrastructure for the poorest, disadvantaged communities. Particular focus has been placed on infrastructure for water reticulation and treatment, sanitation, education, energy, health services and roads. However, the combination of limited resources, public sector restructuring, inefficiency and shortages of key skills has led to extreme pressure on the condition of the public infrastructure asset base (Wall & Rust 2017).

The IRCs grade public sector infrastructure (water, sanitation, solid waste, roads, airports, ports, rail, electricity, and hospitals and clinics) on the following scale:

- A: World-class
- B: Fit for the future
- C: Satisfactory for now
- D: At risk of failure
- E: Unfit for purpose

In order to allow for a finer scale rating, the operators "+" and "–" were used for ratings in-between the main categories, i.e. an A– was one rating above a B+, etc.

The methodology to compile the SAICE Infrastructure Report Cards included:

- Compilation of basic research reports based on desktop work by the CSIR
- Arranging for the drafting of additional reports for selected sectors where the CSIR itself does not have sufficient expertise
- Moderation of the sector reports by SAICE experts with additional inputs where necessary and early results from the survey
- Determination of the final gradings by SAICE
- Writing and publication of the Report Card and its associated commentary by SAICE experts.

For all three Report Cards, the gradings were conducted for the following sectors and subsectors (with minor variations):

- Water (bulk water resources, supply in major urban areas, supply for all other areas)
- Sanitation (major urban areas, all other areas)
- Solid waste management (waste collection in major urban areas, all other areas)
- Roads (national, paved provincial, paved metropolitan, paved municipal, all gravel roads)
- Airports (facilities owned by Airports Company of South Africa only)
- Ports (commercial ports only)
- Rail (heavy-haul freight lines, general freight lines, branch lines, passenger lines, Gautrain)
- Electricity (Eskom generation, Eskom transmission, local distribution)

Table 1 Trend in gradings from 2006 to 2017

Sector	Subsector	2006	2011	2017	Trend
Water	Bulk water resources	D+	D–	D–	↓
	Supply in major urban areas	C+	C+	C+	→
	Supply all other areas	D–	D–	D–	→
Sanitation	Major urban areas	C–	C–	C–	→
	All other areas	E	E–	E	→
Solid waste	Collection major urban areas	C–	C	C	↑
	Collection other areas	D	D	D	→
	Disposal in metros	C	C+	C+	↑
	Disposal in other areas	D–	D	D–	→
Roads	National	C	B	B	↑
	Paved provincial	D–	D–	D	↑
	Paved metropolitan	D–	C–	C–	↑
	Other paved municipal	D–	D	D–	→
	Gravel		E	E	→
Airports	ACSA-owned facilities	B	B+	B+	↑
Ports	Commercial ports	C+	B–	B–	↑
	Fishing harbours		C		
Rail	Heavy-haul freight lines	B	B+	B+	↑
	General freight lines	C	C+	C	→
	Branch lines	E	D	D–	↑
	Passenger lines	D+	C–	D+	→
	Gautrain			A	
Electricity	Eskom generation	C+	C+	C+	→
	Eskom transmission	C+	B–	B–	↑
	Local distribution	C–	D	D	↓
Health care	Hospitals	C	D+	D+	↓
	Clinics	D+	D	D	↓
Education	Public ordinary schools		D+	D+	→
	Universities			C+	
	TVET colleges			D+	
Overall grade		D+	C–	D+	→
Legend:	Gradings: [poor] = poor; [neutral] = neutral; [above average] = above average				
	Trends: ↓ = down; → = neutral; ↑ = up				

- Health care (hospitals, clinics)
- Education (public ordinary schools, universities, TVET colleges (technical vocational education and training colleges).

The SAICE grading process was conducted by a number of peer-review groups, selected for their knowledge and expertise in each sector, to review the CSIR output and reach consensus on the grading of the condition of public sector infrastructure in each of the sectors mentioned above, and also to provide an overall grading for all public sector infrastructure in the country. The process was informed by a set of questions:

- What is the condition of key elements of South Africa's infrastructure in public (i.e. as opposed to private) ownership?
- How does this compare with the previous assessment(s)? What is the overall trend, and what are the trends by sectors?
- What contributes to the condition and its trends? What recommendations can be made? (Wall & Rust 2017)

The three SAICE IRC publications to date (SAICE 2006; 2011; 2017) provide a time series which permits assessment of the trend in infrastructure condition. The overall grading of infrastructure in 2006 was a D+ grade. This improved to a C+ in 2011, mainly due to significant investment by government in prior years in preparation for the Soccer World Cup in 2010. However, in 2017 the grade regressed to a D+ again. Table 1 (p 37) shows the sector-by-sector gradings on a year-by-year basis.

This analysis indicates that, apart from national transport infrastructure, the general condition of infrastructure remains stubbornly resistant to improvement despite significant funding over the past ten years. In particular, the infrastructure that provides for the basic needs of the majority of the people in South Africa, especially the poor, is still in a bad state and is evidently deteriorating. Sectors that are especially distressed include health, water, roads other than national roads, some railway lines, schools and colleges. This indicates a significant inefficiency in the broader infrastructure maintenance system. This is, of course, harmful to service delivery.

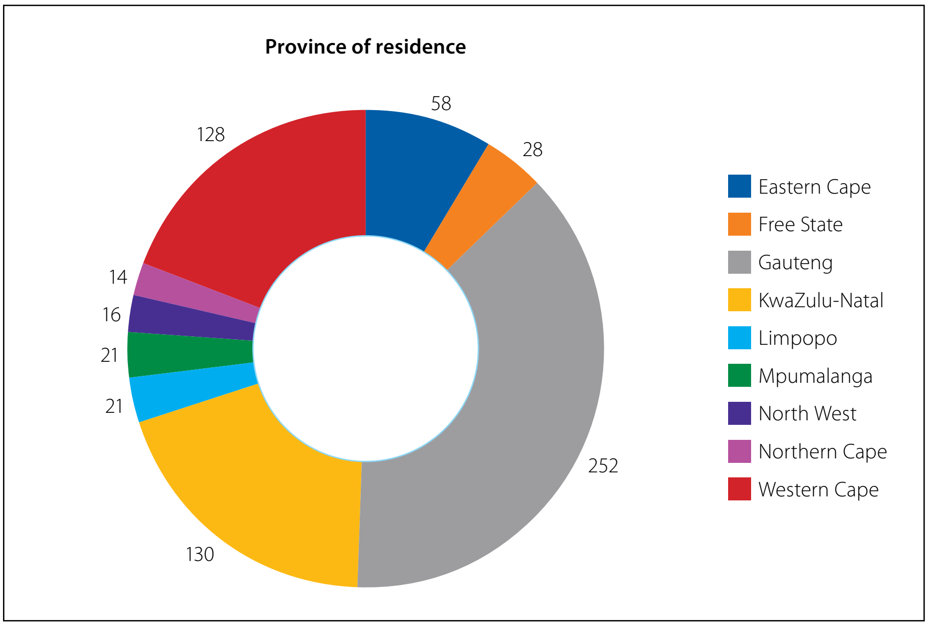

Figure 1 Respondents' demographics related to location

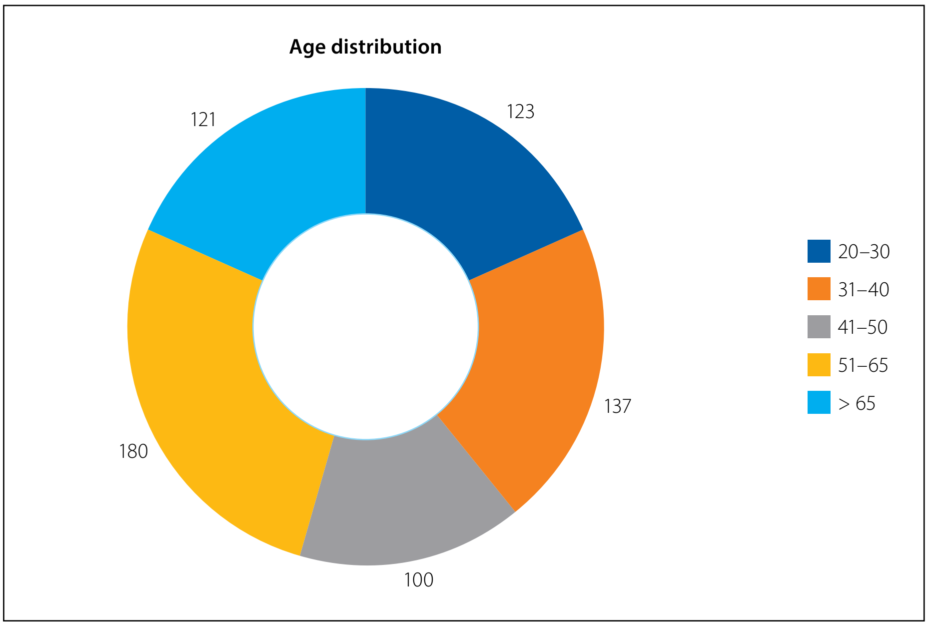

Figure 2 Respondents' demographics per age group

THE OPINION SURVEY

Purpose and methodology

The purpose of the survey was to obtain the opinion of the broader SAICE membership on the condition of infrastructure in the subsectors mentioned. The trend of the condition (becoming better, unchanged or worse), as well as the reasons for the individual grading, was also explored.

The survey was undertaken in the second half of 2017 – that is after the CSIR sector reports had been completed, and in parallel with, but independent of, the SAICE process of review and final grading in preparation for the 2017 Report Card launch at the end of September 2017.

The questionnaire firstly recorded general information of the respondent pertaining to location (province), age group, gender, race, SAICE membership category, category of employer, and areas of expertise. For each of the subsectors and on a provincial basis, the questionnaire then posed the following questions:

- What is your grade for the current infrastructure condition?
- In your opinion, over the past five years, is that condition better, unchanged or worse?
- What are the factors most influential in your assessment?

The respondents scored in the same grade categories as that used for the Score Card process, but these were converted to a five-point Lickert scale for statistical analysis:

- A: World-class (on the Lickert scale = 5)
- B: Fit for the future (= 4)
- C: Satisfactory for now (= 3)
- D: At risk of failure (= 2)
- E: Unfit for purpose (= 1).

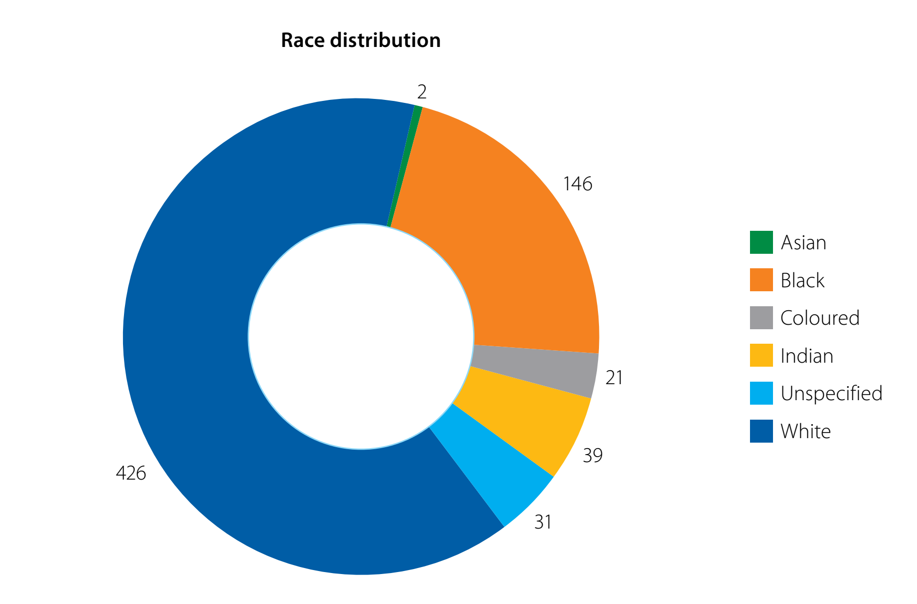

Figure 3 Respondents' demographics per race group

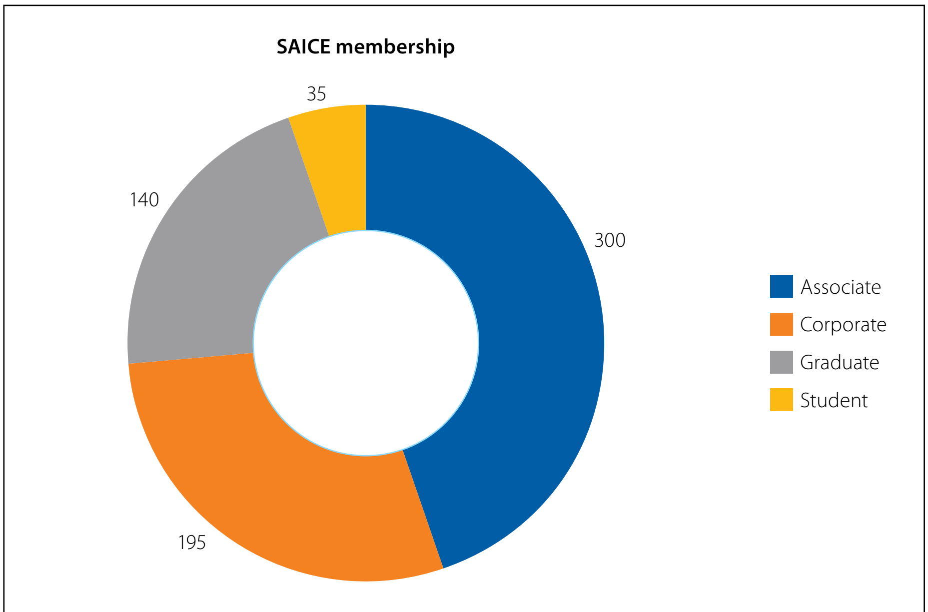

Figure 4 Respondents' demographics per SAICE membership category

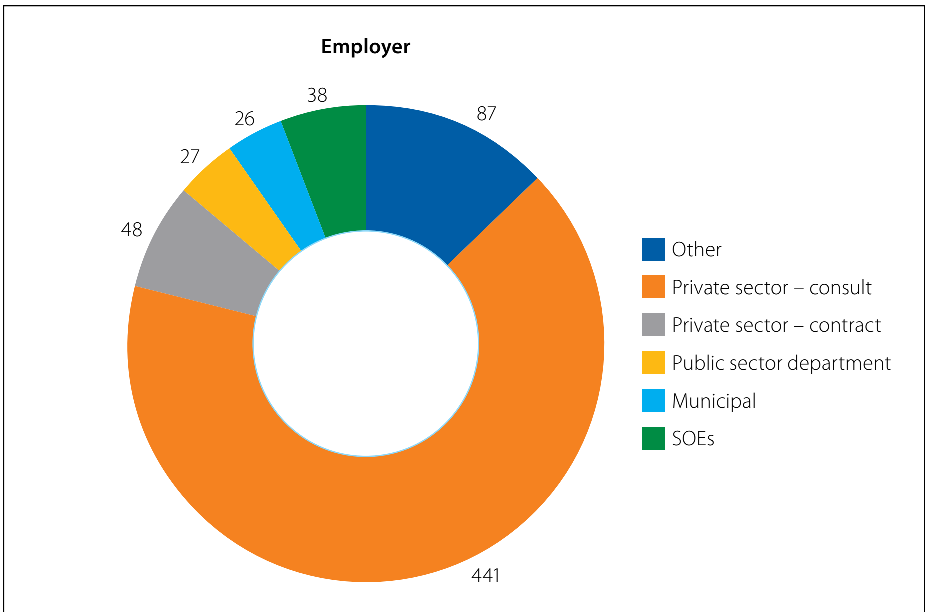

Figure 5 Respondents' demographics per employment category

Respondents were invited to suggest reasons for the infrastructure condition. A drop-down menu with the following options was offered:

- Funding
- Institutional capability
- Industry capability
- Maintenance
- Technical design
- Technology
- Climate change
- Pressure of use / loading
- No comment

Respondents were allowed to select more than one reason per question. The data was then analysed statistically to determine average gradings per province and overall, as well as to determine the paramount reasons for infrastructure condition. The results are discussed below.

Response

669 responses were received from SAICE members across all nine provinces. The response profile in terms of province of residence, age distribution, race distribution, membership type and current employer type is shown in Figures 1 to 5. As expected, the largest number of respondents came from Gauteng, the Western Cape and KwaZulu-Natal. The age and memberships profiles were evenly distributed. Two thirds of the respondents were private sector consultants.

The respondents were asked to rate the condition of infrastructure in each of the sectors and subsectors in which they have expertise on a provincial level. Thus, the results are available per province, as well as for the country.

Survey results at national level

Appendix A (see page 46) gives the results at the national level. Respondents considered that sectors where there are significant challenges with infrastructure include water and sanitation, some areas of waste collection, district and municipal roads, gravel roads, branch and passenger railway lines, health facilities and schools. In these categories the average score was in general lower than 2.5. Infrastructure in the best condition includes the Gautrain, national airports, national roads and commercial ports. In these categories of transport infrastructure, the average score was higher than 3.3, with national airports grading at 4.27 and Gautrain at 4.23. This is in line with the findings from the desktop research and the SAICE panel gradings given in Table 1. This data is represented graphically in Figure 6.

Survey results at provincial level

For the first time, the SAICE Infrastructure Score Card process now included information at provincial level through the survey. Figure 7 shows the overall (i.e. average for all infrastructure sectors) score of infrastructure condition per province.

The condition of infrastructure in the Western Province, KwaZulu-Natal and Gauteng is better than in the other provinces. North West scored particularly low.

The average score per province of each of the main categories of infrastructure is shown in Figures 8 and 9.

At subsector level the data also indicates that infrastructure in the Western Province, Gauteng and KwaZulu-Natal is generally in a better condition than that in other provinces. It can be seen that there are a number of scores lower than 2 which indicate that this infrastructure is seen as at risk of failure or no longer fit for purpose.

Reasons given for gradings

The reasons that respondents provided for their answers are shown in Figure 10. From the graphs the following can be noted:

- For almost all infrastructure sectors, the biggest challenge to infrastructure condition is lack of maintenance, followed by institutional capacity and funding. To some degree these three aspects are interdependent.
- Infrastructure loading (overloading) was also recognised as a significant challenge.
- Design and technology had some influence, especially in the transport and health sectors.

Figure 11 shows the infrastructure condition gradings by class and province. The same pattern as in Figure 10 emerges, with maintenance, institutional capacity, funding and loading being the main reasons for infrastructure condition. The lack of maintenance could of course be caused by a lack of institutional capacity and/or funding. This pattern is consistent over all the provinces, with a few exceptions. There are a few anomalies and outliers in airports, ports and rail due to a low number of respondents in some of the provinces. In rail infrastructure, health infrastructure and education infrastructure the data indicates that a lack of funding and institutional capacity is more significant than the lack of maintenance. The relative importance to infrastructure condition of design and technology is also evident in infrastructure classes that have been recently built or upgraded, such as airports and ports.

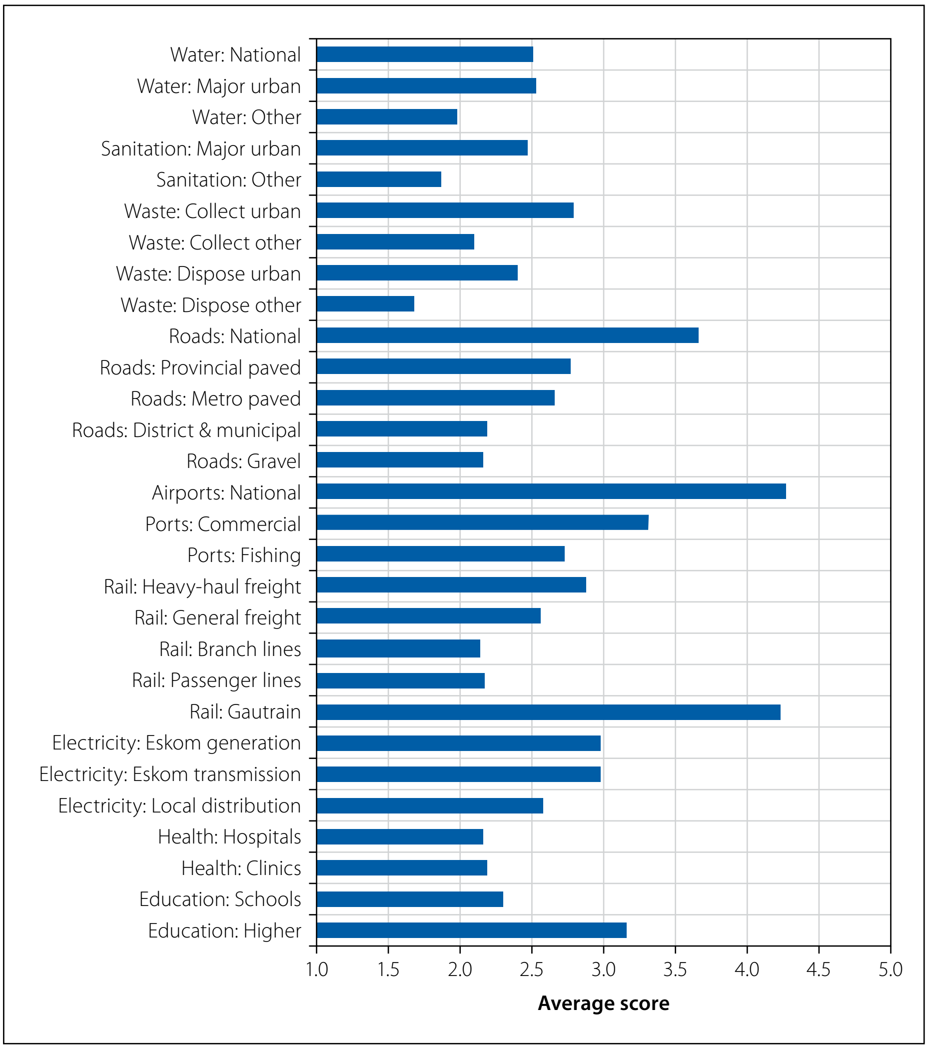

Figure 6 Summary of country level scores per infrastructure class

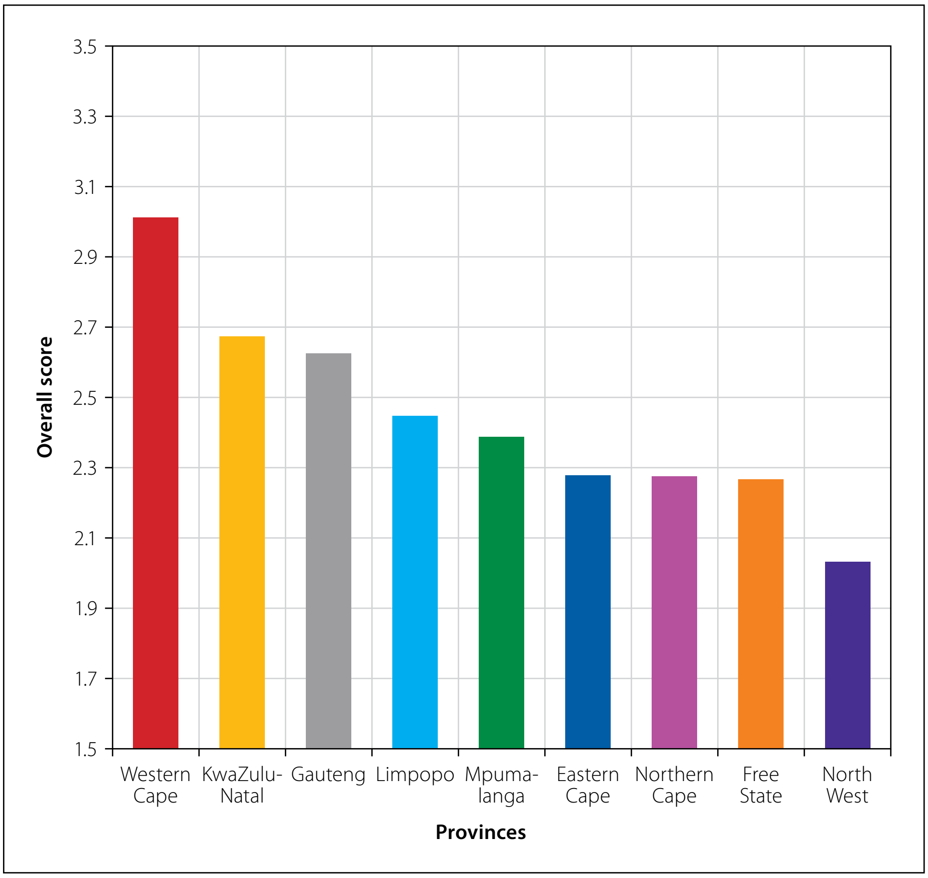

Figure 7 Overall score for the condition of infrastructure per province

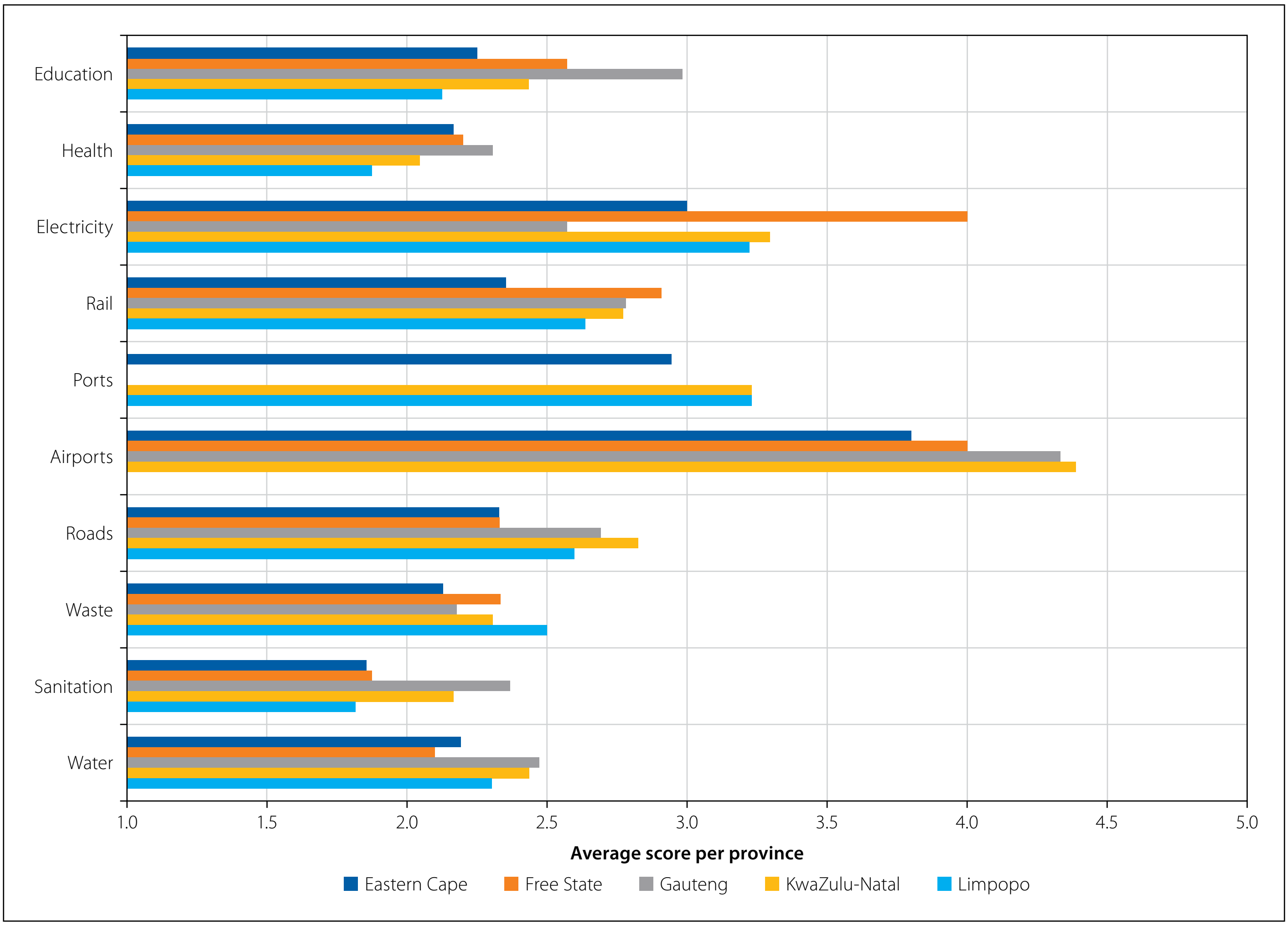

Figure 8 Infrastructure condition score for Eastern Cape, Free State, KwaZulu-Natal and Limpopo

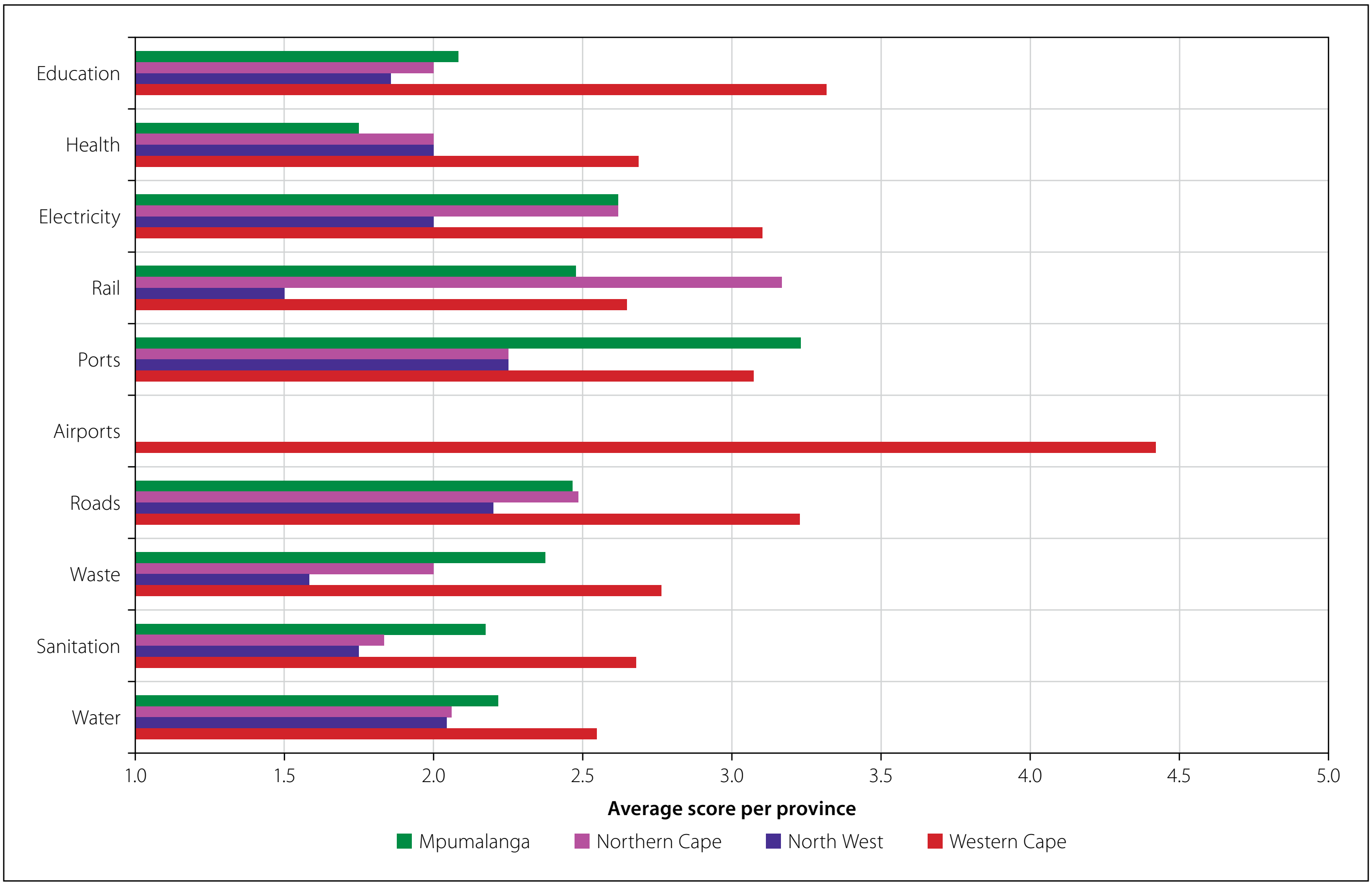

Figure 9 Infrastructure condition score for Mpumalanga, Northern Cape, North West and Western Cape

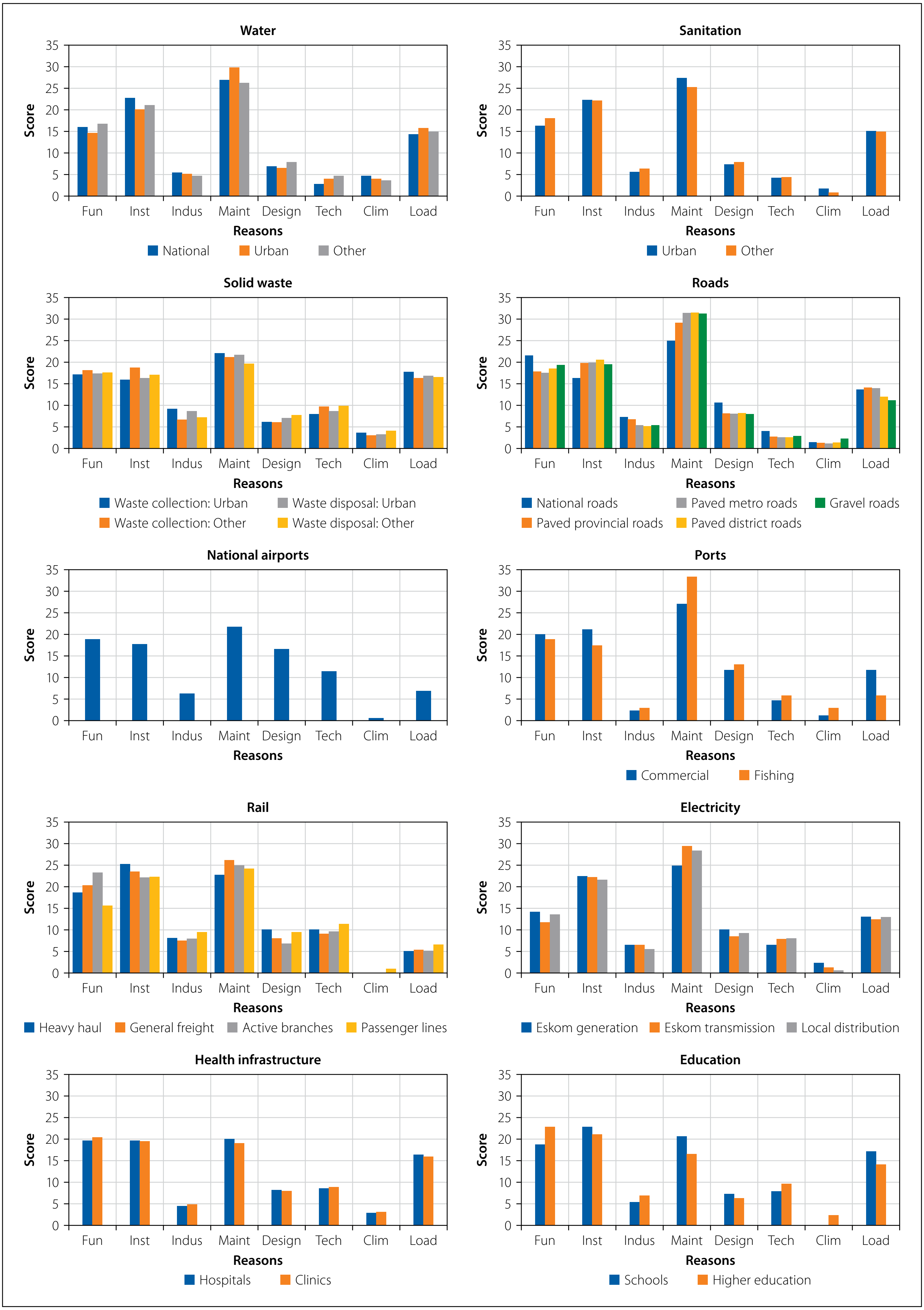

Figure 10 Reasons for infrastructure gradings by class

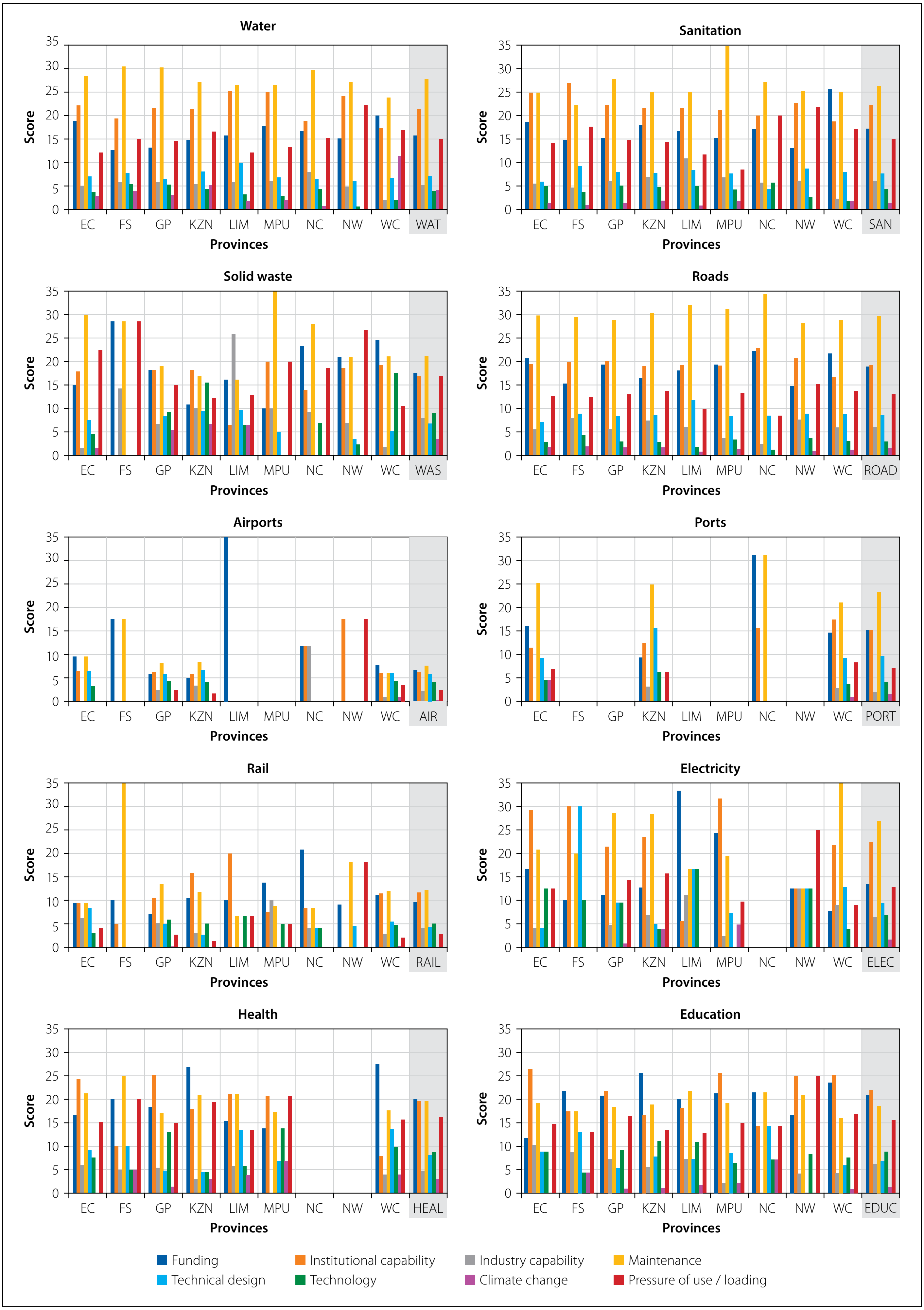

Figure 11 Reasons for infrastructure scores by class and province

For water and sanitation infrastructure across all the provinces, maintenance, institutional capacity and loading are the most significant factors. This, combined with the generally low scores of below two or just over two for these infrastructure subsectors and in view of the current water scarcity issues, is a significant challenge. For solid waste, loading or overloading seems to play a significant role, which could be indicative of the space problem associated with solid waste management. The data also indicates that the relative importance of timely maintenance in roads is much more important than in the other subsectors. This could be due to the sensitivity of roads to water ingress. In the case of electricity infrastructure there is a variety of reasons for the condition of the infrastructure. In health infrastructure, apart from funding and institutional capacity, loading seems to be more important than for the other subsectors.

Apart from a few outliers, industry capability does not seem to be a challenge. The data also indicates that climate change has not yet impacted significantly on the condition of infrastructure.

The comparison in Table 2 indicates that the IRC gradings agreed reasonably well with the survey results and were generally within one grade of each other.

Table 2 Comparison between expert reviews for the Report Card and the survey

Sector	Subsector	IRC	Survey
Water	Bulk water resources	D–	D+
	Supply in major urban areas	C+	D+
	Supply all other areas	D–	D
Sanitation	Major urban areas	C–	D+
	All other areas	E	D–
Solid waste	Collection major urban areas	C	C–
	Collection other areas	D	D
	Disposal in metros	C+	D+
	Disposal in other areas	D–	D–
Roads	National	B	B–
	Paved provincial	D	C–
	Paved metropolitan	C–	C–
	Other paved municipal	D–	D
	Gravel	E	D
Airports	ACSA-owned facilities	B+	B+
Ports	Commercial ports	B–	C+
	Fishing harbours		
Rail	Heavy-haul freight lines	B+	C
	General freight lines	C	C–
	Branch lines	D–	D
	Passenger lines	D+	D+
	Gautrain	A	A–
Electricity	Eskom generation	C+	C
	Eskom transmission	B–	C
	Local distribution	D	D+
Health care	Hospitals	D+	D
	Clinics	D	D
Education	Public ordinary schools	D+	D+
	Universities	C+	C+
	TVET colleges	D+	

CONCLUDING REMARKS AND THE WAY FORWARD

Both the SAICE Infrastructure Report Card and this survey indicated that South African infrastructure is below par and deteriorating further. Several factors have been identified as the main reasons for this situation. However, government will need to act fast to intervene and protect the infrastructure assets worth trillions of Rand. According to the South African National Roads Agency (SANRAL) the replacement value of the road infrastructure in South Africa alone is more than R2.1 trillion (COTO 2014).

South Africa is not alone in this predicament. The American Society of Civil Engineers (ASCE 2017) proposes a number of solutions for improving the condition of the US infrastructure. These include:

- Closing the investment gap by increasing infrastructure investment from 2.5% to 3.5% of Gross Domestic Product
- Increasing user-generated fees and ensuring that such funds are not used to off-set costs of other budget items
- New long-term funding programmes with which to improve specific categories of deficient infrastructure
- Improved leadership and planning to ensure an overall vision for infrastructure, including full life cycle costing and improved management tools
- Incentives for maintenance
- Identification of a pipeline of projects attractive to private sector investment
- Preparing for the future by utilising new methods, materials and technologies to ensure more resilient and sustainable infrastructure
- Considering emerging technologies for infrastructure improvement and when designing new infrastructure
- Funding for research and development into innovative new materials, technologies and processes to modernise and extend the life of infrastructure, expedite repairs or replacement, and promote cost savings.

The Canadian Infrastructure Report Card (CIRC 2016) also emphasises improved long-term planning and asset management.

South Africa is, by contrast with the USA and Canada, a developing nation with an unusual history. Nevertheless, the imperatives for the enhancement of infrastructure are unsurprisingly familiar. The SAICE IRC (SAICE 2017) provides similar guidance in suggesting that South Africa should focus on:

- The protection and care of existing infrastructure to reduce the backwards slide caused by theft, vandalism and abuse
- Development of institutional capability and capacity through accelerated training and the promotion of competent, ethical leadership
- Incentives for further human capital development in civil engineering disciplines to improve the prospects of effective design, maintenance and management of infrastructure
- Better cooperation between spheres of government and increased private-public sector collaboration

- Efforts to improve data management, infrastructure monitoring and evidence-based decisions, e.g. based on smart technologies providing remote, real-time data acquisition
- Reducing wastage from water lost through physical leakage or commercial losses, which is currently in the order of 30 to 40 percent.

At the same time, South Africa should focus on new technologies to provide sustainable, high-performance infrastructure into the future similar to that suggested by ASCE (2017) and based on local research and development programmes, as well as localisation programmes that will deliver home-grown solutions.

From the survey it can be postulated that government should:

- increase emphasis on infrastructure maintenance significantly
- focus on institutional capacity, particularly in the areas and sectors where infrastructure is in the worst condition
- raise additional funding for infrastructure in innovative ways.

Public infrastructure is a vital asset for and driver of healthy socio-economic development and welfare. It is therefore of vital importance to manage and maintain this asset to maximise its impact on the effectiveness of the economy and service delivery.

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Please turn over for Appendix A →

APPENDIX A: SUMMARY OF SURVEY RESULTS AT NATIONAL LEVEL

Water	National	Major urban	Other		
Number of respondents	492	496	458		
Average	2.51	2.53	1.98		
Standard deviation	0.77	0.81	0.75		
Coefficient of variation	31%	32%	38%		
Sanitation	**Major urban**	**Other**			
Number of respondents	303	290			
Average	2.47	1.87			
Standard deviation	0.90	0.81			
Coefficient of variation	36%	43%			
Solid waste	**Collect urban**	**Collect other**	**Dispose urban**	**Dispose other**	
Number of respondents	76	73	77	73	
Average	2.79	2.10	2.40	1.68	
Standard deviation	0.84	0.84	0.75	0.78	
Coefficient of variation	30%	40%	31%	46%	
Roads	**National**	**Province paved**	**Metro paved**	**Districts and municipalities**	**Gravel**
Number of respondents	653	653	642	649	610
Average	3.66	2.77	2.66	2.19	2.16
Standard deviation	0.91	0.88	0.80	0.82	0.83
Coefficient of variation	25%	32%	30%	37%	39%
Aiports	**National**				
Number of respondents	74				
Average	4.27				
Standard deviation	0.85				
Coefficient of variation	20%				
Ports	**Commercial**	**Fishing**			
Number of respondents	39	37			
Average	3.31	2.73			
Standard deviation	0.80	0.65			
Coefficient of variation	24%	24%			
Rail	**Heavy-haul freight**	**General freight**	**Branch lines**	**Passenger lines**	**Gautrain**
Number of respondents	76	79	77	83	52
Average	2.88	2.56	2.14	2.17	4.23
Standard deviation	1.08	0.81	0.77	0.87	1.08
Coefficient of variation	38%	32%	36%	40%	25%
Electricity	**Eskom generation**	**Eskom transmission**	**Local distribution**		
Number of respondents	65	66	66		
Average	2.98	2.98	2.58		
Standard deviation	0.96	0.81	0.88		
Coefficient of variation	32%	27%	34%		
Health	**Hospitals**	**Clinics**			
Number of respondents	73	72			
Average	2.16	2.19			
Standard deviation	0.83	0.83			
Coefficient of variation	39%	38%			
Education	**Schools**	**Higher education**			
Number of respondents	112	111			
Average	2.30	3.16			
Standard deviation	0.84	1.03			
Coefficient of variation	36%	33%			